Open Science Conference

IMBeR FUTURE OCEANS$_2$

Ocean sustainability for the benefit of society: Understanding, challenges and solutions

Conference Booklet

Brest, France 17-21 June 2019

@FutureOceans2

IMBeR Open Science Conference

Future Oceans2

Ocean sustainability for the benefit of society:

understanding, challenges and solutions

17-21 June 2019

Brest, France

Produced by: IMBeR International Project Office
IMBeR Regional Project Office

Poster design and illustration: Sébastien Hervé | commeuneimage@yahoo.com

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Future Oceans 2

Brest, Bretagne

Jun 15 - 21, 2019

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The link to download the app is -> https://whova.com/portal/futur1_201906/

We encourage you to use the meeting website and mobile app for all current information and to navigate the conference.

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WELCOME!

Contents

Note our events!
Early Career Social Event: Sunday 16 June, Le Vauban, 17:30-18:30
Icebreaker and poster session A: Monday 17 June, Le Quartz, 17:30–19:30
Poster session B: Wednesday 19 June, Le Quartz, 17:30–19:30
Conference Dinner (optional): Thursday 20 June, Océanopolis, the bus will leave at 18:00

I. WELCOME

As Chair of the Conference Scientific Organising Committee and the IMBeR Scientific Steering Committee, I would like to take this opportunity to welcome you to the IMBeR Open Science Conference: Future Oceans$_2$ - Ocean Sustainability for the Benefit of Society: understanding, challenges and solutions. The conference is hosted by the Campus Mondial de la Mer, a network of marine science and technology research centres and innovative companies in Brest, France, including the University of Brest (UBO) and the European Institute for Marine Studies (IUEM).

IMBeR workshops and conferences have a reputation for showcasing interdisciplinary marine science and encouraging contributions from early career scientists, and this one is no exception. There are currently 589 researchers from 48 countries registered for Future Oceans$_2$ including 269 students and early career researchers, with an overall gender balance of 53% female: 47% male. The conference includes 9 keynote presentations, 494 talks and 195 posters contributing to 27 sessions, 10 workshops, 5 Town Halls and an Early Career Researchers' Day which cover topics ranging from biogeochemical cycles, foodweb dynamics, global change, fisheries, and interactions between scientists, policy makers and industry. These are collated into the three themes:

1. Understanding and quantifying the state and variability of marine ecosystems
2. Improving scenarios, predictions and projections of future ocean-human systems at multiple scales and
3. Improving and achieving sustainable ocean governance

or 'Grand Challenges' identified in the IMBeR Science and Implementation Plan (2016-2025). We are also very excited to be able to launch our new network of early career researchers, the Interdisciplinary Marine Early Career Network (IMECaN) at the conference.

An event such as this requires a co-ordinated team of organisers and supporters. I'd like to thank all of the members of the Scientific, International and Local Organising Committees, especially John Claydon, Lisa Maddison, Veslemøy Villanger and Fang Zuo and Xiaona Wang from the IMBeR International and Regional Project Offices, Paul Tréguer and Géraldine Sarthou from IUEM and Gwénaëlle Coudroy from Campus Mondial de la Mer who have done the bulk of the work. Also, many thanks to Chris Cvitanovic, the IMECaN organising committee and the convenors of the Early Career Researcher's Day who have brought the launch of IMECaN to fruition.

We are very grateful to the conference sponsors and exhibitors including Agence Française pour la Biodiversité, Biogeosciences, Brest Metropole, Bretagne Région, Campus Mondial de la Mer, Centre National de la Recherché Scientifique (CNRS), East China Normal University (ECNU), Département du Finistère, Institut Français de Recherche pour l'Exploitation de la Mer (Ifremer), Norwegian Institute of Marine Research (IMR), Interdisciplinary Graduate School for the Blue Planet (ISBlue), Journal of Marine Science and Engineering, State Key Laboratory of Estuarine and Coastal Research (SKLEC), Université Bretagne Loire, and the Université de Bretagne Occidentale (UBO), and financial support from the Scientific Committee on Oceanic Research (SCOR), North Pacific Marine Science Organisation (PICES), United States

Welcome

Ocean Carbon and Biogeochemistry program (OCB), Korea Institute of Ocean Science and Technology (KIOST), Plymouth Marine Laboratory, Frontiers in Marine Science, The Royal Society, One Earth, Orienting Young Scientists of EuroMarine (OYSTER) and Copernicus which contributes to funding the conference participation of early career scientists and scientists from developing countries.

I hope you all have a memorable time in Brest.

Carol Robinson

Professor Carol Robinson

Chair of IMBeR Scientific Steering Committee

Professor of Marine Sciences
Centre for Ocean and Atmospheric Sciences (COAS)
School of Environmental Sciences, University of East Anglia
Norwich, United Kingdom

Welcome

On behalf of the Interdisciplinary graduate School for the blue planet ISblue, I am delighted to welcome you all to Brest and the IMBeR Future Oceans2 Open Science Conference.

ISblue (http://www.isblue.fr) is a new and exciting project whose objective is to reinforce synergies between research in marine science and international graduate level training programmes. Funded by the French "Investment for the Future" programme, and led by the University of Brest, ISblue brings together two universities (Brest and Southern Brittany), four engineering schools (ENSTA-Bretagne, IMT-Atlantique, ENIB and the Naval Academy) and three research institutes (Ifremer, CNRS and IRD). Using top-level research-based training, ISblue will train the next generation of ocean innovators and science leaders to place them at the forefront of research, technological and methodological developments.

The IMBeR Future Oceans2 conference is a great opportunity for ISblue researchers and students to immerse themselves in a vibrant international community. The themes of the conference: *Understanding and quantifying the state and variability of marine ecosystems*; *Improving scenarios, predictions and projections of future ocean-human systems at multiple scales*; and *Improving and achieving sustainable ocean governance*, are aligned with major research questions of ISblue. One of our research themes is the living ocean, including marine resources and ecosystems in interaction with the human activities. Another is the role of the ocean in climate, including the biological carbon pump and the evolution of marine ecosystems. ISblue research covers all the aspects of our blue planet, including the exploration of deep-sea ecosystems, technology for observation and marine renewable energies, and challenges facing the coastal societies.

As the Director of ISblue, I thank the Local Organising Committee members who invited IMBeR to bring Future Oceans2 to Brest, and who worked tirelessly to help make this event a great success. I am very happy to support Future Oceans2 and I hope that all participants will have a great time in Brest.

Anne Marie Treguier
Research Director, CNRS / IUEM
Director, ISblue
Laboratoire d'oceanographie physique et spatiale
Institut Universitaire Européen de la Mer

CAMPUS MONDIAL DE LA MER

Campus mondial de la mer brings together France's first community comprising academics, scientists and economic and institutional stakeholders who work in the field of marine science and technology and the maritime economy.

They form the local organising committee and are co-sponsors of Future Oceans$_2$, the 2nd IMBeR Open Science Conference:

UBO
Université de Bretagne Occidentale

UNIVERSITE BRETAGNE LOIRE

ISblue
The interdisciplinary graduate school for the blue planet

AGENCE FRANÇAISE POUR LA BIODIVERSITÉ
ÉTABLISSEMENT PUBLIC DE L'ÉTAT

Ifremer

French National Research Institute for Sustainable Development
IRD
Institut de Recherche pour le Développement
FRANCE

cnrs

MUSÉUM NAL HIST NATURELLE
STATION MARINE CONCARNEAU

CNRS • SORBONNE UNIVERSITÉ
Station Biologique de Roscoff
1872

Brest MÉTROPOLE

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Région BRETAGNE

TECHNOPÔLE BREST-IROISE

II. ORGANISERS

Scientific Organising Committee:

Carol Robinson (Chair) - University of East Anglia (UEA), UK

John Claydon - IMBeR International Project Office, Norway

Eileen Hofmann - Old Dominion University (ODU), USA

Julie Hall - National Institute of Water and Atmospheric Research (NIWA), New Zealand

Paul Tréguer - Institut Universitaire Européen de la Mer (IUEM), France

Maria Grazia Peninno - Instituto Español de Oceanografía (IEO), Spain

Prateep Nayak – University of Waterloo, Canada

Priscila Lopes - Universidade Federal do Rio Grande do Norte (UFRN), Brazil

Local Organising Committee:

Paul Tréguer - Institut Universitaire Européen de la Mer (IUEM), France

Marie Bonnin - Institut de Recherche pour le Développement (IRD), France

Nadia Améziane - Muséum National d'Histoire Naturelle (MNHN), France

Catherine Boyen - Station Biologique de Roscoff, France

Olivier Thébaud - Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), France

Géraldine Sarthou - Laboratoire des sciences de l'environnement marin (LEMAR) de l'UBO, France

IMBeR International Project Office (IPO):

Institute for Marine Research, Bergen, Norway

John Claydon
Lisa Maddison
Anne Mæland
Veslemøy Kjersti Villanger

IMBeR Regional Project Office (RPO):

East China Normal University, Shanghai, China

Fang Zuo
Xiaona Wang
Kai Qin

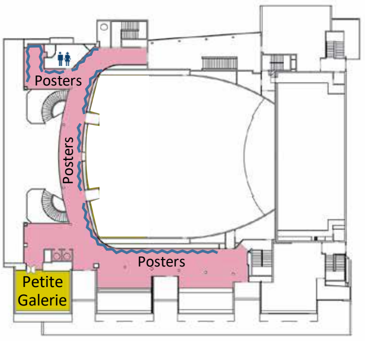
III. PRACTICAL INFORMATION

Meeting logistics

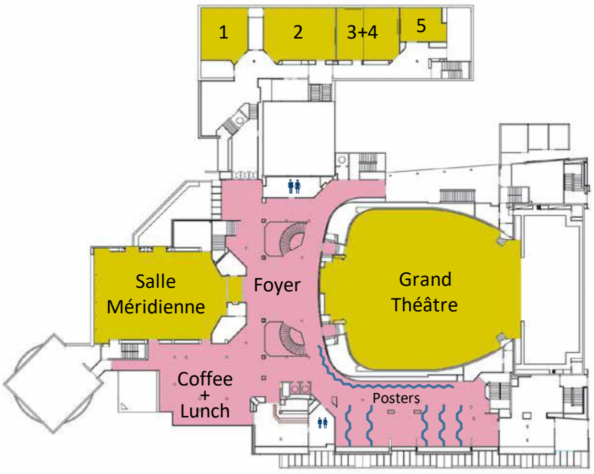
Venue

The conference venue is the Le Quartz Congrès, Square Beethoven, 60 Rue du Château, 29210 Brest, France

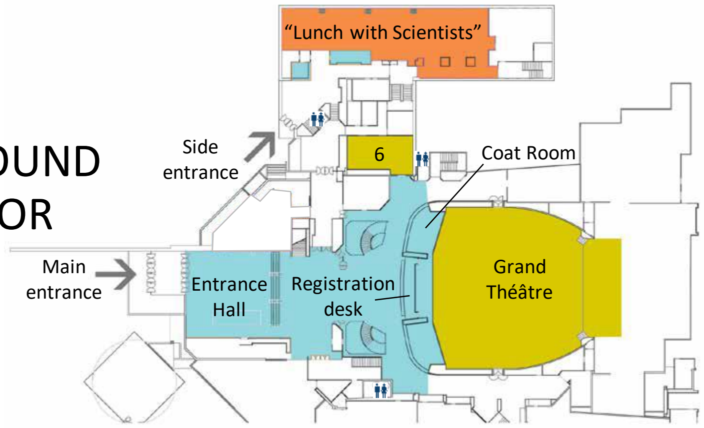
FLOOR 2



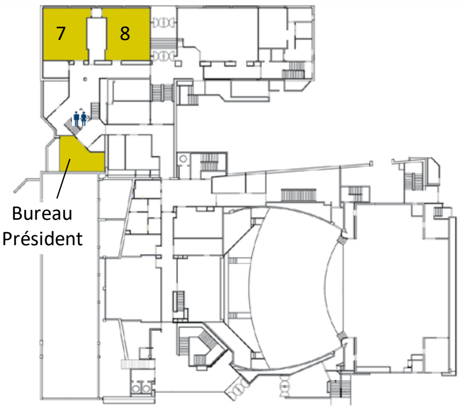
FLOOR 1



GROUND FLOOR



FLOOR -1



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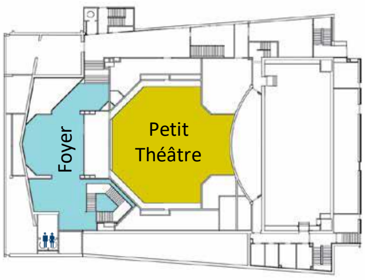

Registration and information desk

The registration desk will be open during the following hours:

Saturday 15 June: 08:00 – 09:00
Sunday 16 June: 08:00 – 09:00
Monday 17 June: 08:00 - 09:00

You will receive tickets for two complimentary drinks for each poster session.

If you need any information during the conference, please come to the registration desk and we will try to assist you.

Alternatively, contact: imber@imr.no

Lunch

Lunch is provided for participants of the all-day workshops over the weekend and each day of the conference.

Social events

Early career social event

Sunday 16 June 17:30 at Le Vauban. Two drinks are included and then there is a cash bar.

Ice-breaker and poster session A

Monday 17 June 17:30 at Le Quartz. Refreshments will be served. Two drinks are included.

Poster session B

Wednesday 19 June 17:30 at Le Quartz. Refreshments will be served. Two drinks are included.

Conference dinner *(optional)*

Thursday 20 June 19:00 at **Oceanopolis**.

Buses will leave Le Quartz at 18:00

On arrival, there will be guided tours of the exhibits.

A cocktail reception (including two drinks) will be served in front of the tanks in the Brittany Pavilion.

Poster information

There are two poster sessions

Monday: Poster session A from 17:30 - 19:30

Wednesday: Poster session B from 17:30 – 19:30

Posters will be displayed on levels 1 and 2.

Each poster has been assigned to a particular poster session and a specific display board. Please refer to the workshop or session programmes to see when you are due to present your poster and the poster ID number.

All posters are to be put up before 4pm on Monday 17 June and will be displayed for the duration of the conference

Please remove your poster after 12:30pm on Friday 21 June.

Any uncollected posters will be removed.

CONFERENCE SPONSORS

IMBeR wishes to thank its generous sponsors for supporting
the 2019 IMBeR Open Science Conference Future Oceans2

List of Conference Sponsors

Agence Française pour la Biodiversité	https://www.afbiodiversite.fr
Biogeosciences (BG)	https://www.biogeosciences.net/index.html
Brest Metropole	https://www.brest.fr
Bretagne Région	https://www.bretagne.bzh
Campus Mondial de la Mer	https://www.campus-mondial-de-la-mer.fr
Centre National de la Recherche Scientifique (CNRS)	http://www.cnrs.fr/en
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Département du Finistère	https://www.finistere.fr
Frontiers in Marine Science	https://www.frontiersin.org/journals/marine-science
Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER)	https://wwz.ifremer.fr/en
Institute of Marine Research (IMR)	http://www.imr.no/en
Interdisciplinary graduate School for the blue planet (ISblue)	https://www.isblue.fr
Journal of Marine Science and Engineering	https://www.mdpi.com/journal/jmse
Korea Institute of Ocean Science & Technology (KIOST)	https://www.kiost.ac.kr/eng.do
North Pacific Marine Science Organization (PICES)	https://meetings.pices.int
Ocean Carbon and Biogeochemistry (OCB) program	https://www.us-ocb.org

Sponsors

One Earth	https://www.cell.com/one-earth/home
Orienting Young Scientists of EuroMarine (OYSTER)	https://www.euromarinenetwork.eu/activities/orienting-young-scientists-euromarine
Plymouth Marine Laboratory (PML)	https://www.pml.ac.uk
Scientific Committee on Oceanic Research (SCOR)	https://scor-int.org
State Key Laboratory of Estuarine and Coastal Research (SKLEC), ECNU	http://english.sklec.ecnu.edu.cn
The Research Council of Norway	https://www.forskningsradet.no/en
The Royal Society Publishing	http://blogs.royalsociety.org/publishing
Université Bretagne Loire	https://en.u-bretagneloire.fr
Université de Bretagne Occidentale (UBO)	https://www.univ-brest.fr/GB

Workshops + IMECaN Early Career Researcher Day

		Salle Méridienne	Room 2	Room 3	Room 4	Room 1
Sat 15 June	09:00 to 10:30		Visioning Global Ocean Futures		Integration of marine and coastal institutional regimes across multiple sectors	Time-varying ecological geography of the global ocean
	11:00 to 12:30					
	14:00 to 15:30			Bioenergetics and survival trajectories …		
	16:00 to 17:30					
Sun 16 June	09:00 to 10:30	IMECaN Early Career Researcher Day	Setting priorities for research into Changing Ocean Biological Systems	Getting the most out of Earth Observation…		Using data hubs to advance knowledge…
	11:00 to 12:30					
	14:00 to 15:30			Marine transboundary planning…		Natural analogues… (AnalogueART)
	16:00 to 17:30					
	17:30 to 18:30	Early Career Social				

Town Hall Sessions

13:00 to 13:50

	Room 2	Room 1	Room 3+4
Wed 19 June	ESSAS Ecosystem Studies of Sub-arctic and Arctic Seas*	GOOS Global Ocean Observing System	UN Decade of Ocean Science for sustainable Development
Thurs 20 June	ICED Integrating Climate and Ecosystem Dynamics*	CLIOTOP CLimate Impacts on Oceanic Top Predators*	

*IMBeR Regional Programmes

Oral Sessions

		Grand Théâtre	Petit Théâtre	Salle Méridienne	Room 2	Room 3+4	Room 1	Room 7	Room 8	Room 5
Mon 17 June	09:00 to 10:30	Opening Ceremony Keynote 1 Keynote 2								
	11:00 to 11:45									
	11:55 to 12:40		Same, same, different: understanding variability and the relative roles of environment, climate, fishing and trophic dynamics in marine ecosystems	Modelling social-ecological systems: methods and tools for scenario development and prediction	Arctic marine ecosystems in a changing climate	Marine governance, challenges for sustainability	The Second International Indian Ocean…	From genes to marine ecosystem functioning: New methods and models …	Working in the science-industry interface: strategies for…	Towards a coordinated global marine biodiversity observing system
	14:00 to 15:30	KEYNOTE TALKS Tues-Thurs 09:00-10:30					Long-term time series of ocean data to describe and better understand dynamics of coastal marine systems and drivers of change..			
	16:00 to 17:30									
Tue 18 June	11:00 to 12:30	Keynote 3 Keynote 4						Ecological feedbacks in the Earth System		Linking microbial activity and the cycling of dissolved organic..
	14:00 to 15:30								Ecosystem-social interactions in marginal seas	
	16:00 to 17:30									
Wed 19 June	11:00 to 12:30	Keynote 5 Keynote 6		The multiple pathways of the biological carbon pump: current understanding and future challenges	Managing the effects of change on Southern Ocean…	Lessons from the extreme events…	Investigating and modelling linkages between biology and fleet behaviour in multi-species…	Designing the quilt of sustainable ocean governance	Biogeochemical and biological processes promoted by ocean mixing	Transboundary fisheries management in changing …
	14:00 to 15:30									
	16:00 to 17:30		Multiple drivers and their role in Ocean Global Change Biology							Blue management and governance of marine resources
Thurs 20 June	11:00 to 12:30	Keynote 7 Keynote 8			"But why won't they use my science?" Improving the impact of marine science on policy; advances in theory and practice	Food web dynamics and contaminants: interactions with global environmental change and implications for food security	Ocean governance in the face of change: confronting the challenge of rebuilding fish…		Southern Ocean ecosystems… (MEASO workshop)	
	14:00 to 15:30							Adaptation in marine socio-ecological systems		Ocean Recovery – Strategies to mitigate anthropogenic pressures and support marine…
	16:00 to 17:30								Responding to policy makers: what can we do?…	
Fri 21 June	09:00 to 10:30									
	11:00 to 12:30	Keynote 9 Closing Ceremony								

VI. IMECaN EARLY CAREER DAY

Conveners: Prue Addison, Stephanie Brodie, Chris Cvitanovic, André Frainer, Maria Grazia Pennino, Priscila Lopes and Kelly Ortega-Cisneros

IMBeR is launching our new Interdisciplinary Marine Early Career Network (IMECaN) at the Future Oceans2 Open Science Conference in 2019. The overarching goal of IMECaN is to bring together early career marine researchers from across the globe working on topics related to the IMBeR Grand Challenges, and in doing so provide:

1. A networking platform for early career marine researchers to develop collaborations;
2. Training and development opportunities for early career marine researchers in areas not traditionally provided through formal education and training programmes (e.g. policy engagement, science communication, etc.); and
3. Leadership opportunities for early career marine researchers, particularly those from developing nations.

IMECaN activities will be overseen by a committee of IMBeR early career researchers and will be open to all marine science students (Masters and PhDs) as well as early career researchers (less than seven years post-PhD, and less than six years since their first research appointment). For more information about IMECaN please refer to the IMECaN page.

Inforgraphics speaker

Stacey McCormack is an entrepreneur in science communication, based in Tasmania, Australia. She is the founder of McCork Studios, a graphic design company that works to help researchers and organisations visualise and communicate their knowledge. She recently completed her PhD in ecosystem modelling and Antarctic food web ecology at the University of Tasmania, where she also discovered her passion for scientific graphic design. Over the past two years, Stacey has created figures for articles in numerous journals, including Nature and PLOS One and has worked with teams of researchers across a broad range of disciplines to develop infographics that have appeared on Twitter, numerous blogs and media websites. In addition to designing creative science communication output, Stacey is passionate about equipping others with the skills to share their science in interesting, understandable and appealing formats. At Future Oceans2, she will convene a visual graphics workshop during the Early Career Day (Sunday 16 June) to teach students and early career researchers 'the basics' of graphic design, thereby helping them to improve their own science communication and ultimately, increase the visibility of their research.

Early Career Day Schedule

0815 – 0845:	Registration
0845 – 0900:	Welcome (Carol Robinson, Chair of the IMBeR Scientific Steering Committee)
0900 – 0915:	Introduction to the Interdisciplinary Marine Early Career Network (IMECaN) and the ECR day structure (Chris Cvitanovic, Chair of IMECaN)
0915 – 1030:	Expert Panel (short talks followed by question and answer session): How to build successful careers in marine science. Speaker 1: Ingrid van Putten, CSIRO, Australia. Speaker 2: Henrik Österblom, Stockholm Resilience Centre, Sweden. Speaker 3: Marta Coll, ICM-CSIC, Spain.
1030 – 1100:	Morning tea
1100 – 1230:	Expert Panel (short talks followed by question and answer session): Alternate career pathways for early career marine researchers. Speaker 1: Peter Mackelworth, Blue World Institute, Croatia Speaker 2: Lisa Maddison, IMBeR, Norway. Speaker 3: Mark Dickey-Collas, ICES, Denmark. Speaker 4: Prue Addison, Berks, Bucks, and Oxon Wildlife Trust, UK.
1230 – 1330:	Lunch
1330 – 1445:	Training session: Developing infographics to communicate your research: Stacey McCormack, University of Tasmania, Australia
1445 – 1515:	Afternoon tea
1515 – 1630:	Training session continued
1515 – 1630:	Science Speed Dating
1700 – late:	Bingo!

VII. PLENARY PRESENTATIONS

MONDAY MORNING PLENARY PRESENTATION

Date: Monday, 17 June 2019
Time: 09:45 to 10:30
Location: Grand Théâtre
Keynote speaker: Edward H. Allison

Carol Robinson, Chair of IMBeR Scientific Steering Committee will introduce Eddie.

Eddie is a Professor in the College of the Environment at the University of Washington, Seattle, WA, USA. His research centres on the human connection to natural resources. His primary areas of focus are 1) the contribution of fisheries and aquaculture to food and nutrition security and coastal livelihoods, 2) governance of small-scale fisheries and aquaculture production and the human rights of fisherfolk, and 3) the vulnerability and adaptation to climate change of people dependent on marine and freshwater resource.

Presentation Description:

Ocean research in support of sustainability:
IMBeR's potential role in shaping the blue future

As planning for the UN Decade of Ocean Science for Sustainable Development (2021-2030) gets underway it is timely for the IMBeR community to consider how our research informs and influences the future human relationship with the oceans. As ocean scholars – whether social or natural scientists, or from the arts and humanities – our theories, empirical data, simulation models, frameworks and narratives either legitimize or challenge key policy orientations towards the coasts, shelf-seas and oceans.

There is a current wave of enthusiasm among governments, international conservation NGOs and private sector investors for the idea of a 'blue economy': a well-governed ocean whose ecosystem services can be sustainably harnessed by capital investment in maritime industries and 'natural capital'. It is out to sea that many now look for the next major source of economic growth. There is also a backwash of resistance to the 'blue economy' from civil society organizations associated with environmental and social justice, who claim that while the blue economy may have the potential for economic and ecological sustainability, it will simply widen existing inequalities.

These contestations have deep historical roots. Inequality on land and sea is in part the product of mercantilism, colonialism, the deregulated expansion of private capital and resurgent nationalism. Science has served all these masters: advances in astronomy enabled mercantilism, and much of the technology we use for ocean observation was originally developed for military use. Who in society does your science best serve? How can you make your science better serve the 'third pillar' of sustainable development: equity? These are some of the questions I'll be inviting you to contemplate during IMBeR Future Oceans2 and beyond.

MONDAY MORNING PLENARY PRESENTATION

Date: Monday, 17 June 2019
Time: 11:00 to 11:45
Location: Grand Théâtre
Keynote speaker: Alistair Hobday

Alistair will be introduced by Kelly Ortega-Cisneros from Rhodes University, South Africa.

Alistair is a Research Director at CSIRO Oceans and Atmosphere and an Adjunct Professor at the University of Tasmania, Australia. He completed an undergraduate degree at Stanford University and a PhD at the Scripps Institution of Oceanography. His research focuses on investigating the impacts of climate extremes, variability and change on marine biodiversity and fishery resources, and developing, prioritising and testing adaptation options to underpin sustainable use and conservation into the future. His projects involve multi-disciplinary teams that seek to support management and policy uptake of research, via co-production with stakeholders. In addition to more than 240 publications, he contributed to the IPCC 4th and 5th assessment Australasia chapters, covering fisheries, oceanic and coastal systems, and is an editor for Fisheries Oceanography, Marine Ecology Progress Series, and Global Change Biology. He is former co-chair of IMBeR´s CLIOTOP (Climate Impacts on Top Ocean Predators) regional programme and is a current Scientific Steering Committee member of IMBeR.

Presentation Description:

Understanding and quantifying the state and variability of marine ecosystems

The title of this presentation speaks to one of the IMBeR Grand challenges. This topic no doubt resonates with many marine scientists as it has been a core challenge for many decades. Advances in ecosystem understanding have come from a series of technological game changers, such as synoptic satellite coverage, in situ observing systems, electronic tags, and most recently, genomic techniques to estimate population sizes. Resolving natural variability from human pressures has also been a priority, and is now more complicated due to climate change, which is operating on slow and fast time scales. Marine extremes are exerting strong pressure and bringing a once-far off climate future into the present. Given the large spatial and temporal scales involved in ocean variability, it is not surprising that collaborative and comparative work has been important in improved ocean understanding. Several examples from IMBeR regional programs illustrate the advantage of such approaches, particularly in the study of links between food webs and biogeochemical cycles and understanding teleconnections between regions. In a non-stationary world, new techniques will be needed to understand ecosystem responses to physical processes, and the pace at which ecosystems can respond and adapt to a range of other increasing ocean pressures. An understanding of ecosystem state, while important for many reasons, must also be complemented by an understanding of future possible and desirable states. Marine scientists will play an important role in communicating the likelihood and value of each of these futures.

TUESDAY MORNING PLENARY PRESENTATION

Date: Tuesday, 18 June 2019
Time: 9:00 to 9:45
Location: Grand Théâtre
Keynote speaker: Lynne Shannon

André Frainer from the Norwegian Institute for Nature Research will introduce Lynne.

Lynne Shannon is a marine researcher at the University of Cape Town in South Africa, undertaking ecological research and modelling to contribute to ecosystem-based management. She has published over 120 peer-reviewed papers. She has constructed trophic models in the Benguela to provide an understanding of structure and functioning and changes in the marine food webs. She explores pragmatic ways in which ecosystem considerations might be incorporated into fisheries management, especially the use of ecological indicators. Lynne co-chairs the international working group "IndiSeas" (www.indiseas.org), evaluating effects of fishing and natural variability on marine ecosystems using suites of ecological, environmental, biodiversity and human dimension indicators in comparative approach.

Presentation Description:

Navigating an ocean under stress:
the combined effects of fishing and environmental forcing on ecosystem dynamics

Our ocean and its food webs are changing! These changes arise from natural environmental change, anthropogenically-induced climate change, fishing and other impacts of human activities. The focus of this talk is on the cumulative and synergistic effects of multiple drivers of ocean change. How are these drivers changing, what are the implications for our marine ecosystems, and how can we communicate this complicated information to decision makers so that appropriate actions can be taken? In particular, I look at how effects of fishing and climate can be identified, quantified, modelled and communicated. Complicated, innovative studies have recently been undertaken by experts in these fields. Some of these are presented, and I single out a few key case studies investigating how marine ecosystem structure and functioning has changed in response to the interactive effects of fishing and climate. I end the talk with a plea for more work to be done on how to effectively disseminate scientific evidence of fishing and climatic drivers of ocean change, so that our decision makers have what they need to implement the necessary management measures. This is particularly important in the light of the recent Global Biodiversity Assessment which paints an exceptionally worrying picture for our world's oceans.

TUESDAY MORNING PLENARY PRESENTATION

Date: Tuesday, 18 June 2019
Time: 9:45 to 10:30
Location: Grand Théâtre
Keynote speaker: Laurent Bopp

Shan Jiang from the State Key Laboratory of Estuarine and Coastal Research (SKLEC) in China will introduce Laurent.

Laurent Bopp is the Research Director at CNRS Laboratoire des Sciences du Climat de l'Environnement (LSCE) at l'Institute Pierre-Simon Laplace in Paris, France. His main research interests focus on the links between marine biogeochemical cycles and climate, and understanding how marine ecosystems and the ocean carbon cycle respond to climate variability and anthropogenically-driven climate change. He develops and uses marine biogeochemical and ecosystem models, coupled to Earth System Models.

Presentation Description:

Projections of marine biological productivity under future climate change

Oceanic net primary production (NPP) fuels marine food webs, but also drives the export of organic carbon to the deep ocean, with implications for the amount of carbon that stays in the atmosphere and impacts climate. Earth System Models, used in the context of Coupled Model Intercomparison Projects (CMIP) and assessed in the last IPCC reports, show consistent declines in global marine NPP in response to future climate change. At the regional scale however, these projections yield large uncertainties over the 21st century, especially in some key regions such as in the tropical belt or in the Arctic Ocean. In this talk, I will discuss these projections, showing how the related uncertainties may be reduced using the techniques of emergent constraints, but also reviewing some of the inherent limits of these modelling approaches. I will also present how these NPP projections may be used to assess the potential effects of global warming on upper trophic levels and potential fisheries catches. Difficulties in estimating the impacts of climate change on ecosystems at the local / regional scale, and on shorter time scales (interannual to decadal) will also be discussed.

WEDNESDAY MORNING PLENARY PRESENTATION

Date: Wednesday, 19 June 2019
Time: 9:00 to 9:45
Location: Grand Théâtre
Keynote speaker: Ingrid van Putten

Ingrid´s talk will be introduced by Katherine Maltby from CEFAS/University of Exeter, UK.

Ingrid van Putten is a Research Scientist with CSIRO Oceans and Atmosphere in the ecosystem modelling team and a Senior Adjunct Researcher at the Centre of Marine Socioecology at the University of Tasmania. Her research focuses on using behavioural sciences, in particular behavioural economics, to improve our understanding of the social and economic behaviour of marine resource users (fisheries, aquaculture, recreation, and other marine sectors) and their interactions with the biophysical marine environment. She tries to improve the management and long-term viability of coupled social-ecological systems by better understanding what prompts resource user's behaviour and find tractable ways to influence their behaviour and reduce risks. Ingrid´s work is both theoretical and applied/empirical, making use of both qualitative and quantitative methods, and a combination of analytical and statistical approaches. She uses different modelling tools and approaches (e.g. Bayesian and network analysis) to represent resource user behaviour and interactions at the appropriate level of complexity. A large part of her research consists of working in interdisciplinary teams and connecting the ecological and human dimensions of marine and coastal management.

Presentation Description:

How difficult can it be? Trade-off decisions in a time of blue economy growth

The blue economy is predicted to grow over the next decades. This will almost inevitably lead to making more, and potentially more difficult to resolve trade-off decisions. Trade-off decisions will need to be made with respect to different sectoral users and triple bottom line outcomes. In parallel with a growing blue economy is the perception that management outcomes depend on the quality of stakeholder participation in decision making, including assessing and deciding on acceptable trade-offs. But behavioural science, in particular psychology, tells us that making trade-off decisions is not easy – but is in fact very difficult. Behavioural insights, for instance loss and ambiguity aversion, are important when trying to resolve trade-offs. I will highlight the need to take note of insights from behavioural sciences if we are to have stable and effective local and global ocean governance, and that this is particularly important at a time when growth expectations are high.

WEDNESDAY MORNING PLENARY PRESENTATION

Date: Wednesday, 19 June 2019
Time: 9:45 to 10:30
Location: Grand Théâtre
Keynote speaker: Samiya Selim

Rhoda Fofack-Garcia from France Energies Marines will introduce Samiya.

Dr. Samiya Selim is an Associate Professor and the Director of Center for Sustainable Development at the University of Liberal Arts Bangladesh (ULAB). She specialises in the interdisciplinary areas of socio-ecological systems, sustainability science, climate change adaptation and resilience, and science-policy interface. Currently her work is focused on achieving the Sustainable Development Goals (SDG), ecosystem-based adaptation and integrated aquaculture in coastal areas of Bangladesh facing increased salinity and erosion.
In the past 10 years, Samiya has worked in the UK and Bangladesh in the field of environmental conservation, climate change and fisheries. Her previous work includes mobilizing hard-to-reach communities to get involved in environmental activities and to bring about behavioural change to achieve sustainability in daily life. Her work has also utilised historical approaches to identify shifting baselines in fisheries and coastal ecosystems. She recently published the first book on achieving the SDG goals relating to the environment in Bangladesh.
She is a member of the IMBeR Human Dimensions Working Group which focuses on the interactions between human and ocean systems and its goal is to promote an understanding of the multiple feedbacks between human and ocean systems.

Presentation Description:

Addressing equity and long-term sustainability in coastal conservation and blue economy development

The role of interdisciplinary research is key to ensuring ocean conservation and sustainable development under global change. My research interests lie in understanding such complex social-ecological systems and identifying solutions that can link both conservation and sustainable development. At the core of the blue economy lies the decoupling of socioeconomic development from ecosystem degradation. SDG target 14.7 also focuses on the issue of blue growth and increasing economic benefits for SIDS and LDCs through sustainable management of marine resources, including fisheries, aquaculture and tourism. My talk is focused on how we can develop a blue economy that is a win-win for coastal conservation and ocean health, meets the needs of current and future generations, drives economic growth whilst combating climate change.

I highlight a few case studies with which I have been directly or indirectly involved that are from coastal regions of Bangladesh vulnerable to climate change. These include ecosystem-based adaptation and sustainable livelihoods (small scale fisheries and aquaculture), the potential for eco-tourism and understanding of recreational ecosystem services, and development of pro-poor technology (renewable energy for cold storage and Integrated multi trophic aquaculture). I thread in SDG 14 and blue economy development in most of these case studies.

I then summarise with reflections from these case studies and highlight why we need to address equity and ensure long term sustainability in coastal ecosystem development projects - what happens when funding/projects end, how do we take these findings to policy. I highlight how sustainability science, capacity building, co-production of knowledge, interdisciplinary and transdisciplinary research, and strong governance is key to successful interventions for the future of our oceans and the people who depend on them.

THURSDAY MORNING PLENARY PRESENTATION

Date: Thursday, 20 June 2019
Time: 9:00 to 9:45
Location: Grand Théâtre
Keynote speaker: Eric Galbraith

Irene Alabia from Hokkaido University in Japan will introduce Eric.

Eric Galbraith is an ICREA Research Professor, based at the Universitat Autònoma de Barcelona in Spain. He previously worked as a research associate at Princeton University in the USA, and as a professor at McGill University in Canada. His research is broadly interdisciplinary, and is generally concerned with using numerical models and data analysis to better understand the interactions between climate change, human activities and the marine ecosystem. Eric has worked on both past and anticipated climate changes and their links with ocean biogeochemistry, as well general principles of air-sea exchange, nutrient cycling and ecosystem stoichiometry. His current research focuses on the inclusion of fishing activity as an integral component of global marine ecosystem models, to better understand linkages from human wellbeing to biogeochemical cycling, and to inform future projections. He is a founding coordinator of the fisheries and marine ecosystem model intercomparison project (Fish-MIP).

Presentation Description:

From whirls to wellbeing: A bird's eye view of ocean change from integrative global models

Human impacts on the ocean are rapidly intensifying. These impacts come in many forms, from climate change to pollution to fishing, and interact with diverse local ecosystems, resulting in a bewilderingly complex picture and uncertain implications for human wellbeing. This talk will highlight the ability of integrated global ecosystem models to provide a bird's-eye perspective on these global changes in the human-ocean system. One class of global models is founded on the dynamics of the size spectrum, a simple but inclusive way to capture the ecosystem that reflects the emergent outcome of all ecological processes. Although the size-based approach has seen limited use in marine ecology, it has a long history and strong theoretical foundations. The size spectrum perspective allows simple hypotheses to be articulated, such as the influence of changes in water temperature and primary production on biomass distributions, and can be readily extended to other stressors, making it particularly appropriate to help understand the complex changes underway. Recent results from multiple global models participating in the Fish Model Intercomparison Project (FishMIP) unanimously project declines in large animal biomass under future warming, in agreement with fishery-based reconstructions. When an interactive industrial fishery is coupled with a size-based fish model, technological improvement and fisheries regulation emerge as terms of similar importance to climate change. Although there are many uncertainties, it would appear that – at the global scale - improved regulation can offset future climate change impacts on the total large animal biomass by rebuilding fisheries. Finally, simple representations of fishing communities can also be integrated into the framework to estimate the changes in lived experience that might occur under different future scenarios.

THURSDAY MORNING PLENARY PRESENTATION

Date: Thursday, 20 June 2019
Time: 9:45 to 10:30
Location: Grand Théâtre
Keynote speaker: Derek Armitage

Derek will be introduced by Zach Koehn from the University of Washington, USA.

Derek Armitage is Professor, School of Environment, Resources and Sustainability and co-lead of the Environmental Change and Governance Group at the University of Waterloo (Canada). His research focuses on the human dimensions of environmental change, community-based conservation and the relationship to adaptive and collaborative forms of governance in coastal systems. He has worked on interdisciplinary projects in Canada, southeast Asia and the Caribbean, and has led working groups in several major research partnerships, including the Community Conservation Research Network, the OceanCanada Partnership, and the Partnership for Canada-Caribbean Community Climate Change Adaptation. He is co-editor of 'Governing the Coastal Commons: Communities, Resilience and Transformation' (Routledge).

Presentation Description:

Knowledge co-production and the governance of our future oceans and coasts

Knowledge co-production involves a collaborative process of knowledge generation and sharing to address complex problems, and it is an important catalyst for the effective governance of our future oceans and coasts. In this presentation, I outline key features of knowledge co-production, and highlight selected examples of knowledge co-production efforts at different scales (e.g., in co-management process in the Arctic). I also summarize some of the challenges of knowledge co-production and reflect on the implications for the IMBeR science community.

FRIDAY MORNING PLENARY PRESENTATION

Date: Friday, 21 June 2019
Time: 11:00 to 11:45
Location: Grand Théâtre
Keynote speaker: Coral Robinson

John Claydon, Director of IMBeR will introduce Carol.

Carol Robinson is a Professor of Marine Sciences at the University of East Anglia in the UK and Chair of the Scientific Steering Committee of IMBeR. Her research focuses on the role of marine bacteria, phytoplankton and zooplankton in the global cycling of carbon and oxygen, and how this varies in space and time and with changing environmental conditions such as increasing nutrient supply, temperature and carbon dioxide and decreasing dissolved oxygen. This involves laboratory and field observations, including the use of gliders and time series datasets, remote sensing and numerical models. Carol currently leads two international projects which study the role of marine bacteria and phytoplankton respiration in the cycling and sequestration of carbon, and her team contributes to projects on zooplankton mediated carbon flux in the Southern Ocean and quantifying the capacity for marine carbon storage as recalcitrant dissolved organic carbon and how this might change in a changing environment.
Carol's presentation will summarise recent key advances in IMBeR science and propose some future directions that will help address the research questions identified in the IMBeR Science Plan as needed to progress towards securing sustainable, productive and healthy oceans.

Presentation Description:

IMBeR's contribution to achieving ocean sustainability for the benefit of society; past, present and future

IMBeR's mission is to "Promote integrated marine research and enable capabilities for developing and implementing ocean sustainability options within and across the natural and social sciences, and communicate relevant information and knowledge needed by society to secure sustainable, productive and healthy oceans".

To achieve this mission, the IMBeR Science Plan identifies three 'Grand Challenges' which inform all IMBeR activities:

1. Understanding and quantifying the state and variability of marine ecosystems

2. Improving scenarios, predictions and projections of future ocean-human systems at multiple scales and
3. Improving and achieving sustainable ocean governance

including the themes, sessions and workshops contributing to the Future Oceans$_2$ conference. This presentation will summarise recent key advances in the research undertaken within the IMBeR working groups, regional programmes and endorsed projects to address these challenges, including some of the research presented and discussed during the Future Oceans$_2$ conference. The presentation will conclude by highlighting new research directions and suggesting ways in which to address the remaining knowledge gaps preventing progress towards the IMBeR vision of securing sustainable, productive and healthy oceans.

VIII. SESSION DESCRIPTION

Session 1: Adaptation in marine socio-ecological systems

Conveners: Alistair Hobday and Alex Magnan

Marine socio-ecological systems describe the interface between human livelihoods and well-being, and marine and coastal natural resources. Both direct and indirect uses are involved, going from economic activities (e.g., fisheries, aquaculture and tourism) to cultural dimensions. In regions experiencing rapid social and environmental change, adaptation of the human and biological components are needed in order to prevent socio-ecological system failure. This session will address the ways to avoid such a failure by enhancing dynamic, long-term adaptation strategies driven by human societies. Common questions that we ask presenters to address include:

- To what extent do changes in environmental features affect human societies?
- What are the cascading effects explaining why environmental changes (loss of biodiversity, climate change impacts, etc.) threaten human societies' stability and long-term well-being? What are the implications in terms of adaptation needs and options?
- What complementarity exists between incremental and transformational adaptation? What does it mean in terms of rethinking the human/ecosystems interface? To what extent does it force societies to think in terms of adaptation pathways?
- Which lessons can be learnt from both adaptation and maladaptation real-world case studies?
- What are common principles for enhancing worldwide marine and coastal adaptation pathways?

Session 2: Arctic marine ecosystems in a changing climate

Conveners: Ken Drinkwater, Naomi Harada, George Hunt, Hein Rune Skjoldal, and Franz Mueter

The Arctic is undergoing unprecedented changes due to the rapid loss of sea ice, rising ocean temperatures, ocean acidification, and changing freshwater budgets. This session seeks to document major changes occurring in Arctic marine ecosystems and to understand the mechanisms responsible for these changes. How are the biogeochemistry and biological components of these systems changing and why? What are the consequences of these changes for human populations in the Arctic and beyond? How have these systems changed in the past? We especially seek new insights into the forces responsible for the fluxes of water through the Arctic gateways and the fate of these waters, their associated properties, and the organisms they carry. How do these fluxes affect the Arctic? What are the effects of outflows from the Arctic on the Subarctic? How are these fluxes expected to change in the future under climate change? Will the productivity in the Arctic increase or decrease? How will fish populations respond to these changes? How will existing fisheries change, and what are the prospects for new, emerging fisheries? What governance structures are needed to effectively manage Arctic marine resources?

Session 3: Biogeochemical and biological processes promoted by ocean mixing

Conveners: Jun Nishioka, Yutaka Yoshikawa and Naomi Harada

Marine biogeochemical and biological processes are strongly affected by ocean mixing (e.g., isopycnal and diapycnal mixings etc.) through their hydrography and nutrients' supply. In the Arctic Ocean, recent catastrophic sea-ice reduction has enhanced the air-sea interaction and has also increased meso-submeso scale eddies appearances with eddy induced productivities. Moreover, at the rim of the eddy, nutrient supplies caused by diffusive mixing may preferentially increase the pico-phytoplankton biomass in the Arctic Ocean. At the Kuroshio extension area in the western North Pacific, near-inertial internal waves occur in subsurface depths after tropical cyclone passage. Such near-inertial internal waves upwell nutrients from the deep layer to the euphotic zone and enhance primary production associated with increasing turbulent kinetic energy in the subsurface. This session invites papers which discuss how biogeochemical and biological systems relate with physical mixing. What is the key mechanism for the mixing processes? How much nutrients are introduced into the euphotic zone by the mixing? How much is biological production enhanced? Is there any impact on biological functions and ecosystems? We welcome interdisciplinary presentations and active discussions on physical, chemical, and biological aspects of this topic.

Session 4: Blue management and governance of marine resources

Conveners: Marie Bonnin, Sophie Bertrand, Barnaby Andrews, Silvia Ferrini, Irene Lorenzoni, Tiziana Luisetti and Ruth Parker

Marine environments are subject to growing and simultaneous pressures from the primary, secondary and tertiary sectors directly shaping the spatial distribution of human activities at sea and the burden inflicted to marine ecosystems. Increased traffic density, changing land-use of coastal areas and expansion of industrial usages of marine environments (e.g. dredging, mining, renewable energies) are some example of those pressures. Meanwhile, the role of the coast, shelf seas and ocean in climate regulation and especially their role in ‘blue’ carbon are still poorly understood and there are no international agreements safeguarding ‘blue’ carbon despite its relevance to climate change mitigation and natural capital management. As a consequence, new regulatory frameworks will be increasingly needed to monitor and optimize the range of feasible and sensible uses of marine areas and resources.

A first aim of this session is then to review and discuss the current state of the art on ocean governance and management related to marine common pool resources, in particular considering blue carbon and the biophysical and geo-political conditions of uncertainty surrounding it.

A second aim of this session is to assess the opportunities offered by Marine Spatial Planning, which is spreading throughout the world, for integrating environment into public policies and the ecosystem-based approach. Marine spatial planning offers indeed an attractive setting to combine different uses of marine resources within a single area through its aim to reconcile human uses and nature conservation. A specific focus of the session will be on the tropical regions where policies regulating marine and coastal environments are predominantly sector-based, thus hindering comprehensive understanding and relevant response design to challenges posed by the management of marine and coastal environments.

This session will open the floor to present and discuss the **challenges** we need to overcome in the inter-sectorial collaboration efforts to transcend traditional regulatory limits, via a set of themes and case studies. Moreover, investigating the link between policy relevant knowledge and decision support tools will allow to weigh alternatives and balance marine spatial planning and governance options, keeping in mind their impact to the environment, including blue carbon, and on human communities throughout the decision-making process.

Session 5: “But why won’t they use my science?” Improving the impact of marine science on policy: Advances in theory and practice

Conveners: Chris Cvitanovic, Mark Dickey-Collas and Ingrid van Putten

Successfully navigating the complex and uncertain challenges facing the world’s marine and coastal ecosystems requires the integration of new and evolving knowledge into decision-making processes. Further, many international treaties demand that ‘best available knowledge’ underpins decision-making processes. Science is one form of knowledge that is critical in this regard, however, the uptake and integration of scientific research into decision-making processes remains a significant challenge. This has led to an increased academic focus on how to improve the impact of marine science on policy and practice. Simultaneously many new local, regional and global initiatives have been established to improve the extent to which marine science informs policy and practice. In this session we invite contributions from both researchers and practitioners working at the interface of science and policy so as to improve our understanding of progress in the field. In particular, contributions are invited from people working across different contexts and scales, so as to share our diverse learnings and experiences and identify strategies to enable a more effective relationship between marine science, policy and practice.

Session 6: Designing the quilt of sustainable ocean governance

Conveners: Robert Stephenson, Chris Cvitanovic, Alistair Hobday and Ingrid Van Putten

Ocean governance is a complex topic. In recent decades there has been considerable research and attempted implementation of a number of concepts including a Social-Ecological Systems Approach, Ecosystem Approach to (or Ecosystem-based) Management, Precautionary Approach, Integrated Management, Marine Spatial Planning, and Participatory or Co-management. At the moment, these concepts appear very much as separate entities. They have parallel literature streams, and where they have been applied in practice they have appeared most often as individual concepts in partial attempts to improve governance and management outcomes. Yet at face value there would seem to be many similarities and overlaps, and possibility for synergies, among these concepts. At present these concepts may in many ways seem to be competing for attention, when in fact they should work together to form the quilt of sustainable ocean governance. This session will bring together experts in the diverse concepts with an objective of producing a conceptual synthesis of overlaps and differences among the concepts in order to improve implementation. The session will explore both theoretical and practical aspects including their development and history of use, and consider if and how the concepts might work better together. A few key working papers by teams of subject experts will attempt to cross-walk concepts, identifying areas of similarity and difference. Accepted contributed papers will be presented at one open session where the discussion will focus on identifying approaches for practical unification and synergies in implementation. The assembled key subject experts will then meet in a later facilitated workshop to discuss the concepts in more detail and to map out a synthesis (paper) on the integration of concepts in achieving ‘the quilt of sustainable ocean governance’.

Session 7: Ecological feedbacks in the Earth System

Conveners: Lester Kwiatkowski, Charlotte Laufkötter, Andrew Yool, Laurent Bopp and Eugene Murphy

The biosphere is a crucial component of the Earth System, influencing climate in two-way interactions that can generate feedback effects, dampening or amplifying the impacts of change. Our knowledge of those interactions is limited, and our understanding of the processes and their importance is extremely poor. Despite the fact that some of these processes may feedback on the physical climate system the large majority of those processes are not included in the current generation of Earth System models. Ecological interactions in global and regional models can significantly alter the results of physical and biogeochemical projections and predictions, and hence subsequent biological and biogeographical responses. Knowledge of feedback processes, their amplitude, and potential evolution is needed to appropriately parameterize coupled physical-biogeochemical-ecological models of the ocean. In the ocean the focus until now has been on the role of biological processes in biogeochemical cycles, which influence the storage and flux of carbon dioxide and other greenhouse gases, thereby affecting future climate. A broader understanding of ecological feedbacks at seasonal, interannual and decadal scales is critical to interpreting and predicting, or projecting, marine ecological responses to global and local changes. This session is aimed at advancing understanding of ecological feedbacks in the Earth System. We welcome reports of field, laboratory, data syntheses and modelling studies that address key research questions of this challenge:

- How do ocean ecosystem interactions with other components of the Earth System significantly affect climate processes and how are these interactions affected by change?
- What level of complexity is needed to represent these interactions and feedbacks?
- What approaches are needed for these interactions and feedbacks to be modelled and projected?
- How can ocean-human system interactions be incorporated into Earth System models?

Session 8: Ecosystem-social interactions in marginal seas

Conveners: Richard Bellerby and Su Mei Liu

Continental marginal systems, where societal dependence for food, livelihoods and recreation is growing, are undergoing rapid change following human activity and climate change. Integrating environmental, ecological and economic knowledge of continental margin systems, and how these systems may change under different perturbation scenarios, is imperative to understand the interplays between human use of the oceans and present management strategies of marginal systems; optimising the services they provide. Lessons learned from multidisciplinary syntheses and inter-regional comparative studies of coastal socio-ecological systems will help rationalise and optimize marginal seas management approaches. This session is aimed at improving our understanding of marginal social-ecological systems, guiding sustainable development of resources and advising governance regimes to facilitate sustainable governance, facilitating equitable sharing of margin resources, and evaluating alternative research approaches and partnerships that address major margin challenges.

Session 9: Food web dynamics and contaminants: interactions with global environmental change and implications for food security

Conveners: Michael Bank, Heidi Pethybridge, Anne Lorrain and David Point

Contaminant exposure in marine predators is often interconnected with global environmental change factors, including climate variability, increases in terrestrial runoff and shifts in ocean biogeochemistry and circulation patterns. Food web dynamics are also related to changes in the environment and exert important controls over contaminant bioaccumulation and biomagnification regimes. This session will address questions and promote ideas to further understand the complex relationship between contaminants such as, but not limited to, heavy metals, persistent organic pollutants and microscale and nanoscale plastic particles and global environmental change and human dimensions across a wide array of spatial and temporal scales. Papers on a broad range of topics will be considered, including contaminant exposure assessments, food web analyses and isotopic niches, effects of climate and/or habitat change on marine predator population dynamics, socio-economic dimensions of marine fisheries as well as human health risk assessments and implications for food security. Additional empirical, theoretical and modelling contributions relevant to this theme will also be considered.

Session 10: From genes to marine ecosystem functioning: New methods and models for integrating big data and small bugs in trait-based approaches

Conveners: Sakina-Dorothée Ayata, Ya-Wei Luo, Frederic Maps, Meike Vogt, Meng Xia, Yongsheng Wu

Marine ecosystems have been undergoing abrupt changes forced by anthropogenic and natural impacts in recent years. Numerical models have been widely used to study the functions of marine ecosystems and to predict their changes caused by anthropogenic and natural impacts. The models usually couple physical processes with ecosystems at food web (and/or microbial loop) levels, largely assembling marine biomes into tens of variables. Nevertheless, marine biomes are much more diverse, so that their functioning and sustainability are more complex. Their flexibility under a changing environment, i.e., their acclimating capability, is also a key to predict their response to global change. Omics and physiological trait data are key to have a better understanding of these questions, but have only been adopted in a limited number of studies. Indeed, functional traits such as size, trophic regime or life-cycle strategies, are phenotypic characteristics of organisms influencing individual fitness and thus the ecological success of marine species. Trait-based approaches hence provide new tools for a better understanding of biodiversity and ecosystem services and are vital to assess the response of marine ecosystems to climate and environmental changes that will lead to unforeseen states.

The aim of this session is to bring together marine ecologists working at the interface between traditional and novel marine ecosystem and/or trait-based data, as well as mechanistic and statistical marine ecosystem modelling. It will foster the development of these different but complementary trait-based approaches in order to study the links between marine species composition, ecosystem dynamics and functioning at multiple spatio-temporal scales (local to global; diurnal to seasonal to decadal) for the past, present or future ocean. Studies based on recent methodological developments such as high throughput sequencing or imaging to investigate ecological patterns in marine ecosystem structure and function, studies integrating different streams of novel observational data into trait-based or statistical models, or those combining mechanistic models and trait data to test and verify classical macro-ecological theories in the marine realm are particularly welcome. In addition to inviting submission of presentations that already incorporate omics and physiological processes into ecosystem models, we particularly encourage submissions from those scientists seeking to upscale their biological findings to larger spatial and longer-temporal scales through models, and those scientists seeking to improve their modelling results by incorporating biological knowledge.

Session 11: Investigating and modelling linkages between biology and fleet behaviour in multi-species fisheries and ecosystems

Conveners: Carey McGilliard, Alan Haynie, Gavin Fay, Jörn Schmidt, Sigrid Lehuta and Katell Hamon

Fleet behaviour in multi-species fisheries can be driven by a variety of factors, including spatial dynamics, catch limits, markets for individual species, regulations such as spatial closures and bycatch limits, and shifts in population and food web dynamics, changes in climate, and other conditions. Typical single-species modelling approaches often assume that the fleet will catch its quota of each species, but this is unlikely to occur given the complexity of multi-species fishery systems. Exploring drivers of fleet behaviour, considering approaches to modelling that behaviour, and linking biological and fleet behaviour models are important steps for furthering our understanding of ecosystems and improving our ability to conduct predictive modelling under plausible future conditions. The goal of this session is to (1) gather together researchers who are investigating and/or modelling linkages between biology and fleet behaviour in multi-species fisheries, and (2) to discuss innovations in modelling approaches and emerging themes from the collective body of recent research.

In particular, the session will address topics including different approaches to fleet behaviour modelling and how fleet behaviour models should be included in management strategy evaluation and ecosystem and stock assessment models. Talks will be geographically diverse and will draw on the experiences of the co-conveners in the North Pacific, North Atlantic, and elsewhere and in the context of ICES and PICES efforts to better integrate human activities into ecosystem-based management. We welcome presentations on empirical studies of fleet behaviour, as well as approaches to modelling fleet behaviour and including fleet dynamics in all types of population dynamics and ecosystem models.

Session 12: Lessons from the extreme events of the early 21st century for the future oceans

Conveners: Hiroaki Saito and Steven Bograd

Impacts of climate change on marine ecosystems are becoming more apparent and persistent. In particular, we have seen an apparent rise in the frequency of extreme events in the global oceans. Examples include the sustained 2014-16 North Pacific marine heat wave (the “warm blob”) and the 2015-16 marine heat wave in the tropical waters off Australia, which were followed by the strong 2016-17 El Niño. The ecosystem impacts of these climate events can be unexpected, such as the giant jellyfish blooms in the marginal seas of the western North Pacific, which was a result of multiple stressors including coastal human activities (eutrophication, overfishing, coastal development) combined with increases in winter sea water temperature which enhanced production. Such extreme events can be viewed as climate change "stress-tests”, giving us insight into possible shifts in ecosystem structure, species’ abundance and distribution, and the frequency and strength of ecosystem disruptions. In order to maintain resilient and sustainable marine ecosystems, it is imperative that management and conservation strategies are developed to mitigate and/or adapt to these impacts. We encourage contributed papers examining the processes and mechanisms of extreme events, and their impacts on the future state of our changing oceans, their marine ecosystems, and the human communities that depend on them.

Session 13: Linking microbial activity and the cycling of dissolved organic matter using –omics approaches

Conveners: Gerhard J. Herndl and Federico Baltar

Our understanding of the cycling of dissolved organic matter (DOM) in the ocean is still rather rudimentary. Recent advances in analytical methods opened new avenues to shed light onto the diversity of organic molecules in the oceanic environment. Similarly, the application of metagenomics, -transcriptomics and –proteomics allow obtaining insights into the metabolic diversity within heterotrophic microbial communities from the sunlit surface waters to the deep ocean realm. Chemical analyses of the DOM pool and the –omics approaches are frequently not directly performed on the same samples. In contrast to the now widely used –nucleic acid-based approaches, metaproteomics is the most direct approach to link metabolic function to substrate utilization. Gene or protein abundance do not provide information, however, on turnover rates of specific DOM compounds. Hence, a combination of approaches is required to fully understand the transformation of DOM by microbial communities combining recently developed approaches to characterize DOM with methods targeting the functional diversity of microbial communities and linking this to bulk measurements of microbial activity such as microbial biomass production and respiration to mechanistically understand the role of microbial communities in the carbon cycling of the current and future ocean. This session should bring together scientists from the fields of marine biogeochemistry and microbial oceanography. The focus ranges from the transformation of individual organic molecules to analyses of the bulk DOM and from metabolic characterization of single microbial cells to basin-scale variation in microbial communities.

Session 14: Long-term time series of ocean data to describe and better understand dynamics of coastal marine systems and drivers of change: integrated tools, methods, in situ observation systems, models and results

Conveners: Valerie Cariou, Guillaume Charria, Victor Quilfen, Nicolas Savoye and Marie Cachera

A good understanding of the dynamics of coastal marine systems subject to large-scale climate variability and to multiple and increasing anthropogenic pressures is crucial for sustainability of marine resources. Management of marine waters implies environmental assessment, high quality and relevant monitoring, as well as relevant predictions. Development of integrated high quality coastal observing systems, combining remote sensing, in situ observations, and numerical modelling on various time and space scales, from long-term to near real time observations, is a key challenge to improve our knowledge of the marine environment and ensure suitability of coastal waters.

On the one hand, it is now possible to combine ancient data (digitalization, data rescue) with historic numerical data in order to generate relevant datasets. However, the exploration of such long-term data series needs (i) wise data collecting, high storage capacities, easy accessibility and; (ii) different methodologies to be able to detect long-term fluctuations by considering the wide range of time scales from extreme events and shifts to pluri-decadal fluctuations.

On the other hand, numerical modelling is under development to integrate multi-scale processes and several ecosystem compartments, but needs high-quality and near-real time in-situ observations to describe and predict ecosystem dynamics. These two approaches for ocean sciences interact with each other and aim for integrative, comprehensive, cross-disciplinary and adaptable coastal observing systems.

This session is dedicated to integrated long-term and real-time ocean information and more specifically to high-quality data, innovations for in-situ and remote monitoring, data sharing platforms, data-mining and modelling in ocean science. This session fosters the multidisciplinary approaches including, for example, atmospheric dynamics, ocean dynamics, advanced statistical methodologies, biogeochemistry, and ecology, to better understand the role of large-scale (e.g. basin-scale atmospheric conditions) and local (e.g. river-induced, environmental disaster) forcings on the long-term dynamics of coastal ocean.

Session 15: Managing the effects of change on Southern Ocean ecosystems: Understanding, challenges, and solutions

Conveners: Rachel Cavanagh, Andrew Constable, Stuart Corney, Eileen Hofmann, Nadine Johnston, Jess Melbourne-Thomas, Eugene Murphy, Andrea Piñones and Rowan Trebilco

The IMBeR regional programme, Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED), is focused on generating a coordinated circumpolar approach to better understand climate interactions in the Southern Ocean, the implications for ecosystem dynamics, the impacts on biogeochemical cycles, and the development of conservation and sustainable management procedures. Climate change is expected to modify Southern Ocean ecosystem dynamics and associated ecosystem services, necessitating modifications to conservation and resource management that anticipate and adapt to potential changes. A recent focus of ICED has been to facilitate the development of ecosystem models that can project the future states of Southern Ocean ecosystems in support of sustainable governance. A crucial aspect of this is to incorporate our understanding of the responses of these ecosystems to past and current change across trophic levels, and at different spatial and temporal scales.

This session will be coordinated by ICED and will include a workshop: Southern Ocean ecosystems: a workshop on the Marine Ecosystem Assessment for the region (MEASO) and its general application. The aim of the morning session is to reflect on the past decade of ICED science and apply insights to improve research on understanding and projecting changes in Southern Ocean ecosystems so that it is relevant to conservation and management decisions. The session will focus on: (i) Southern Ocean species and ecosystems; (ii) Modelling and projections of ecological change; (iii) Policy implications and decision-making (with a focus on integrated understanding of natural and human systems interactions).

This session will consist of three invited seminar-style presentations on each of the session focus areas. Each presentation will be followed by a set of short "lightning presentations" that introduce the session posters. Points raised by the seminar and lightning presentations will then be the subject of a mediated discussion. We therefore encourage abstracts for posters (please indicate whether you would also like to deliver a lightning presentation to summarise your poster) and participation from a range of stakeholders including scientists, conservation and fisheries organisations, and policy-makers.

Session 16: Marine governance, challenges for sustainability

Conveners: Marion Glaser, Anna Zivian, Leopoldo Gerhardinger, and Alice Newton

The challenges of marine governance are complex and require linked, transdisciplinary knowledge and action to be overcome, particularly in this time of rapid global change. Functional, healthy marine ecosystems and vibrant ocean communities depend on governance frameworks that are fit for purpose and consider human needs, ecosystem health, and ecosystem function.

The oral presentations will focus on best practices, synergies, and dysfunctionalities of marine governance at multiple scales and in different sectors. Abstracts should specify the scale (local to global, coastal-regional sea-ocean). They can include a consideration of the relationship among different sectors, with a focus on cross-cutting solutions and avoiding silos, and an evaluation of which decision making tools are most appropriate for ocean management in the face of global change, with consideration of where elements of inequity and lack of access may affect risk responses.

Presentations should focus on positive aspects as well as problems. The approach is to seek solutions rather than describe problems so examples of positive synergies and good practices that may be adapted to different contexts are particularly encouraged.

The World Café will focus on knowledge sharing and exchange on marine governance, seeking solutions to common, global problems that can be implemented at a range of scales. Each table in the World Café will consider different aspects to the problems and challenges, and participants will have the opportunity to cover several topics over the course of the session.

This is a joint session from IMBeR, Earth System Governance, Future Earth Coasts, and the Future Earth Ocean Knowledge Action Network.

Session 17: Modelling social-ecological systems: methods and tools for scenario development and prediction

Conveners: Jan-Jaap Poos, Jörn Schmidt, Olivier Thébaud and Ingrid van Putten

Coupled process understanding of marine socio-ecological systems is attracting growing attention and debate, demonstrating that this is an important research area. Formal methods and tools for scenario analysis are increasingly being used in support of ecosystem-based management of natural resources, including marine fisheries. In addition, there is a growing requirement for these methods and tools to enable the evaluation of alternative decision rules that fully encompass (i) the dynamics of marine social-ecological systems and transition phases associated with management implementation, and (ii) multiple economic, social and ecological objectives of management. While many studies focus on the exploration of possible futures, there is also a need to develop so-called normative scenarios, which consider objectives for the management of ocean uses, and possible pathways for these objectives to be met in the future.

This session will focus on the presentation and discussion of recent advances and key scientific challenges in the formal modelling of marine socioecological systems, and alternative management scenarios. Presentations are invited that focus on the methodological dimensions or on practical case studies in a range of settings. These settings may include ecosystem-based management and fisheries restoration strategies. They can also include integrated ecosystem assessments or biodiversity scenarios, such as those which are being developed under the work of IPBES.

The session will address the IMBeR Grand Challenge II, by examining scenarios of how social and governance systems operate and interact over different scales to determine human response to change, and feedback effects on ecosystem structure and functioning. It will also address Grand Challenge III by considering the ways in which such scenarios can effectively be developed at the interface of science, society and policy.

The session will combine oral presentations and open discussion with participants. A synthesis manuscript co-authored by the conveners and developed in collaboration with the speakers will be produced based on the session.

Session 18: Multiple drivers and their Role in Ocean Global Change Biology

Conveners: Philip Boyd, Sinead Collins, Marion Gehlen, Jon Havenhand and David Hutchins

There is growing awareness that a wide range of drivers, in addition to warming or ocean acidification, are influencing the physiological, ecological and evolutionary responses to ocean global change. These drivers include hypoxia, altered salinity, stratification, nutrient and trace metal supply, and changes to underwater light climate. The suite of drivers that influence nearshore, shelf and offshore waters will vary with locale and often with season, making their study particularly challenging. In addition, there are often interactive effects between drivers that can either offset or enhance their influence on marine life. This wide range of permutations for the modes of environmental control means that we must better integrate the efforts of experimentalists, observationalists and modellers, and ideally that these groups should work together within both national and international frameworks.

In this session, we seek to invite researchers across these disciplines to illustrate the challenges of conducting holistic research in the face of so many permutations, and to present examples of how we can begin to resolve these pressing issues.

Session 19: Ocean governance in the face of change: confronting the challenge of rebuilding fish stocks, fisheries and viable coastal communities and preparing for future change

Conveners: Ratana Chuenpagdee and Barbara Neis

Achieving the combined objectives of rebuilding fisheries resources, fisheries and coastal communities in ways that can accommodate future change is a critical challenge for our time. A vivid example of this is the situation associated with the groundfish fisheries moratoria in Atlantic Canada, which began with the announcement of the closure of the northern cod fishery in 1992. Newfoundland and Labrador fisheries have changed a lot since then and are in yet another period of transition marked by declining crab and shrimp quotas, expanding lobster harvests, limited signs of cod stock recovery, changed and changing resource access, trade agreements and markets, an aging workforce, and some ongoing conflict around stock assessment science, resource access and management, and union representation for fishery workers. This transition is taking place in the context of poorly understood climate change impacts.

In the face of global change, rebuilding collapsed stocks and revitalizing fisheries-dependent coastal communities is a complex governance challenge. This session will provide an opportunity to share lessons and experiences from different parts of the world related to efforts to develop governance approaches with the capacity to support sustainable fisheries and viable communities while taking into account changing natural and social environments. Based on the presentations and the general discussion, the session will produce a report summarizing best practices, as well as priorities and strategies for moving forward towards improving and achieving sustainable ocean governance.

The session will begin with a presentation by the convenors to help set the stage for the larger discussion. The presentation will draw on insights from a Taking Stock Dialogue exercise currently underway within 'Informing Governance Responses in a Changing Ocean', a module within the Ocean Frontier Institute (OFI; oceanfrontierinstitute.com). In this exercise, we are bringing together social and natural science researchers from multiple institutions and community, industry and government organizations to synthesize existing local and international research relevant to understanding past and present governance processes in Newfoundland and Labrador in the periods leading up to and since the groundfish moratoria of the 1990s. The purpose of this exercise is to take stock of what is known and not known about the ecological, economic and social dynamics of collapse and rebuilding in this context and to place it in the context of experience and insights from elsewhere. We invite submissions from researchers and research groups that face similar challenges to share lessons and best practices from their initiatives, and to be part of the discussion about moving forward locally as well as globally.

Session 20: Ocean Recovery – Strategies to mitigate anthropogenic pressures and support marine ecosystem recovery for a sustainable future ocean

Conveners: Anja Engel, Enno Prigge, Carlos Duarte and Thorsten Blenckner

Decades of marine research showed that human activities have strongly altered marine systems. As a consequence, marine life, ecosystem functioning and the linked benefits for human societies are at risk. It is currently unknown whether and to which extent the reduction of individual stressors can stop ecosystem degeneration. With the current and expected future level of human impact on marine ecosystems it is thus uncertain if protection and preservation measures are sufficient to sustain ecosystem functioning and services. Future strategies to counteract the on-going degradation of marine ecosystems and to support their recovery might go well beyond ‘classical’ conservation measures and include active intervention. Such strategies will give rise to novel, scientific, conceptual, legal, and ethical questions. The interrelation of marine and human systems requires comprehensive and transdisciplinary approaches to transform current trajectories of ocean use and management.

Our session encourages scientists from various disciplines to present their research on mitigating pressures (e.g. eutrophication, (plastic) pollution, habitat destruction and resource exploitation) and on enhancing recovery of marine ecosystems. We welcome solution-oriented research to support marine ecosystem recovery, including monitoring of marine ecosystem change, the effectiveness and consequences of marine management strategies and new approaches of marine ecosystem restoration by active ecosystem intervention, such as (e.g.) ecological replacement strategies and assisted evolution. We envisage this session to provide new understanding of the underlying ecological processes of marine ecosystem change both as a consequence of anthropogenic pressures and as a result of conservation and restoration measures. We welcome in particular submissions that explore interdisciplinary case studies of the challenges, risks and rewards of ecosystem intervention to support marine ecosystem recovery and the linked shoreline-crossing effects on society.

Session 21: Responding to policy makers: what can we do, what do we need? Bridging the methodological gaps for better transparency

Conveners: Emilie Tew-Kaï, Florent Le Courtois, Bazile Kinda and François Le Loc'h

With a growing need for relevant marine spatial planning in a context of global change and blue economy growth, scientists are requested to evaluate ecosystem functioning and state under the pressure from anthropogenic activities. This challenge necessitates to (i) estimate spatial and temporal variations of marine ecosystems, from physical to biological fluctuations; (ii) be able to link ecosystem functioning to goods and services provided by the ocean; (iii) understand how pressures and natural variability affect ecosystem functioning; (iv) evaluate cumulative impacts of anthropogenic activities on marine ecosystems (Cumulative Effect Assessment (CEA) and Cumulative Impact Assessment (CIA) approaches); (v) estimate impact thresholds of activities' intensity. Responding to policy makers thus implies a trans-disciplinary approach, combining physical oceanography, biology, ecology, acoustics, chemistry, and so on. Regarding the complexity of these trans-disciplinary processes, a dedicated framework for data certification and knowledge diffusion may be required. Moreover, it should lead to the identification of gaps and assessment of uncertainties. In particular, the definition of expert judgment based on the estimation of uncertainties is of main interest when supporting decision making in the policy process. As ecosystems are studied by many disciplinary fields, it appears important to use a diversity of valuable expert judgment as well as to diagnose uncertainty propagation at each step of a multi-criteria assessment (from data quality to expert judgment and mathematical assumptions).

In this context of response to policy makers, this session will address trans-disciplinary approaches and recent methodological strategies to bridge the gap between governance problematic and scientific innovation. This implies to exhibit the willingness for a mutual understanding to cooperate between institutions, scientists and society. The session will thus focus on sharing (i) new developments considering trans-disciplinarity (acoustics, physics, chemistry, ecology, economic and social approach…), (ii) proper and transparent treatment of sources of uncertainty as well as quality and validation assessment (mathematical theory of evidence, expert judgment validation methods, Bayesian network…), (iii) exchanges on uncertainty in the decision making process and; (iv) research based on stressor-response relationships, their potential impacts, and their relevance to determine threshold values required by policy makers.

Session 22: Same, same, different: understanding variability and the relative roles of environment, climate, fishing and trophic dynamics in marine ecosystems

Conveners: Alida Bundy, Mariano Koen-Alonso and Paul E. Renaud

Many continental shelf ecosystems support high-value fisheries with a long history of exploitation. In the data rich northern hemisphere, over a century of management and monitoring of these ecosystems has produced a substantial database on their structure and functioning and led to development of policies for their sustainable use. Yet despite this, we still have limited understanding of ecosystem variability, species and ecosystem responses to change and the impacts of climate change. Some ecosystems that ostensibly appear very similar can respond quite differently to pressures such as fishing and climate change. Understanding how these drivers, singly and in combination, affect stock size, production, and energy flow through the system will provide insight into the commonalities and differences of the underlying mechanisms of observed ecosystem changes. This is critical both to understand system response to the various drivers, but also to project response to new stressors, to develop future scenarios and to manage for the future. Developing this understanding requires a combination of data compilation, novel analytical approaches, and ecological modelling.

The objective of this session is to explore marine ecosystem variability and the relative roles of environment, climate, fishing and trophic dynamics in marine ecosystems and implications for future management. We invite papers and posters that address these questions at the individual ecosystem level and through comparative process studies using analytical and modelling approaches and:

- take a comparative approach to explore patterns in variability across multiple ecosystems
- use novel analytical techniques to explore these questions
- explore the major linkages, interactions and dependencies between and within human and ocean systems
- explore the combined effects of fishing and global change
- explore ecosystem variability over time and space

This session will consist of oral presentations, posters with associated speed presentations and a panel discussion on the question: “What is limiting our understanding of ecosystem variability? Implications for fisheries management”.

Session 23: The multiple pathways of the biological carbon pump: current understanding and future challenges

Conveners: Frederic Planchon, Clara Manno, Bernard Queguiner, Emmanuel Laurenceau-Cornec, Anna Belcher and Stephanie Henson

The Biological Carbon Pump (BCP), the transfer to the deep sea of organic carbon fixed at the surface by marine organisms, is a key driver of atmospheric CO_2 levels and an essential component of Earth climate. Despite substantial advances made during the past decades, our understanding of the magnitude and variability of the BCP remains limited. Global-scale model estimates of surface carbon export are still largely divergent (range from 5 to 13 PgC yr^{-1}) and have an uncertainty range that is as large as the total amount of CO_2 emitted annually by anthropogenic activities. Reducing this uncertainty represents a major scientific challenge and is required to infer realistic predictions of the global carbon cycle, and by extension, of climate change.

Understanding needs to be improved first at the process level. How organic carbon produced by autotrophic organisms is transferred at depth, reprocessed by heterotrophic food webs, and/or transferred through pelagic food webs up to top predators is still an open question. It is now well assumed that bacterial degradation, along with phytoplankton community structure, and assimilation/excretion by zooplanktonic organisms (including high trophic levels such as fish and/or gelatinous organisms) are important processes to consider. But, how does the heterotrophic community structure control the fate of carbon in the mesopelagic zone, and can we quantify this? For instance, zooplankton can perform large vertical migrations and actively transport carbon downwards through respiration and the production of fast sinking faecal pellets, but they can also consume and respire sinking particles.

This session will also focus at the observational level. Despite numerous and comprehensive field studies, large regions of the global ocean still remain severely under-sampled precluding a comprehensive view of the spatio-temporal variability of the surface and deep carbon export. This is particularly true for the Southern and Indian Oceans, which have received disproportionally low attention in comparison to other oceanic regions. Methodologies to study carbon fluxes have greatly improved in recent years. The advent of new generation instruments such as autonomous profilers or in situ optical imaging systems have allowed to reach unprecedented details on the characteristics of the sinking particle flux. What did we learn by implementing these new methodologies? Do these techniques compare with classical methods (moored/free-drifting sediment traps, marine snow catchers, radiotracers, nutrients/DIC budgets)? These are among the questions we would like to address during this session. We encourage submissions of field, experimental and modelling studies that have been carried out recently and focused on the general topic of the BCP.

Session 24: The Second International Indian Ocean Expedition (IIOE-2): Motivating New Exploration in a Poorly Understood Basin

Conveners: Jerry Wiggert, Raleigh Hood, Jerome Vialard, Benjamin Kürten, and Francis Marsac

The Indian Ocean remains one of the most poorly sampled and under studied regions of the world ocean. The associated knowledge gaps are compounded by the Indian Ocean being a dynamically complex and highly variable system under monsoonal influence. The biogeochemical and ecological impacts of this complex physical forcing are not yet fully understood. Moreover, more than 25% of the world's population lives in the Indian Ocean region and the population of most Indian Ocean rim nations is increasing rapidly. These increases in population are giving rise to multiple stressors in both coastal and open ocean environments. Combined with oceanic warming and acidification due to global climate change, these regional stressors are resulting in both the loss of biodiversity in the Indian Ocean as well as changes in the phenology and biogeography of many species. These pressures have given rise to an urgent need to understand and predict changes in the Indian Ocean, but the measurements and models that are needed to do this are still rudimentary in many aspects. In response to these needs, SCOR, IOC and IOGOOS have stimulated a second International Indian Ocean Expedition (IIOE-2), following up on an initiative of the SIBER regional programme's membership. The overarching goal of the IIOE-2 is to advance our understanding of interactions between geologic, oceanic and atmospheric processes that give rise to the complex physical dynamics of the Indian Ocean region, and to determine how those dynamics modulate climate, extreme events, marine biogeochemical cycles, ecosystems, fisheries and human populations, in an end to end approach.

This session will bring together observationalists and modellers to exchange information and understanding on the current 'state-of-knowledge', gaps, challenges, and future directions in observing and modelling the complex physical, biogeochemical and ecological processes in the Indian Ocean in the context of anthropogenic influences and climate change. This session will also provide an opportunity for participants to find out about current IIOE-2 research and implementation efforts.

Session 25: Towards a coordinated global marine biodiversity observing system

Conveners: Frank Muller-Karger, Gabrielle Canonico, Mark Costello and Isabel Sousa-Pinto

Living marine resources are essential to the nutritional, recreational, and health needs of billions of people, yet marine biodiversity and ecosystem processes remain major frontiers in ocean observing. Implementing operational, sustained programmes to observe biodiversity and to integrate these observations with environmental information is critical to understanding changing patterns of biodiversity in the face of increasing stressors and changing ecosystems, and to determining impacts on natural capital and ecosystem services. The Marine Biodiversity Observation Network (MBON) is working in partnership with the Global Ocean Observing System (GOOS), the Ocean Biogeographic Information System (OBIS), and the Integrated Marine Biosphere Research project (IMBeR) to make available the marine biological and ecosystem observations needed to ensure living marine resources are sustainably conserved and managed and are able to support essential human needs. Efforts to date include developing new advanced methods to evaluate marine biogeographic provinces (seascapes) using multidisciplinary satellite remote sensing data, advancing 'omics methods, and capacity building in informatics and other areas to integrate existing and new field data into global clearinghouses like OBIS and the Global Biodiversity Information Facility (GBIF) following agreed standards.

This session invites presentations on field and remote observations, models, and synthesis that seek to quantify and understand life in the sea and how it is changing. Presentations on strategies for observing biodiversity and biological processes over small and large scales, advanced methods for biological observing, methods to characterize and monitor biodiversity, successful integration of biodiversity measures into observing systems, sustaining observations over the long term to detect change, and relevance to conservation science and uses of deep ocean resources are welcome.

This session also welcomes papers that promote the collection and widespread use of biological diversity and production data concurrent with other types of ocean observations. We invite talks that focus on ideas for implementation of “ecosystem essential ocean variables” eEOVs and improvements to marine data and information management.

Session 26: Transboundary fisheries management in changing North Atlantic and Pacific Oceans: taking stock, future scenarios

Conveners: Rashid Sumaila, Olav Kjesbu and David L. VanderZwaag

This 4-part session will highlight the changing distributions and abundances of transboundary fish stocks in the North Atlantic and Pacific and explore how selected bilateral and regional fisheries management arrangements are faring in addressing changing marine and maritime conditions and mobilities. First, how transboundary fisheries management arrangements in the Northwest Atlantic and Northeast Pacific are assessing and addressing ecosystem changes will be described. Northwest Atlantic arrangements include the Northwest Atlantic Fisheries Organization (NAFO), the North Atlantic Salmon Conservation Organization (NASCO), the International Commission for the Conservation of Atlantic Tunas (ICCAT), and Canada-U.S. bilateral cooperation in managing shared groundfish on Georges Bank. Northeast Pacific arrangements include the Pacific Salmon Commission, the Western and Central Pacific Fisheries Commission, the North Pacific Fisheries Commission, and the Pacific Halibut Commission. Second, the current state of and future scenarios for biological and economic changes in transboundary fish stocks will be projected for these marine regions with a particular focus on which countries are likely to be future "winners or losers." Third, a Northeast Atlantic case study will examine changing fisheries distributions in the Northeast Atlantic and review challenges to transboundary fisheries management raised by shifting migrations of key species such as mackerel, hake, and Atlantic bluefin tuna off coastal Europe and Scandinavia. Commissions in this region to be discussed include North East Atlantic Fisheries Commission (NEAFC) and the Joint Norwegian-Russian Fisheries Commission. In addition, Norway is a contracting party in the Northwest Atlantic Fisheries Organization (NAFO) and ICCAT. Fourth, bilateral management of specific Canadian and US fisheries is discussed using game theory, which may provide clearer insights into socio-economic implications of climate change, thus providing optimal scenarios for policy management. Finally, a broad discussion with academic participants will be encouraged regarding the key constraints in transboundary governance arrangements and possible innovative ways to move forward. Invited speakers include each of the conveners; Phillip Saunders, Cecilia Engler, and Olga Koubrak Dalhousie University; and William Cheung and Juliano Palacios-Abrantes, University of British Columbia. This session will be the launch of a special issue of Ecology and Society to be published in 2019.

All slots for presentations are already filled and so abstracts will not be accepted.

Session 27: Working in the science-industry interface: strategies for effective collaboration and pathways to positive environmental change

Conveners: Prue Addison and Chris Cvitanovic

Scientists are increasingly encouraged to work in the science-policy-practice interface to conduct research that addresses pressing environmental and sustainability issues. In the environment sector, many scientists have collaborated effectively with the public sector (e.g., government agencies and not-for-profit organisations), and have made significant contributions by embedding science in environmental policy and practice. In line with this, our understanding of what makes for successful and effective science-policy collaborations has deepened through research into the process of knowledge exchange and research impact across the science-policy interface. What has received less attention, however, is how science-industry collaborations can effectively contribute to addressing ocean sustainability challenges. The private sector – from big corporations to small and medium enterprises - hold significant power and influence to change their impacts and dependencies on the marine environment; they are critical players to address global environmental challenges and directing ocean sustainability initiatives.

In this session, presenters will share insights from working in the marine science-industry interface and: (i) articulate the case for science-industry relationships in addressing ocean sustainability challenges; (ii) share lessons around what makes for successful and effective science-industry relationships; and, (iii) identify new opportunities, pathways and research needs to develop effective science-industry collaborations, contribute to global sustainability challenges, and support positive environmental change.

The session involves two parts: (i) lessons from the convenors and participants from their research into science-industry collaborations; and (ii) facilitated discussion with participants to compare and contrast individual experiences in science-policy and science-industry collaborations in addressing global environmental and sustainability challenges. This session is open to all participants to present in and attend the group discussion.

IX. WORKSHOPS

Getting the most out of Earth Observation data for marine & coastal science: new satellites, tools and research

9:00am - 12:30pm, Jun 16
Room 3

Conveners: Gordon Campbell, Cat Downy and Antoine Mangin

The aim of the workshop is to highlight (potentially with speed talks) some of the recent innovations and developments in Earth Observations (EOs) and gather user requirements and feedback from the IMBeR-wide community on their EO data needs.

Key topics that it will cover:

New satellites – updated technology means better measurements of the ocean and coastal environments, with better resolution, coverage and access. These data have applications from monitoring changes in Earth's climate to tracking marine pollution.

New tools - one of the priority research questions IMBeR asks is, "How can IMBeR contribute to the synthesis and integration of global datasets and link these to ecosystem modelling?" As the diversity and complexity of EO data available continues to increase, the need for efficient data access, information extraction, data management and processing tools are key issues for handling such large amounts of data.

New research – scientific advances in satellite research can provide solutions for sustainability problems: e.g. data analytics assess the direct optical measurement of seaborne plastic waste from satellites, or methods for enabling sustainable ocean governance beyond areas of national jurisdiction.

Integration of marine and coastal institutional regimes across multiple sectors

9:00am – 5:30pm, Jun 15
09:00am - 12:30pm, Jun 16
Room 4

Conveners:
Manuel Bellanger, Robby Fonner, Cameron Speir and Olivier Thébaud

Marine and coastal activities are often closely interrelated and resources spanning marine and coastal environments are also likely to span multiple jurisdictional boundaries and ecological structures, making it critical to take into account land-ocean interactions and to foster cross management agency coordination. This requires examination of how well institutional systems are designed and integrated across multiple sectors and resources to avoid inefficiencies arising from conflicting regulations and ensure that the variety of stakeholders are properly incentivized for the management system to deliver outcomes as planned. In particular, piecemeal approaches to marine and coastal management can result in governance structures with overlapping and conflicting mandates within and across resources, economic sectors, and jurisdictional boundaries.

This workshop will be an opportunity to bring together case studies from a variety of contexts (e.g. conflicts between offshore wind power and fisheries, interactions between agricultural sector and river flow impacting marine protected resources, interactions between biodiversity protection and fisheries management; …) and researchers working in different geographical areas around the world to inform and advance the development of decision-making frameworks to address cross-sectoral management issues. The focus of the workshop will be on methodological approaches that can be used to (1) understand what environmental and societal factors lead to governance conflicts; (2) design policy alternatives that align management and stakeholders incentives; (3) evaluate policy alternatives considering management tradeoffs across competing objectives. Abstracts for oral and poster presentations are invited which address these themes.

Marine transboundary planning, combining conservation with conflict resolution

2:00pm - 5:30pm, Jun 16
Room 3

Conveners: Peter Mackelworth and Jungho Nam

There are many examples of marine boundaries contested between adjacent states. Most political boundaries do not coincide with ecological boundaries and the connective nature of the marine environment further complicates this situation. With increasing recognition of the role of the sea for natural resources, new forms of power and shipping routes, conflicts between states are increasing. While there are areas where conflict is increasing to the detriment of the marine environment, such as the Spratly Islands, in other areas strategies based around collaboration over the marine environment are aiding conflict resolution. This workshop will look at the potential for the development of coordinated conservation across international marine borders. It will explore the conditions for the development of successful transboundary conservation through a series of case studies. It will seek to analyse the influence of international law, soft law and the role of non-governmental actors in affecting the development of transboundary marine conservation. In addition, it will consider the role of conservation as a means to facilitate other objectives, such as conflict resolution.

The workshop will be divided into three sessions. The morning session will bring together a number of case studies from varying contextual situations to examine the underlying reasons for their success or failure. Effort will be made to bring case studies from a wide range of jurisdictions, including territorial seas, continental shelves, exclusive economic zones and areas beyond national jurisdiction. Included in this session will be a presentation of the Spratly Island case study.

The second session, will aim to take best practice and apply it to one case study of particular prominence, the Korean West Sea Maritime Peace Zone (MPZ). Originally developed in 2003 by the Korea Maritime Institute it was the first attempt in the Republic of Korea (ROK) to adopt the marine peace park approach to reconcile conflicts in the transboundary coastal and marine area. Until early 2018, the MPZ was shelved until the government of the ROK changed and adopted a more conciliatory approach to the Democratic People's Republic of Korea (DPRK).

The final section, will assess the potential for developing a framework for wider international cooperation from the results of these marine transboundary conservation initiatives. The ultimate aim with be to formulate guidelines for a framework for conservation conflict resolution and the role of conservation.

The conveners aim to invite researchers from both the ROK and the DPRK, both of which are able to travel to France to discuss the MPZ. In addition, the convenors will invite specialists, in cooperation with the Horizon 2020 MarCons COST networking action, and researchers studying the Spratly Islands case study. In total, up to five other case studies will be included as well as the Spratly Islands and Korean Maritime Peace Zone cases, and the workshop is open for abstract submissions.

Natural analogues of an Arctic in rapid transition (AnalogueART): Using natural analogues to investigate the effects of climate change and ocean acidification on northern ecosystems

2:00pm - 5:30pm, Jun 16
Room 1

Conveners: Samuel Rastrick, Jason Hall-Spencer, Kumiko Azetsu-Scott, Melissa Chierici and Naomi Harada

Northern oceans are in a state of rapid transition. The polar ocean is experiencing one of the most rapid shifts in biogeographic boundaries on the planet due to rapid warming, resulting in polar and tundra ice melt, and coupled with ocean acidification (OA) - that affect the ecology of marine organisms. Still, our knowledge on the likely effects of climate change and acidification on northern ocean chemistry and ecosystems is inadequate. As it is based mainly on limited oceanographic observations and single-species, rapid perturbation experiments on isolated elements of the ecosystem that focus on a limited number of carbonate chemistry drivers. It is difficult to extrapolate from such studies to larger scales, as these are generally too short-term to reveal how organisms may adapt/acclimatise, have often set steady pCO_2 levels (which are unrealistic), and use organisms that are separated from their natural suite of food, competitors, predators, and facilitators.

Natural analogues to OA, such as CO_2 vents, have been used to further our knowledge on the sensitivity of biological systems to this global change driver. Thus, assessing the capacity of different tropical and temperate species to show long-term acclimatisation and adaptation to elevated levels of pCO_2. Natural analogues have also provided the means to scale-up from single-species responses to community and ecosystem level responses. A range of Arctic and sub-Arctic sites, including CO_2 vents, methane cold seeps, estuaries, up-welling areas and polar fronts, that encompass gradients of pH, carbonate saturation state and alkalinity, are suggested for future high latitude, in-situ ocean acidification research. This workshop will examine how monitoring the chemical oceanography combined with observational and experimental (in situ and laboratory) studies of organisms around these natural analogues can be used to attain more accurate predictions of the impacts of OA and climate change on high latitude species and ecosystems.

Consequently, this workshop aims to provide a platform for collaboration between international experts with complementary experience in 1) monitoring carbonate chemistry across spatial and temporal gradients at high latitudes, 2) using natural analogues (including temperate and tropical systems) to assess the effects of predicted OA at different levels of biological organisation and 3) the effect of elevated pCO_2 and low carbonate saturation on high latitude species. We invite applications for poster and oral presentations of studies that have used natural analogues to investigate the biological effects of OA and related carbonate chemistry drivers, particularly those where the methods could be applied to Arctic and Sub-Arctic systems. We also invite presentations on all aspects of the effects of OA and climate change in northern ecosystems, principally, studies assessing natural spatial and temporal fluctuations in carbonate chemistry, the ecological and physiological effects of these fluctuations, and investigations using natural analogues of future climate change in Arctic waters.

This workshop is convened by the IMBeR regional programme Ecosystem Studies of Subarctic and Arctic Seas (ESSAS) working group Natural analogues of an Arctic in rapid transition (AnalogueART).

Setting priorities for research into Changing Ocean Biological Systems

9:00am - 5:30pm, Jun 16
Room 2

Conveners: Philip Boyd, Sinead Collins, Marion Gehlen, Jon Havenhand and David Hutchins

The workshop will commence with several plenary talks to stimulate discussion. We also invite participants to offer short informal presentations on what the state-of-the-art is in the research theme of Ocean Global Change Biology. For example, what are the rate limiting steps for modellers that are preventing further advances in this field? What are the next steps for experimentalists investigating physiological, ecological and evolutionary aspects of this broad topic? And are these communities effectively sharing ideas and their findings. At a broader scale, can we better link the research being conducted by international programmes, and how can the cumulative weight of these activities help to set future research priorities?

Southern Ocean ecosystems: a workshop on the marine ecosystem assessment for the region (MEASO) and its general application

11:00am - 3:30pm, Jun 20
Room 8

Conveners: Andrew Constable, Rachel Cavanagh, Stuart Corney, Eileen Hofmann, Nadine Johnston, Jess Melbourne-Thomas, Eugene Murphy, Andrea Piñones and Rowan Trebilco

A first Marine Ecosystem Assessment for the Southern Ocean (MEASO) is under development to facilitate contributions from the Antarctic and Southern Ocean marine science community to the 6th Assessment Review (AR6) of the Intergovernmental Panel on Climate Change (IPCC), the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC), the Commission for the Conservation of Antarctic Marine Living Resources and other recent initiatives to assess status and trends in global ocean Ecosystems. The MEASO, which is supported by and coordinated with the IMBeR regional programme Integrated Climate and Ecosystem Dynamics (ICED) and the Scientific Committee on Antarctic Research (SCAR), is intended to complement specific scientific requirements for annual management needs with long-term assessments. The MEASO is intended to provide a forward-looking assessment of what trends in Southern Ocean ecosystems are occurring now and likely to occur into the future, along with research and management needs for the future. The aim is to have a quantitative assessment that enables managers to achieve consensus in adapting their management strategies to ecosystem change so that objectives for sustainable ecosystems can be achieved.

The first MEASO international conference, held in Hobart, Tasmania, in April 2018, provided a venue to share relevant science, enhance community input into the design and planning of the MEASO and develop an initial work plan. The aim is to publish the first MEASO in 2019, for use in the IPCC AR6, then for work to commence toward subsequent MEASO iterations on a cycle that aligns with IPCC reporting (i.e. an updated MEASO, say, every 6 years).

This workshop will explore and discuss (i) the merits of different methods for assessing the status and trends of ecosystems, (ii) the respective utilities of the results for making management decisions on mitigating or adapting to prognoses of change, and (iii) how best to communicate the results to end-users. Natural and social scientists are encouraged to attend to input their ideas for the general application of ecosystem assessment methods for the global oceans. Reading materials will be made available prior to the workshop.

The workshop is linked to the oral session “Managing the effects of change on Southern Ocean ecosystems: Understanding, challenges, and solutions.”

Time-varying ecological geography of the global ocean

9:00am - 5:30pm, Jun 15
Room 1

Conveners: Siv Lauvset and Nadine Goris

Terrestrial ecosystems are categorized into biomes, which are regions of comparable climate and dominant plant types. For the oceans, a similar categorization into biomes is more challenging due to the movement of water masses and the more distributed trophic food web. Several concepts of partitioning the global oceans have been proposed such as Large Marine Ecosystems, Marine Ecoregions of the World, Biogeochemical Provinces and open ocean biomes. This workshop focusses on ecological divisions of the ocean, including methodology on how to best define such divisions. Strong emphasis will be placed on temporal variations on seasonal, annual, and decadal time scales and how these affect both the environmental conditions defining the ecological divisions and the trophic food webs within the divisions. With ongoing climate change, it is expected that the ecological divisions might change in size, distribution, and/or location. We welcome abstracts about the impact of climate change on ecological divisions and associated changes in trophic food webs and overall ecosystem functioning.

Using data hubs to advance knowledge and improve our understanding of biodiversity state and dynamics

9:00am - 12:30pm, Jun 16
Room 1

Conveners: Yvan Le Bras, Christelle Le Grand, Bénédicte Madon, Claire Bissery and Mathieu Merzereaud

Appropriate data management and data analysis practices are essential to deal with the need for accessibility and reproducibility in ecological science. This is particularly the case to successfully extract information from raw data from around the world, to produce/identify indicators to evaluate the state of biodiversity. There is also a need to link practitioners with scientists and policy experts as well as citizens. To address these challenges, it is crucial to facilitate access to data, metadata, publications, and open source tools. The purpose of this workshop is to exchange information about data and metadata management, as well as data analysis tools and practices. Through oral presentations and a panel discussion, the workshop will focus on examples from initiatives related to French Biodiversity Research infrastructures as marine system domains.

Visioning Global Ocean Futures

9:00am - 5:30pm, Jun 15
Room 2

Conveners: Carolyn Lundquist, Kate Davies, Karen Fisher, Beth Fulton, Alison Greenaway, and Ingrid van Putten

Scenarios are powerful tools to envision how different pathways of development and stakeholder decisions might impact nature and its contributions to people. While frequently used in economic planning and climate change contexts, scenario use is in its infancy in environmental planning and decision making for ocean management. Current scenarios (i.e., Shared Socio-economic Pathways (SSPs)) treat nature as endpoints of socio-economic development pathways and neglect the central role of biodiversity and ecosystem services in underpinning human development. However, humanity and nature are intertwined, as reflected in the linkages between targets for human well-being and nature conservation in the United Nations Sustainable Development Goals (SDGs). Internationally, the use of top down scenarios as drivers of potential environmental futures is evolving, through scenario developments that are reframing the environmental scenarios landscape to better integrate with participatory decision making, diverse values and knowledge systems, cross-scale interactions, and social-ecological feedbacks between the state of the environment and human well-being.

The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) has initiated the development of multiscale scenarios for Nature Futures based on positive visions for human relationships with nature, and a preliminary Nature Futures Framework will be presented at this workshop. This framework and its associated scenarios are envisaged to shift the traditional ways of forecasting impacts of society on nature toward nature-centred visions and pathways that will integrate interlinkages of social-ecological systems across biodiversity, ecosystem functions and services, and human well-being. An initial set of visions was developed at an international participatory visioning workshop in September 2017, including one vision specific to Oceans. These visions were used to develop the preliminary Nature Futures Framework at a further workshop in June 2018. At this workshop, participants will explore how the Nature Futures Framework resonates for the Oceans, contributing to iterative cycles of visioning, stakeholder co-creation, and modelling at global, regional and local scales that are supported by the IPBES Scenarios and Models Expert Group. Participants will enrich, complement and fill the remaining gaps in the framework, and explore the suitability of the framework to integrate with existing predictive modelling, and to explore consequences of alternative policy and management options in nature conservation and sustainable development for both national EEZ and high seas management. This workshop will also integrate learnings from cumulative effects scenarios, recognising that nationally and internationally, coastal and ocean management is typically fragmented across statutes, management agencies and geographies, challenging the ability to account for cumulative effects. The workshop is designed to illuminate shared learnings, barriers, and pathways to address ocean management that extend across EEZs, and enable long term protection, integrity and use of coastal and marine environments.

Conference Schedule

Below is the conference schedule as of 12th June 2019. There may be some changes which will be reflected in the App and interactive schedule online.

Oral and poster presentations are listed by presenter (not author). Complete details are found in *Abstracts* section.

SESSION 1: ADAPTATION IN MARINE SOCIO-ECOLOGICAL SYSTEMS

Room 7

Thu 20 June	Time Block 1 of 1
14:00 - 14:15	**Patricia Angkiriwang** Participatory system modelling for fisheries, food and culture to increase climate resilience on seafood availability in Tla'amin Nation
14:15 - 14:30	**Iroshani Galappaththi** Social-ecological resilience in community-based setting: The case of coastal shrimp farmers in northwestern Sri Lanka
14:30 - 14:45	**Eike Martina Holzkämper** The role of social networks for adopting innovative production techniques as a response to environmental change
14:45 - 15:00	**Katherine Maltby** The fishing forecast: using perceptions to understand fishers' adaptation to future climate change
15:00 - 15:15	**Katherine Mills** Assessing the status of climate adaptation in marine fisheries
15:15 - 15:30	**Sara Miñarro** Differences in well-being among small-scale fisheries
Posters	
Session B	**Chaewon Yoo** More than just a food: the role of pollock in social change and the construction of place in a fishing-dependent community

SESSION 2: ARCTIC MARINE ECOSYSTEMS IN A CHANGING CLIMATE

Room 2

Mon 17 June	Time Block 1 of 7
11:55 - 12:00	**Franz Mueter** Session introduction
12:00 - 12:20	**Ben Fitzhugh** From long-interval, late Holocene paleo-records to scenario-building for adaptive planning in future fisheries
12:20 - 12:40	**Elena Eriksen** Warming in the Barents Sea: ecosystem benefits and problems
Mon 17 June	Time Block 2 of 7
14:00 - 14:18	**Wieslaw Maslowski** The importance mesoscale processes and bio-physical coupling for Arctic ecosystem modeling and prediction

14:18 - 14:36	**Amane Fujiwara** Controlling factor of primary production in the "warmed" Arctic Ocean
14:36 - 14:54	**Eiji Watanabe** FAMOS multi-model intercomparison of the pan-Arctic ice algal productivity on seasonal and decadal timescales
14:54 - 15:12	**Timothée Bourgeois** A numerical analysis of the effects of contemporary sea ice loss on Arctic primary production
15:12 - 15:30	**Takuhei Shiozaki** Factors regulating nitrification in the Arctic Ocean: the potential impact of sea-ice reduction and ocean acidification
Mon 17 June	Time Block 3 of 7
16:00 - 16:18	**Shigeto Nishino** Nutrient and phytoplankton distributions associated with ocean circulation, eddies, and mixing in the Pacific Arctic Region
16:18 - 16:36	**Sünnje Basedow** Surface patches of *Calanus* sp. and the seasonal advection of zooplankton into the Arctic Basin through the Atlantic gateway, Fram Strait
16:36 - 16:54	**Anette Wold** Awakening of zooplankton below drifting sea ice after the dark Arctic winter
16:54 - 17:12	**Haakon Hop** Atlantification of zooplankton in Arctic fjords, Kongsfjorden and Rijpfjorden, Svalbard
17:12 - 17:30	**Slawomir Kwasniewski** Spatial variations in taxonomic and functional diversity of zooplankton from boreal to Arctic seas
Tue 18 June	Time Block 4 of 7
11:00 - 11:18	**Raul Primicerio** Climate change impact on Barents Sea ecosystem functioning and vulnerability
11:18 - 11:36	**Laurent Oziel** Increasing Atlantic currents drive poleward expansion of temperate marine species in the Arctic Ocean
11:36 - 11:54	**Bérengère Husson** Extreme climatic event drive immediate response of fish communities in the Barents Sea
11:54 - 12:12	**André Frainer** Rapid borealization of Arctic marine fish communities
12:12 - 12:30	**Ute Daewel** On the role of higher trophic levels for long-term changes in ecosystem productivity: A modelling study in the North Atlantic/Arctic Ocean
Tue 18 June	Time Block 5 of 7
14:00 - 14:18	**Andrea Bryndum-Buchholz** Marine animal biomass shifts under 21st century climate change in Canada's three oceans

14:18 - 14:36	**Irene Alabia** Modeling abundance of demersal fish in the Pacific Arctic under climate change: implications on future resource availability to fisheries
14:36 - 14:54	**Nicole Misarti** Tracking long-term trends in trophic levels of Pacific cod through carbon and nitrogen stable isotopes
14:54 - 15:12	**Benjamin Laurel** Climate impacts on spawning habitat of Pacific cod (Gadus macrocephalus)
15:12 - 15:30	**George Hunt** SE Bering Sea ice: the importance of location, amount, persistence and timing for the recruitment of zooplankton and pollock
Tue 18 June	Time Block 6 of 7
16:00 - 16:18	**Louise Copeman** The effects of temperature and food quality on the lipid condition and trophic biomarkers of juvenile polar cod (Boreogadus saida) and co-occuring Alaskan congeners.
16:18 - 16:36	**Caroline Bouchard** Climate-driven change in Arctic zooplankton species composition could decrease feeding success of polar cod larvae
16:36 - 16:54	**Frode Vikebø** Barents Sea polar cod in a changing climate
16:54 - 17:12	**Bungo Nishizawa** Associations between seabirds and their prey in the northern Bering Sea during summer of 2017 and 2018
17:12 - 17:30	**Anne Kirstine Frie** Changes in female age distribution parameters of severely declining Greenland Sea hooded seals 1958-1999: Clues to ecosystem impacts on a large piscivore marine mammal?
Wed 19 June	Time Block 7 of 7
11:00 - 11:18	**Ken Drinkwater** Expected Changes in the Physical, Chemical and Phytoplankton Environments in the Subarctic to Arctic Transition Zones in the Atlantic and Pacific Sectors of the Arctic
11:18 - 11:36	**Franz Mueter** Prey resources, food webs, fish and fisheries in rapidly changing Subarctic and Arctic marine systems
11:36 - 11:54	**Alan Haynie** Are Fishery Management Systems Prepared for Change? A Comparison of Alaska, Norway, and Japan from the RACArctic Project
11:54 - 11:57	**Jonaotaro Onodera** Particle flux change reflecting input of Pacific-origin water in the southwestern Canada Basin
11:57 - 12:00	**Miriam Seifert** Glacial meltwater effects on the carbon cycle of Scoresby Sund (Greenland), the world's largest fjord system

12:00 - 12:03	**Anja Engel** Inter-annual variability of organic carbon concentration in the eastern Fram Strait during summer (2009-2017)
12:03 - 12:06	**Olivier Gaëtan** Impact of sea ice/snow distribution on the seasonal and inter-annual variability of ocean primary production and carbon export flux in Baffin Bay: a 1D modeling approach
12:06 - 12:09	**Hyung-Gyu Lim** Effect of the anthropogenic nitrogen on Arctic amplification in present and future climate
12:09 - 12:12	**Emilia Trudnowska** The glacier-influenced coastal Svalbard waters as a habitat for protists and zooplankton
12:12 - 12:15	**Emilia Trudnowska** Ecological plasticity – a key skill to survive in a changing Arctic, tested on *Calanus* – the basis of the high latitude marine food webs.
12:15 - 12:18	**Malin Daase** Isfjorden Marine Observatory Svalbard: seasonal and long term trends in Arctic zooplankton communities
12:18 - 12:21	**Hongliang Li** Overlooked Contribution of the Biological Pump to the Pacific Arctic Nitrogen Deficit
12:21 - 12:30	**Conveners** Closing remarks

Posters

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Session 3: Biogeochemical and biological processes promoted by ocean mixing

Room 8

Wed 19 June	Time Block 1 of 3
11:00 - 11:30	**Ichiro Yasuda** Progress report: Ocean mixing processes: impact on biogeochemistry, climate and ecosystems (OMIX)
11:30 - 11:48	**Claude Estournel** Dense water formation in the Northwestern Mediterranean: from the physical forcings to the biogeochemical consequences
11:48 - 12:06	**Mark Hague** The impact of Antarctic sea ice on surface mixing and primary production
12:06 - 12:24	**Faycal Kessouri** Seasonal modulation of nutrients cycles and phytoplankton biomass by submesoscale circulation in the California Current System
12:24 - 12:27	**Yutaka Yoshikawa** Deceleration of particle sinking by ocean surface turbulence
12:27 - 12:30	**Maki Aita** Response of lower trophic level ecosystems to decadal scale variation of climate system in the North Pacific Ocean
Wed 19 June	Time Block 2 of 3
14:00 - 14:18	**Zimkhita Gebe** Short-term changes in carbon and nitrogen biomass of picophytoplankton over a 10-day period at a station off St. Helena Bay
14:18 - 14:36	**Inès Mangolte** Impact of submesoscale processes on phytoplankton community structure across oceanic fronts
14:36 - 14:54	**Peng Zhou** The Kuroshio Subsurface Water Intrusion onto the East China Sea continental shelf as traced by dissolved inorganic iodine species
14:54 - 15:12	**Jianfang Chen** Monsoon and El Nino regulated biological pump in the South China Sea based on long-term sediment trap mooring
15:12 - 15:30	**Kazuaki Tadokoro** Seasonal and interannual variation of mesozooplankton community structure in the

	Oyashio and Kuroshio-Oyashio Transition waters, western North Pacific
Wed 19 June	Time Block 3 of 3
16:00 - 16:18	**Keerthi Madhavan Girijakumari**
	Mechanisms responsible for intraseasonal variations of the spring phytoplankton bloom
16:18 - 16:36	**Caroline Ulses**
	Budget of dissolved oxygen in the western Mediterranean sea during the deep convective year 2012-2013
16:36 - 16:54	**Feng Zhou**
	Hypoxia: A rising physical-biogeochemical coupled issue driven by the estuary-shelf-slope interactions in the East China Sea
16:54 - 16:57	**Jun Nishioka**
	Iron supply from the marginal seas to the North Pacific Ocean
16:57 - 17:00	**Jianrong Zhu**
	Dynamics of the sediment plume over the Yangtze Bank in the Yellow and East China Seas
17:00 - 17:03	**Aicha Berrada**
	Three-dimensional modeling of primary production, phytoplankton diversity and functional groups in the Canary Current System by remote sensing
17:12 - 17:30	**Jun Nishioka;Yutaka Yoshikawa;Naomi Harada**
	Concluding remarks
Posters	
Session B	**Yutaka Yoshikawa**
	Deceleration of particle sinking by ocean surface turbulence
Session B	**Maki Aita**
	Response of lower trophic level ecosystems to decadal scale variation of climate system in the North Pacific Ocean
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SESSION 4: BLUE MANAGEMENT AND GOVERNANCE OF MARINE RESOURCES

Room 5

Wed 19 June	Time Block 1 of 2
16:00 - 16:10	**Conveners**
	Session introduction
16:10 - 16:30	**Raphaël Billé**
	Supporting integrated coastal management implementation in Pacific Island Countries and Territories: challenges and avenues for progress

16:30 - 16:50 **Beatrice Ferreira**
Connectivity across the seascape: challenges and opportunities in a tropical coast

16:50 - 17:10 **Betty Queffelec**
How to avoid MSP to become an ocean grabbing tool?

17:10 - 17:30 **Maike Scheffold**
Towards evaluating the potential of marine biological carbon management

Thu 20 June Time Block 2 of 2

11:00 - 11:10 **Conveners**
Session introduction

11:10 - 11:30 **Ateret Shabtay**
Marine spatial planning and human-predator interactions. The case of shark risk in Réunion Island (Indian Ocean)

11:30 - 11:50 **Sebastian Thomas**
Exploring an Australian Aboriginal blue carbon approach: cultural, environmental, and social ecosystem services

11:50 - 12:10 **Armelle Jung**
"No good planning without good training": Blue Planning in Practice (BPiP), cross analysis of a comprehensive approach experimented over four continents

12:10 - 12:30 **Solange Teles da Silva**
"Blue Amazon": the legal-political challenges for the implementation of marine spatial planning

Posters

Session B **Philippe Fotso**
Environmental protection in Marine Spatial Planning: insights from the cross-analysis of legal and uses data

SESSION 5: "BUT WHY WON'T THEY USE MY SCIENCE?" IMPROVING THE IMPACT OF MARINE SCIENCE ON POLICY: ADVANCES IN THEORY AND PRACTICE

Room 2

Thu 20 June Time Block 1 of 4

11:00 - 11:20 **Laura Basconi**
Accounting for Ecosystem Service (ES) in the marine environment: background, needs and possible implementation.

11:20 - 11:40 **Annette Breckwoldt**
Look who's asking! (Reflections on participatory research approaches)

11:40 - 12:00 **Christopher Cvitanovic**
Bright spots at the marine science-policy-practice interface: the case (and need) for optimism

12:00 - 12:20 **Julie Hall**
Translating science to policy – bridging the gap in New Zealand

Thu 20 June Time Block 2 of 4

14:00 - 14:20 **Mark Dickey-Collas**
Science 2 advice at ICES, an evaluation of the factors influencing the take up of new

	knowledge.
14:20 - 14:40	**Giulia Donati**
	Using science fuel to drive a change: a case study involving microplastics, whale sharks and stakeholders in the Maldives
14:40 - 15:00	**Raye Evrard**
	The problem isn't the managers: Managers can't use what scientists won't share
15:00 - 15:20	**Stephani Zador**
	Communication, collaboration, and transparency: Tailoring ecosystem science to inform fisheries management
Thu 20 June	Time Block 3 of 4
16:00 - 16:20	**Jason Landrum**
	A view from Philanthropy: The Lenfest Ocean Program Approach
16:20 - 16:40	**Marie Löf**
	Building university-based boundary organisations that facilitate impacts on environmental policy and practice
16:40 - 17:00	**Claire Macher**
	Roles and impacts of science and interactions with stakeholders and decision makers in decision-support to fisheries management: sharing experiences and practices from an inter-disciplinary collective of researchers
17:00 - 17:30	**Conveners**
	Discussion
Fri 21 June	Time Block 4 of 4
09:00 - 09:20	**Dominique Pelletier**
	Science-based evidence in support of management of coastal (marine protected) areas
09:20 - 09:40	**Ashley Wilson**
	What can we learn from the use of ICES scientific advice on fishing opportunities by decision-makers when setting EU total allowable catches (TACs)?
09:40 - 10:00	**Alicia Said**
	Transdisciplinarity in Fisheries: Are We on Track?
10:20 - 10:30	**Conveners**
	Discussion
Posters	
Session B	**Laura Basconi**
	Accounting for Ecosystem Service (ES) in the marine environment: background, needs and possible implementation.
Session B	**Aliou Sall**
	How to bridge the gap between the scientific community and indigenous knowledge bearers : Opportunities for marine policy and practice.
Session B	**Chiara Venier**
	Multi-objective zoning for biodiversity and aquaculture in the Adriatic-Ionian region
Session B	**Sabine Schmidt**
	ODATIS: a single gateway to French in situ marine and coastal data to facilitate data access

Session B	**Chiara Venier** Marine ecosystem services trade-off assessment: a methodological approach to inform maritime spatial planning

Session 6: Designing the quilt of sustainable ocean governance

Room 7

Wed 19 June	Time Block 1 of 4
11:00 - 11:15	**Robert Stephenson; Christopher Cvitanovic; Alistair Hobday; Ingrid van Putten** Introduction and objectives of the session
11:15 - 11:30	**Alida Bundy** Ecosystem Approach
11:30 - 11:45	**Mark Dickey-Collas** EBM mandates and implementation
11:45 - 12:00	**David VanderZwaag** Precautionary Approach
12:00 - 12:30	**Robert Stephenson; Christopher Cvitanovic; Alistair Hobday; Ingrid van Putten** Discussion
Wed 19 June	Time Block 2 of 4
14:00 - 14:15	**Eddie Allison** Social-ecological Systems approach
14:15 - 14:30	**Astrid Jarre** Resource limitations, uncertainty and power plays: lessons from exploring a systems-based approach to ocean governance in the Benguela Large Marine Ecosystem
14:30 - 14:45	**Derek Armitage** Governing the ocean and coastal commons
14:45 - 15:00	**Rachel Kelly** Social licence for marine protected areas: A Tasmanian case-study
15:00 - 15:30	**Robert Stephenson; Christopher Cvitanovic; Alistair Hobday; Ingrid van Putten** Discussion
Wed 19 June	Time Block 3 of 4
16:00 - 16:15	**Maria Grazia Pennino** Marine Spatial Planning
16:15 - 16:30	**Robert Stephenson** Integrated Management: Does it provide the pattern for the quilt of ocean Sustainability?
16:30 - 16:45	**Kate Brooks** The challenges and opportunities of integrating coastal management; a study of the New South Wales social-ecological systems approach
16:45 - 17:15	**Robert Stephenson; Christopher Cvitanovic; Alistair Hobday; Ingrid van Putten** Discussion
17:15 - 17:30	**Robert Stephenson; Christopher Cvitanovic; Alistair Hobday; Ingrid van Putten** Synthesis
Thu 20 June	Time Block 4 of 4
11:00 - 12:30	**Robert Stephenson; Christopher Cvitanovic; Alistair Hobday; Ingrid van Putten** Core team meeting for synthesis and drafting

Session 7: Ecological feedbacks in the Earth System

Room 7

Tue 18 June — Time Block 1 of 3

11:00 - 11:30 **Emma Cavan**
How does varying the metabolic response of organisms to warming influence global particulate organic carbon export?

11:30 - 11:50 **Inga Hense**
Comparison of two model approaches for describing phytoplankton adaptation to temperature

11:50 - 12:10 **Stanley Nmor**
Can diatoms thrive in low silicic conditions?

12:10 - 12:30 **Rémy Asselot**
The relative importance of phytoplankton light absorption and ecosystem complexity for the climate system

Tue 18 June — Time Block 2 of 3

14:00 - 14:30 **Wolfgang Koeve**
The bottleneck of marine ecological feedbacks on atmospheric pCO_2

14:30 - 14:50 **Leonardo Bertini**
The reversibility of anthropogenically-forced change in biogeochemical drivers in the North Atlantic. Can we still go back to pre-industrial levels?

14:50 - 15:10 **Meike Vogt**
An observation-based, objective classification of plankton functional types for use in climate and Earth System models

15:10 - 15:30 **Lester Kwiatkowski**
The impact of variable phytoplankton stoichiometry on projections of primary production, ocean carbon uptake and trophic cascades in the global ocean

Tue 18 June — Time Block 3 of 3

16:00 - 16:30 **Daniele Bianchi**
The abundance and biogeochemical role of fish in the ocean

16:30 - 16:50 **Ian Hatton**
The marine size-spectrum and human effects on oceanic systems

16:50 - 17:10 **Kim Scherrer**
Integrating humans into a global model of the marine wild-capture fishery: small-scale fishing by coastal communities

17:10 - 17:30 **Priscilla Le Mézo**
Human influence on the nutrient cycling by the global commercial fish community

Session 8: Ecosystem-social interactions in marginal seas

Room 8

Tue 18 June — Time Block 1 of 2

14:00 - 14:30 **Song Sun**
New challenges for Marine Ecosystem Based Management-- A Lesson from Macro-algae Bloom

14:30 - 14:50	**Richard Bellerby** Towards a common framework for marginal seas socioecological research: case studies from Norwegian and Chinese coastal systems
14:50 - 15:10	**Su Mei Liu** Environment status under the impact of eco-aquaculture—A case study in Sanggou Bay, the western Yellow Sea
15:10 - 15:30	**Louise Teh** Taking Stock: Status and Trends in East China Sea fisheries
Tue 18 June	Time Block 2 of 2
16:00 - 16:30	**Shion Takemura** Fisheries management toolbox: A fishers' self-assessment scheme to identify visions and next actions toward sustainable development of coastal communities
16:30 - 16:50	**Thamasak Yeemin** Managing dive ecotourism in the Western Gulf of Thailand
16:50 - 17:10	**Xochitl Cormon** Multiple threats to Western Baltic cod fishery
17:10 - 17:30	**Conveners** Discussion
Posters	
Session A	**Jie Liu** Ecosystem-based management under a changing environment via outputs from coupled marine physical and biogeochemical models and participance of stakeholders
Session A	**Wu Nian** Response of nutrient compositions affected by human activities in the lower Yellow River （Huanghe）
Session A	**TBD TBD** Small-scale fisheries and tourism: a two-faced charade?

SESSION 9: FOOD WEB DYNAMICS AND CONTAMINANTS: INTERACTIONS WITH GLOBAL ENVIRONMENTAL CHANGE AND IMPLICATIONS FOR FOOD SECURITY

Room 3+4

Thu 20 June	Time Block 1 of 4
11:00 - 11:15	**Roberta Hansman** Contribution of nuclear applications to study the transfer of contaminants in marine organisms and to promote seafood safety.
11:15 - 11:30	**Marianne Robert** Better knowledge on food web structure and functioning can help improving stocks and ecosystems management
11:45 - 12:00	**Nathalie Bodin** Ecosystem regime shifts affect the bioaccumulation of essential and non-essential hazardous metals in coral reef-associated mesopredatory fish
12:00 - 12:15	**Heidi Pethybridge** Modelling ecosystem responses to contaminants within the Atlantis framework

12:15 - 12:30	**David Point** Using mercury stable isotopes to unravel methylmercury source origin and distribution in Tuna from the South Western Pacific Ocean
Thu 20 June	Time Block 2 of 4
14:00 - 14:15	**Lydie Couturier** Global-scale analysis of trophic interactions in co-occurring tropical tuna using stable isotope analyses
14:15 - 14:30	**Alex Lira** Trophic flow structure of a neotropical estuary in northeastern Brazil and the comparison of ecosystem model indicators of estuaries
14:30 - 14:45	**Catherine Munschy** Persistent Organic Pollutant (POP) levels and profiles in top predator fish from the Western Indian Ocean in relation to their trophic ecology
14:45 - 15:00	**Marina Renedo-Elizalde** Mercury isotopes as a tool to investigate the spatial origin of Arctic seabird contamination
15:00 - 15:15	**Xiaoxia Sun** Ingestion of microplastics by zooplankton and fish from the Yellow Sea
15:15 - 15:30	**Inna Senina** Modeling 137Cs contamination of marine food-webs following Fukushima accident: from zooplankton to tunas.
Thu 20 June	Time Block 3 of 4
16:00 - 16:15	**Annukka Lehikoinen** Spatial aspects of the Baltic fish dioxin risk formation: Social-ecological system analysis
16:15 - 16:30	**Qian Zhou** The Distribution and Morphology of Microplastics in Coastal Soils Adjacent to the Bohai Sea, the Yellow Sea and South China Sea
16:30 - 16:45	**Carsten Spisla** Are jellyfish winners of Ocean Acidification?
16:45 - 17:00	**Anaïs Médieu** Is there enough data to perform robust spatial and temporal analyses of mercury levels in commercial tuna at a global scale?
17:00 - 17:30	**Conveners** Panel discussion
Fri 21 June	Time Block 4 of 4
09:00 - 09:15	**Nathalie Bodin** Regional patterns in mercury and selenium concentrations of swordfish in the Indian Ocean
09:15 - 09:30	**Gaël Le Croizier** Ecological trade-off between the intake of essential and toxic components in the great white shark
09:30 - 09:45	**Aourell Mauffret** Fish contamination and trophodynamic in three French subregions
09:45 - 10:00	**Jelena Mandic**

	PAH sediment toxicity assessment in Adriatic Sea
10:00 - 10:15	**Diana Nur Afifah** Food Insecurity and Children Malnutrition in Coastal Area of Central Java that was affected by Climate Change
10:15 - 10:30	**Conveners** Panel discussion
Posters	
Session B	**Mahammed Moniruzzaman** Physiological status and reproductive strategy of fish in a tropical estuary in face of climate fluctuation
Session B	**Michael Sswat** Ocean acidification affects survival of herring larvae via food web alteration
Session B	**Alex Lira** Mass balanced model to assess the trophic web in a tropical estuary, Northeastern Brazil and the flows of biomass of estuarine ecosystems

SESSION 10: FROM GENES TO MARINE ECOSYSTEM FUNCTIONING: NEW METHODS AND MODELS FOR INTEGRATING BIG DATA AND SMALL BUGS IN TRAIT-BASED APPROACHES

Room 7

Mon 17 June	Time Block 1 of 3
11:55 - 12:10	**Laurene Pecuchet** Trait-based network analysis: predator-prey trait matching and functional changes of the Barents Sea food web
12:10 - 12:25	**Blanche Saint-Béat** Food web modelling and network analysis quantify the role of various functional groups of Zooplankton in three contrasted Arctic marine ecosystems.
12:25 - 12:40	**Ingrid Sassenhagen** Interactions of parasitic marine alveolates with diverse protist species in the Southern Ocean
Mon 17 June	Time Block 2 of 3
14:00 - 14:15	**Mathilde Cadier** Modeling optimal strategies, competition and seasonal succession within unicellular plankton using a mechanistic trait-based approach
14:15 - 14:30	**Ya-Wei Luo** An optimality-based cellular model in predicting response of nitrogen fixer Trichodesmium to ocean acidification
14:30 - 14:45	**Aurélien Boyé** From theory to conservation priorities for the functioning and resilience of marine benthic systems across habitats: trait-based approach to monitoring data along 500 km of coastline
14:45 - 15:00	**Fabio Benedetti** Using species functional traits to explore the potential impacts of climate change on plankton functional diversity. The case of planktonic copepods in the Mediterranean Sea

15:00 - 15:15	**Damiano Righetti** Relating taxonomic phytoplankton richness to cell size spectra in the ocean
15:15 - 15:30	**Paul Frémont** Genomic Investigation of climate-change induced reshuffling of global plankton biogeography
Mon 17 June	Time Block 3 of 3
16:00 - 16:15	**Marc Sourisseau** Selection and mixing of marine phytoplankton over a coastal tidal front
16:15 - 16:30	**Emile Faure** From genes to functional traits in the global ocean : building de novo plankton functional types from environmental metagenomics data
16:30 - 16:45	**Guilhem Sommeria-Klein** The drivers of global community structure in open ocean eukaryotic plankton
16:45 - 17:00	**Giulia Donati** From macro- to micro- evolutionary processes: how dispersal shapes gene flow and species diversification in coral reef fishes
17:00 - 17:15	**Punyasloke Bhadury** Exploring biogeographic patterns of marine planktonic cyanobacteria in coastal habitats- what can we infer from 'omics' based approach?
17:15 - 17:30	**Virginie Sonnet** Linking morphological characteristics of phytoplankton to functional traits from continuous imaging in Narragansett Bay, U.S.
Posters	
Session A	**Virginie Sonnet** Linking morphological characteristics of phytoplankton to functional traits from continuous imaging in Narragansett Bay, U.S.

SESSION 11: INVESTIGATING AND MODELLING LINKAGES BETWEEN BIOLOGY AND FLEET BEHAVIOUR IN MULTI-SPECIES FISHERIES AND ECOSYSTEMS

Room 1

Wed 19 June	Time Block 1 of 3
11:00 - 11:05	**Carey McGilliard** Introduction
11:05 - 11:20	**Alan Haynie** FishSET: Methods and Models to Assess the Economic Impacts of Fisheries Management Actions and Environmental Change
11:20 - 11:35	**Julia Calderwood** The interaction between catch patterns, discard avoidance tools and fleet economics in Irish fisheries
11:35 - 11:50	**Raphaël Girardin** Consequences of management measures on fishers' behaviour and marine ecosystems: the example of the Eastern English Channel flatfish fisheries.
11:50 - 12:05	**Francois Bastardie** Eliciting spatial approaches to avoid unwanted catches in an EU Landing obligation

	context: A bio-economic evaluation in the Celtic Sea
12:05 - 12:20	**Jonathan Sweeney** Predicting the economic impacts of climate change requires understanding the link between environment and economic production
12:20 - 12:30	**Conveners** Discussion
Wed 19 June	Time Block 2 of 3
14:00 - 14:15	**Amanda Schadeberg** The promises and limitations of integrating fishing styles analysis into fleet behaviour models
14:15 - 14:30	**Alan Haynie** Empirical Fleet Behavior Models for Multispecies Rights-Based Fisheries
14:30 - 14:45	**Daniel Holland** Choice sets for fishery location choice models in the presence of fine-scalespatial heterogeneity: An application to the Pacific mutlispecies groundfish fishery
14:45 - 15:00	**Pierre Bourdaud** Purse-seine fisheries modelling in a context of environmental and management challenges
15:00 - 15:15	**Ching Villanueva** Evaluating how fisheries, environment and biological resources influence marine mammal fish depredation
15:15 - 15:30	**Conveners** Discussion
Wed 19 June	Time Block 3 of 3
16:00 - 16:15	**Sarah Kraak** Opening up the dead-end street of assuming constant métier-level catchabilities in mixed-fisheries models
16:30 - 16:45	**Vicky Wing Yee Lam** Projecting global fishing effort dynamics in the 21st century under climate change
16:45 - 16:50	**Tannaz Alizadeh Ashrafi** Seasonal variation and spatial distribution in the Norwegian Cod fishery
16:50 - 16:55	**Guillermo Ortuno Crespo** Exploring area-based fisheries management in multi-species oceanic fisheries
16:55 - 17:00	**Eileen Hofmann** Factors affecting distribution of the Atlantic surfclam (Spisula solidissima), a continental shelf biomass dominant, during a period of climate change
17:00 - 17:05	**Juan Carlos Villaseñor-Derbez** Change in behavior and effort redistribution after implementation of Large Scale Marine Protected Areas
17:05 - 17:10	**Jean-Noël Druon** Is the local fishing effort adapted to the changing fish resources? Confronting LPUE at 0.05-degree resolution in the ICES area and satellite-derived ocean productivity available to fish.

17:10 - 17:15 **Chen Rabi**
The effect of desiccation events and habitat complexity on the spatial distribution and temporal stability of species in the rocky intertidal shore of Israel

17:15 - 17:30 **Conveners**
Discussion

Posters

Session B **Tannaz Alizadeh Ashrafi**
Seasonal variation and spatial distribution in the Norwegian Cod fishery

Session B **Eileen Hofmann**
Factors affecting distribution of the Atlantic surfclam (Spisula solidissima), a continental shelf biomass dominant, during a period of climate change

Session B **Guillermo Ortuno Crespo**
Exploring area-based fisheries management in multi-species oceanic fisheries

Session B **Juan Carlos Villaseñor-Derbez**
Change in behavior and effort redistribution after implementation of Large Scale Marine Protected Areas

Session B **Chen Rabi**
The effect of desiccation events and habitat complexity on the spatial distribution and temporal stability of species in the rocky intertidal shore of Israel

SESSION 12: LESSONS FROM THE EXTREME EVENTS OF THE EARLY 21ST CENTURY FOR THE FUTURE OCEANS

Room 3+4

Wed 19 June Time Block 1 of 3

11:00 - 11:05 **Conveners**
Introduction

11:05 - 11:27 **Nicolas Gruber**
Double, triple, and quadruple whammies: Compound extremes in ocean biogeochemistry

11:27 - 11:49 **Robert Schlegel**
Primary drivers of marine heatwaves in the North Atlantic

11:49 - 12:11 **Stuart Corney**
Surface and sub-surface marine heatwaves on the Kerguelen Plateau and their possible impact on the Patagonian Toothfish fishery

12:11 - 12:33 **Shin-ichi Uye**
The giant jellyfish blooms in the East Asian Marginal Seas: drivers, impacts, and countermeasures for fisheries sustainability

Wed 19 June Time Block 2 of 3

14:00 - 14:22 **Lester Kwiatkowski**
Amplification and shift of seasonal extremes in ocean acidity during the 21st century

14:22 - 14:44 **Friedrich Anton Burger**
Ocean Acidity Extremes Altered by Variability Changes

14:44 - 15:06 **Tayler Clarke**
Role of ocean deoxygenation and warming in the declines of fisheries resources in the

	Eastern Tropical Pacific
15:06 - 15:28	**Xiao Ma**
	Severe hypoxia off the Changjiang Estuary in summer 2016 associated with El Niño
Wed 19 June	Time Block 3 of 3
16:00 - 16:22	**Charlotte Laufkötter**
	Attribution of recent marine heatwaves to anthropogenic climate change
16:22 - 16:44	**Angelica Pena**
	Phytoplankton responses to the 2014–2016 warming anomaly in the Northeast Subarctic Pacific Ocean
16:44 - 17:06	**Alexei Pinchuk**
	Doliolid blooms in the southeastern Gulf of Alaska as a result of the recent heat wave of 2014-2016
Posters	
Session B	**Remi Caillibotte**
	Impact of an extreme storm and flood episode on the biogeochemical balance in an exploited coastal lagoon (Thau, south of France): approach by coupled hydrodynamic-biogeochemical modelling.
Session B	**Flora Desmet**
	Ocean acidification extreme events in the California Current System
Session B	**Chunjiang Guan**
	Jellyfish blooms in coastal waters nearby thermal discharges of nuclear power plant
Session B	**Pamela Hidalgo Díaz**
	Diversity, biomass and size-structure of copepods in the coastal upwelling area off Humboldt Current System in the eastern South Pacific Ocean
Session B	**Eike Eduard Köhn**
	Oxygen variability and extremes in the eastern tropical South Pacific between 1979 and 2016
Session B	**Maria Iohara Quirino Amador**
	Historical reconstruction of Brazilian reef landscapes using the memory of active users

SESSION 13: LINKING MICROBIAL ACTIVITY AND THE CYCLING OF DISSOLVED ORGANIC MATTER USING –OMICS APPROACHES

Room 5

Tue 18 June	Time Block 1 of 2
11:00 - 11:18	**Federico Baltar**
	Lifting the Lid: the microbial ecosystem under the Ross Ice Shelf
11:18 - 11:36	**Zihao Zhao**
	Increase in secretory enzyme capability is a genomic adaptation of dark ocean prokaryotes
11:36 - 11:54	**Pavla Debeljak**
	Microbial utilization of organic matter in the Southern Ocean as revealed by metaproteomics

11:54 - 12:12	**Ingrid Obernosterer** Seasonal changes in free-living and attached prokaryotic communities in the Southern Ocean
12:12 - 12:30	**Marta Varela** Linking microbial diversity (Bacteria and Archaea) and chemodiversity of dissolved organic matter in the major water masses of the north Atlantic
Tue 18 June	Time Block 2 of 2
14:00 - 14:18	**Roberta Hansman** Temperature dependence of prokaryotic inorganic carbon assimilation in the dark ocean
14:18 - 14:36	**Michel Denis** Evidence for pulsed exportation in the water column of the northwestern Mediterranean Sea
14:36 - 14:54	**Anwesha Ghosh** Exploring changes in bacterioplankton community structure in response to tannic acid, a major component of litterfall, in a mangrove ecosystem: a laboratory mesocosm approach
14:54 - 15:12	**Maria Pinto** Metagenomics of a microbial community capable of surviving with low-density polyethylene as the sole carbon source
15:12 - 15:30	**Renyan Liu** Microbial Community Diversity and Phycotoxin Risk of Toxic Microalgae from China Coast
Posters	
Session A	**Marion Urvoy** Microbial enzymatic activities: critical methodological issues to understand organic matter cycling
Session A	**Ingrid Obernosterer** Seasonal changes in free-living and attached prokaryotic communities in the Southern Ocean
Session A	**Renyan Liu** Microbial Community Diversity and Phycotoxin Risk of Toxic Microalgae from China Coast

SESSION 14: LONG-TERM TIME SERIES OF OCEAN DATA TO DESCRIBE AND BETTER UNDERSTAND DYNAMICS OF COASTAL MARINE SYSTEMS AND DRIVERS OF CHANGE: INTEGRATED TOOLS, METHODS, IN SITU OBSERVATION SYSTEMS, MODELS AND RESULTS

Room 1

Mon 17 June	Time Block 1 of 4
16:05 - 16:10	**Jean-Pierre Gattuso** Carbonate system time-series in the coastal Arctic
16:10 - 16:15	**Edith Le Borgne** High frequency observation of turbidity near the seafloor in Brittany (France)
16:15 - 16:20	**Lei Lin** Vertical average irradiance shapes winter phytoplankton biomasses in the Yellow Sea
16:20 - 16:25	**Anne Goffart** Response of phytoplankton to climate-driven changes in a Mediterranean coastal area : results from 4 decades of observations
16:25 - 16:30	**Mariarita Caracciolo** SOMLIT-Astan time-series: a morphogenetic approach to study the seasonal succession of the eukaryotic marine plankton communities in the coastal waters.
16:35 - 16:40	**Celia Marlowe** Plug and play monitoring: developing novel solutions for marine observations using divers as citizen scientists
16:40 - 16:45	**Ana Belén Venegas** Time series of zooplankton biomass to assess the ecological response of EBUS to climate change: the upwelling zone off central-southern Chile as a model
16:45 - 16:50	**Marianne Robert** Spatio temporal co-variation of assemblages and environmental and fishing drivers in the Celtic Sea – 2000 to 2016.
16:50 - 16:55	**Julien Normand** An ecological time series of oyster growth and survival: data curation and analysis of 24 years of monitoring along the French coast
16:55 - 17:00	**Nicolas Savoye** Monitoring coastal ecosystems over decades: the SOMLIT Network
17:00 - 17:05	**Angus Atkinson** Response of a planktonic biomass spectrum to variability at scales from inter-annual, seasonal to that of an extreme storm event
17:05 - 17:10	**Aurélien Boyé** Decadal dynamics of benthic communities at the regional scale
17:10 - 17:15	**Jeandria Freire** Temporal variations of the relative abundance of Acoupa weakfish-Cynoscion acoupa, (Lacepède, 1801) in the region of the influence of the plume of the Amazon River and its relations with oceanographic parameters estimated by remote sensors.
17:15 - 17:20	**Michele Giani** Time series of organic matter and nutrients in the north-eastern Adriatic Sea (gulf of Trieste)

Tue 18 June	Time Block 2 of 4
11:05 - 11:25	**Alexa Latapy** Long-term evolution of the Northern France coastal zone and relationship with historical sea-level changes
11:25 - 11:45	**Maximilian Unterberger** Extreme event occurrence linked with natural and anthropogenic climate variations in coastal waters of western Europe and their impact on the marine ecosystem
11:45 - 12:05	**Sabine Schmidt** Assessment of a long-term, multi-site and high frequency monitoring of a tidal estuary after 15 years
12:05 - 12:25	**Francois Schmitt** Multiscale methods for characterizing and predicting long-term marine time series
Tue 18 June	Time Block 3 of 4
14:05 - 14:25	**Arnaud Lheureux** The influence of global and local drivers on the long-term seasonality and variability of the nutrients in the French marine coastal ocean: the case study of the Arcachon Lagoon.
14:25 - 14:45	**Benjamin Planque** Integrated time-series analyses to support ecosystem assessment.
14:45 - 15:05	**Francisco Chavez** Climate variability and change: Response of a coastal ocean ecosystem
15:05 - 15:30	**Conveners** Discussion time
Tue 18 June	Time Block 4 of 4
16:05 - 16:25	**Anthony Banyouko Ndah** Recent changes in the ocean carbon pump in the South China Sea and implications for regional atmospheric CO_2 accumulation
16:25 - 16:45	**Yosr Ammar** Emergence of novelty in the Anthropocene: the Baltic Sea case
16:45 - 17:05	**Yann Ferret** Multidisciplinary expertise of historical information for the characterization of water levels during storm and flooding events
17:05 - 17:25	**Maite Erauskin-Extramiana** Large-scale distribution of tuna and billfish species in a warming ocean
Posters	
Session A	**Angus Atkinson** Response of a planktonic biomass spectrum to variability at scales from inter-annual, seasonal to that of an extreme storm event
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SESSION 15: MANAGING THE EFFECTS OF CHANGE ON SOUTHERN OCEAN ECOSYSTEMS: UNDERSTANDING, CHALLENGES, AND SOLUTIONS

Room 2

Wed 19 June	Time Block 1 of 2
14:00 - 14:10	**Rachel Cavanagh; Stuart Corney; Eileen Hofmann; Nadine Johnston; Eugene Murphy; Rowan Trebilco** Welcome & introduction
14:10 - 14:30	**Nadine Johnston** Theme 1 Seminar: Southern Ocean Species and Ecosystems: Progress and challenges in understanding biogeochemical cycling to higher predators
14:30 - 14:33	**Angus Atkinson** Response of Antarctic krill to rapid regional warming over the last 90 years
14:33 - 14:36	**Jilda Caccavo** An integrated approach to test spatially-based population structure and life history connectivity of Antarctic silverfish (*Pleuragramma antarctica*) in the southern Weddell

	Sea
14:36 - 14:39	**Tracey Dornan** Sound scattering in the Scotia Sea: Environmental drivers of mesopelagic species distribution and behaviour
14:39 - 14:42	**Juan Höfer** The effect of regional environmental forcing on the similarities of two embayment's along the Western Antarctica Peninsula
14:42 - 14:45	**Kunio Takahashi** The spatial and temporal variations in mean total zooplankton abundance and average copepod community size of the Southern Ocean from the SO-CPR activities
14:45 - 15:00	**Nadine Johnston** Theme 1 Q & A discussion: Southern Ocean species and ecosystems
15:00 - 15:20	**Stuart Corney** Theme 2 Seminar: Modelling and projecting ecological change: Progress and challenges in modelling the Southern Ocean ecosystem
15:20 - 15:23	**Stuart Corney** How good is good enough? Tools for the assessment of a physical ocean model to use as forcing of ocean ecosystem models
15:23 - 15:26	**Juan Höfer** Future constrains for phytoplankton growth in coastal Antarctic Waters: the effect of nutrient stoichiometry in icebergs under increasing glacier melting scenarios
15:26 - 15:29	**John Klinck** Distribution of CDW Intrusion Sites in Eastern Amundsen Sea and West Antarctic Peninsula Continental Shelves Revealed by Antarctic Seals
15:29 - 15:32	**Stacey McCormack** Alternative energy pathways to alternative futures - a balanced food web model for Prydz Bay, East Antarctica
Wed 19 June	Time Block 2 of 2
16:00 - 16:03	**Elodie Salmon** Modelling Southern Ocean primary productivity change with climatic change.
16:03 - 16:06	**Sally Thorpe** Environmental and behavioural drivers of krill distribution at the South Orkney Islands – I. A large-scale perspective
16:06 - 16:09	**Sally Thorpe** Environmental and behavioural drivers of krill distribution at the South Orkney Islands – II. A regional perspective
16:09 - 16:12	**Rowan Trebilco** Implications of foodweb change for Southern Ocean fisheries, conservation and carbon export
16:12 - 16:15	**Devi Veytia** Improving the uncertain future of Antarctic krill: Estimating future Antarctic krill growth using CMIP5 projections
16:15 - 16:30	**Stuart Corney** Theme 2 Q & A discussion: Modelling and projections of ecological change in the

	Southern Ocean
16:30 - 16:50	**Rachel Cavanagh**
	Theme 3 seminar: Policy implications and decision-making for Southern Ocean ecosystems (with a focus on integrated understanding of natural and human systems interactions)
16:50 - 16:53	**Rowan Trebilco**
	Marine Ecosystem Assessment for the Southern Ocean (MEASO)
16:53 - 16:56	**Eugene Murphy**
	Developing projections of the impacts of change in Southern Ocean ecosystems for the sustainable management of krill fisheries
16:56 - 16:59	**Ricardo Roura**
	Protected areas in the Southern Ocean: The last five years, the next five years and beyond
16:59 - 17:02	**Sara Sergi**
	Ecological hotspots, physical drivers, and jurisdictional frameworks of the subantarctic Southern Ocean

Posters

Session B	**TBD TBD**
	Enhancing essential observing on Southern Ocean ecosystems: progress in SOOS and future developments
Session B	**Nadine Johnston**
	Future directions of Integrating Climate and Ecosystems Dynamics (ICED) in the Southern Ocean programme
Session B	**Eugene Murphy**
	Developing models of krill population processes and projections of the impacts of change: krill recruitment processes and post-larval growth
Session B	**Rachel Cavanagh**
	Informing ecosystem management in the context of climate change: incorporating ICED science into decision-making.
Session B	**Angus Atkinson**
	Response of Antarctic krill to rapid regional warming over the last 90 years
Session B	**Jilda Caccavo**
	An integrated approach to test spatially-based population structure and life history connectivity of Antarctic silverfish (Pleuragramma antarctica) in the southern Weddell Sea
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Session B	**Eugene Murphy** Developing projections of the impacts of change in Southern Ocean ecosystems for the sustainable management of krill fisheries
Session B	**Ricardo Roura** Protected areas in the Southern Ocean: The last five years, the next five years and beyond
Session B	**Sara Sergi** Ecological hotspots, physical drivers, and jurisdictional frameworks of the subantarctic Southern Ocean

SESSION 16: MARINE GOVERNANCE, CHALLENGES FOR SUSTAINABILITY

Room 3+4

Mon 17 June	Time Block 1 of 6
11:55 - 12:25	**Marion Glaser** Session overview 1

12:25 - 12:30	**Alice Newton** Session overview 2
12:30 - 12:35	**Leopoldo Gerhardinger** Session overview 3
12:35 - 12:40	**Anna Zivian** Session overview 4
Mon 17 June	Time Block 2 of 6
14:00 - 14:12	**Pierre Scemama** How to consider offset governance in the context of Marine Spatial Planning: insights from the management of natural resources
14:12 - 14:24	**Stefan Koenigstein** Ocean Limited: A game-based learning approach for marine sustainability education
14:24 - 14:36	**Ida Maria Bonnevie** Assessing synergies and conflicts arriving from spatial-temporal proximity between marine human-based uses
14:36 - 15:30	**Anna Zivian** World café, synthesis, discussion
Mon 17 June	Time Block 3 of 6
16:00 - 16:12	**Dave Reid** Integrated ecosystem analysis in Irish waters; decision support tools for sustainable ecosystem-based management
16:12 - 16:24	**Priscila Lopes** Crossing the quantitative bridge to integrate local knowledge into fisheries management
16:36 - 16:40	**Yan Yang** The cost-effective solution of natural coastline conservation programme in Fujian Province, China
16:40 - 17:30	**Marion Glaser** Discussion: Decision-making tools and criteria
Tue 18 June	Time Block 4 of 6
11:00 - 11:12	**Julia Jung** Using information and communications technology to find and share community owned solutions to sustainability challenges
11:12 - 11:24	**Julia Fraga** Sargassum Blooming in Mexican Caribbean: Nightmare or Opportunities for Socioeconomic Actors in the Context of Marine Governance
11:24 - 11:36	**Bianca Haas** Regional Fisheries Management Organizations and the development of best practice
11:36 - 12:30	**Anna Zivian** World café, synthesis, discussion: Linking sectors, system levels and scales
Tue 18 June	Time Block 5 of 6
14:00 - 14:12	**Louise Gammage** Improving the involvement of marginalised fishers in governance processes: Can structured decision-making tools be useful?

14:12 - 14:24	**Marieke Norton** Being well-governed: Compliance inspectors and their role in the pursuit of well-being
14:24 - 14:36	**Alicia Said** Aligning the sustainable development goals to the small-scale fisheries guidelines: a case for EU fisheries governance
14:36 - 14:40	**Kate Davies** Tackling cumulative effects: A mountains-to-sea approach from Aotearoa New Zealand
14:41 - 15:00	**Marion Glaser** Discussion: Issue-based integration
Tue 18 June	Time Block 6 of 6
16:00 - 16:12	**Ella-Kari Muhl** Community rights, conservation rezoning and the implications for sustainable marine governance
16:12 - 16:24	**Lydia Teh** Opportunities and challenges in applying human rights to implement socially responsible seafood
16:24 - 16:28	**Alicia Said** Investigating the governability of the FAD fisheries: Mediterranean and French-Caribbean Islands
16:28 - 17:03	**Annette Breckwoldt** Fisheries management organizations and strategies at the regional and sub-regional levels in the South Pacific Ocean
17:03 - 17:30	**Marion Glaser** Discussion
Posters	
Session A	**Kate Davies** Tackling cumulative effects: A mountains-to-sea approach from Aotearoa New Zealand
Session A	**Bianca Haas** Regional Fisheries Management Organizations and the development of best practice
Session A	**Alicia Said** Investigating the governability of the FAD fisheries: Mediterranean and French-Caribbean Islands
Session A	**Yan Yang** The cost-effective solution of natural coastline conservation programme in Fujian Province, China
Session A	**Annette Breckwoldt** Fisheries management organizations and strategies at the regional and sub-regional levels in the South Pacific Ocean

Session 17: Modelling social-ecological systems: methods and tools for scenario development and prediction

Salle Méridienne

Mon 17 June	Time Block 1 of 8
11:55 - 12:15	**Olivier Thébaud** Modelling social-ecological systems: methods and tools for scenario development and prediction
12:15 - 12:35	**Benjamin Planque** Modelling Chance and necessity in natural systems
12:35 - 12:40	**Beth Fulton** Walking backwards into the future
Mon 17 June	Time Block 2 of 8
14:00 - 14:20	**Fabio Boschetti** An empirical analysis of different ways to think about Ocean Futures
14:20 - 14:40	**Alistair Hobday** Foresighting to guide scientific investment and preparation for a disrupted future
14:40 - 15:00	**Benjamin Planque** Building scenarios for marine social-ecological systems
15:00 - 15:20	**Colette Wabnitz** The future of High Seas governance under climate change
15:20 - 15:25	**Raphaela le Gouvello** Material Flow Analysis as a Circular economy tool to address the future stakes of fishery dependent costal socio-ecological systems
15:25 - 15:30	**Fabio Boschetti** Beyond adaptive management: modelling regional futures at decadal scale
Mon 17 June	Time Block 3 of 8
16:00 - 16:20	**Mark Dickey-Collas** Tools for credible decision making; an analysis of successful tool application in ecosystem based management.
16:20 - 16:40	**Sakari Kuikka** Bayesian models in interdisciplinary policy analysis
16:40 - 17:00	**Annukka Lehikoinen** Dioxins in Baltic herring and salmon: an inter-sectoral decision analysis for optimal management of the problem
17:00 - 17:20	**Florence Briton** Using ecoviability to provide an integrated TAC advice for the management of mixed fisheries
17:20 - 17:30	**Conveners** Discussion
Tue 18 June	Time Block 4 of 8
11:00 - 11:20	**Camilla Novaglio** Exploring trade-offs in mixed fisheries by integrating fleet dynamics into multispecies size-spectrum models

11:20 - 11:40	**William Cheung** Using integrated scenarios and models to explore trade-offs in future seafood sustainability under global change
11:40 - 12:00	**Tyler Eddy** Scenarios for the future ocean: A FishMIP approach
12:00 - 12:05	**Silke Kroeger** There is carbon on the shelf! Quantifying and valuing coastal and shelf sea carbon for policy making and management purposes
12:05 - 12:10	**Kim Scherrer** A global fisheries model with dynamic regulation: implications for future marine catches
12:10 - 12:15	**Ching Villanueva** Optimizing space-time use by fishermen to reduce depredation risk by sperm whales in the Patagonian toothfish longline fisheries
12:15 - 12:30	**Conveners** Discussion
Tue 18 June	Time Block 2 of 8
14:00 - 14:20	**Katell Hamon** Shared Socioeconomic Pathways (SSPs) for fisheries and aquaculture in Europe
14:20 - 14:40	**Alan Haynie** Adaptive fisheries management under changing environmental and economic conditions: socioeconomic scenarios in the Alaska Climate Integrated Modeling (ACLIM) Project
14:40 - 15:00	**Katherine Mills** Using climate and adaptation scenarios to understand vulnerabilities and opportunities for Northeast U. S. fishing communities
15:00 - 15:05	**Vidette McGregor** From data compilation to model validation: A comprehensive analysis of a full deep-sea ecosystem model of the Chatham Rise
15:05 - 15:10	**Zelin Chen** A fishery system approach using socio-ecological model: a case study of Fujian swimming crab fishery in China
15:10 - 15:15	**Conveners** Discussion
Tue 18 June	Time Block 3 of 8
16:00 - 16:20	**Kelsey LaMere** Making the Most of Mental Models: Advancing the Methodology for Mental Model Elicitation and Documentation with Expert Stakeholders
16:20 - 16:40	**Claire Macher** Developing a partnership bio-economic decision-support framework for fisheries management with stakeholders: challenges and opportunities towards trans-disciplinary approaches
16:40 - 17:00	**Carey McGilliard** Overcoming challenges in conducting management strategy evaluation in a complex multi-species, multi-sector, multi-gear, and multi-government fishery system, with

	application to bycatch harvest policies for Pacific halibut in the Bering Sea and AleutianI
17:00 - 17:05	**Carolyn Lundquist**
	Visions for nature and nature's contributions to people for the 21st century
17:10 - 17:30	**Conveners**
	Discussion
Wed 19 June	Time Block 4 of 8
11:00 - 11:20	**Eva Plaganyi**
	Approaches to integrate customary management with biological sustainability of a data poor sea cucumber fishery in Torres Strait, Australia
11:20 - 11:40	**Heike Schwermer**
	Stakeholder perception on social-ecological systems – the case of Western Baltic cod fishery
11:40 - 11:45	**Laura Basconi**
	Including multiple Ecosystem Services (ES) assessment in the Maritime Spatial Planning (MSP) context: an operational tool for marine ecosystems management and conservation.
11:45 - 11:50	**Mingbao Chen**
	Cooperation Mechanism in Island socio-ecological system Network Governance in Macao
11:50 - 12:30	**Conveners**
	Session discussion
Posters	
Session A	**Raphaela le Gouvello**
	Material Flow Analysis as a Circular economy tool to address the future stakes of fishery dependent costal socio-ecological systems
Session A	**Fabio Boschetti**
	Beyond adaptive management: modelling regional futures at decadal scale
Session A	**Silke Kroeger**
	There is carbon on the shelf! Quantifying and valuing coastal and shelf sea carbon for policy making and management purposes
Session A	**Kim Scherrer**
	A global fisheries model with dynamic regulation: implications for future marine catches
Session A	**Ching Villanueva**
	Optimizing space-time use by fishermen to reduce depredation risk by sperm whales in the Patagonian toothfish longline fisheries
Session A	**Vidette McGregor**
	From data compilation to model validation: A comprehensive analysis of a full deep-sea ecosystem model of the Chatham Rise
Session A	**Zelin Chen**
	A fishery system approach using socio-ecological model: a case study of Fujian swimming crab fishery in China
Session A	**Carolyn Lundquist**
	Visions for nature and nature's contributions to people for the 21st century

Session B	**Laura Basconi** Including multiple Ecosystem Services (ES) assessment in the Maritime Spatial Planning (MSP) context: an operational tool for marine ecosystems management and conservation.
Session B	**Mingbao Chen** Cooperation Mechanism in Island socio-ecological system Network Governance in Macao

SESSION 18: MULTIPLE DRIVERS AND THEIR ROLE IN OCEAN GLOBAL CHANGE BIOLOGY

Petit Théâtre

Wed 19 June	Time Block 1 of 5
16:00 - 16:10	**Christina McGraw** Opening comments
16:10 - 16:45	**Sinead Collins** Plenary
16:46 - 16:47	**Justine Courboules** Interactive Effects of warming and acidification on heterotrophic bacteria and phytoplankton communities during induced bloom and post-bloom in Mediterranean coastal waters
16:47 - 16:48	**Frédéric Gazeau** Present and future impact of atmospheric deposition on the structure and functioning of plankton communities in the Mediterranean Sea (Peacetime project)
16:48 - 16:49	**Frédéric Gazeau** Impact of dust enrichment on the metabolism of Mediterranean plankton communities under present and future conditions of pH and temperature
16:49 - 16:50	**Carla Geisen** Dissolution of Fe and Si from desert and volcanic aerosols and impact on phytoplankton
16:50 - 16:51	**Maria Aranguren-Gassis** Exploring the effect of nitrogen limitation on phytoplankton acclimation to warming
16:51 - 16:52	**Yanfang Li** Pathway of inflow of cold bottom water in the Bohai Sea and its ecological effects
16:52 - 16:53	**Florian Koch** The various faces of trace metal limitation in a changing ocean
16:53 - 16:54	**Elvira Pulido-Villena** Relative contribution of internal vs. external sources of phosphate to the surface mixed layer in the P-depleted Mediterranean Sea (Peacetime cruise)
16:55 - 16:56	**Franziska Pausch** Interactive effects of light, CO_2 and iron on growth and species composition of a natural phytoplankton assemblage of the Drake Passage
16:56 - 17:30	**Conveners** Discussion
Thu 20 June	Time Block 2 of 5
11:00 - 11:15	**Pierre-Amaël Auger** Multiple drivers of the spatial distribution of primary productivity in the

	Humboldt Current system
11:15 - 11:30	**Jana Hinners**
	Mapping the fitness landscape of marine diatoms
11:30 - 11:45	**Thierry Moutin**
	The Oligotrophic to UlTra-oligotrophic PACific Experiment (OUTPACE)
11:45 - 12:00	**Lavenia Ratnarajah**
	Co-limitation drives competition between phytoplankton and bacteria in the Southern Ocean
12:00 - 12:15	**Houda Beghoura**
	How new experimental knowledge of sediment particulate iron may change our understanding of the global ocean biogeochemical cycles ? Insights from numerical model experiments
12:15 - 12:30	**Conveners**
	Speaker panel discussion and general questions
Thu 20 June	Time Block 3 of 5
14:00 - 14:15	**Stephanie Henson**
	Emergence of novel climates in environmental drivers of marine ecosystems
14:15 - 14:30	**Sara Mynott**
	The effect of multiple stressors on anti-predator defences
14:30 - 14:45	**Uta Passow**
	Phytoplankton Response to Multiple Environmental Stressors
14:45 - 15:00	**Cristina Fernández González**
	Interactive effects of temperature and nutrient supply on the abundance of PSII and RuBisCo proteins in Synechococcus sp.
15:00 - 15:15	**Christina McGraw**
	Aligning multiple driver research through video tutorials
15:15 - 15:30	**Conveners**
	Speaker panel discussion and general questions
Thu 20 June	Time Block 4 of 5
16:00 - 16:15	**Kunshan Gao**
	Loosing C as a strategy against ocean acidification in CCM efficient algae
16:15 - 16:30	**Marion Angelini**
	Endangered species in hypoxia environment: analysis of the impact of hypoxia to the prey of the endangered endemic Maugean skate in Macquarie harbour as an indirect threat
16:30 - 16:45	**Marianne Camoying**
	Understanding the interactive effects of Ocean Acidification and the availability of iron on the two Southern Ocean key phytoplankton groups - diatoms and cryptophytes
16:45 - 17:00	**Paul Renaud**
	Arctic Sensitivity? Shifting Species Distributions due to Changing Environmental Drivers
17:00 - 17:15	**Tilla Roy**
	The IMBeR Ocean Data Hub: linking high-value global data sets online to inspire analyses and exchange.
17:15 - 17:30	**Conveners**

	Speaker panel discussion and general questions
Fri 21 June	Time Block 5 of 5
09:00 - 09:15	**Christina McGraw** Session recap
09:15 - 09:45	**Conveners** Breakout groups
09:45 - 10:00	**Conveners** Reports from breakout groups
10:00 - 10:20	**Conveners** Moderated group discussion
10:20 - 10:30	**Sinead Collins** Summary
Posters	
Session B	**Maria Aranguren-Gassis** Exploring the effect of nitrogen limitation on phytoplankton acclimation to warming
Session B	**Houda Beghoura** How new experimental knowledge of sediment particulate iron may change our understanding of the global ocean biogeochemical cycles ? Insights from numerical model experiments
Session B	**Haimanti Biswas** Arctic diatom Chaetoceros socialis showed high resilience under future projected CO_2 concentrations
Session B	**Justine Courboules** Interactive Effects of warming and acidification on heterotrophic bacteria and phytoplankton communities during induced bloom and post-bloom in Mediterranean coastal waters
Session B	**Ophélie Da Silva** Are we ready for populations (meta)genomics ? Challenges for understanding abiotic drivers shaping genetic patterns of plankton in the Mediterranean Sea.
Session B	**Deniz DISA** Spatiotemporal Variability of Coral Reef Biogeochemistry
Session B	**Kunshan Gao** Loosing C as a strategy against ocean acidification in CCM efficient algae
Session B	**Frédéric Gazeau** Present and future impact of atmospheric deposition on the structure and functioning of plankton communities in the Mediterranean Sea (Peacetime project)
Session B	**Frédéric Gazeau** Impact of dust enrichment on the metabolism of Mediterranean plankton communities under present and future conditions of pH and temperature
Session B	**Carla Geisen** Dissolution of Fe and Si from desert and volcanic aerosols and impact on phytoplankton
Session B	**Nadine Goris** Can we use open ocean biomes as an integrated measure for future physio-biogeochemical change?

Session B **Ryan Heneghan**
Exploring the mechanisms underlying diverse responses to climate change in the FishMIP project

Session B **Florian Koch**
The various faces of trace metal limitation in a changing ocean

Session B **Siv Lauvset**
Using machine learning to assess how climate change alters ocean biogeochemical provinces

Session B **Yanfang Li**
Pathway of inflow of cold bottom water in the Bohai Sea and its ecological effects

Session B **Franziska Pausch**
Interactive effects of light, CO_2 and iron on growth and species composition of a natural phytoplankton assemblage of the Drake Passage

Session B **Renaud Person**
Sensitivity of Ocean Biogeochemistry to the Iron Supply from The Antarctic Ice Sheet explored with a Biogeochemical Model

Session B **Francesc Peters**
Natural and anthropogenic atmospheric deposition and their effects on bacterial community assembly in the northwestern Mediterranean

Session B **Elvira Pulido-Villena**
Relative contribution of internal vs. external sources of phosphate to the surface mixed layer in the P-depleted Mediterranean Sea (Peacetime cruise)

Session B **Carolina Araújo**
Argonauts as indicators of long-term interannual variability in the Southeastern Brazilian Bight

Session B **Leonardo Capitani**
Future scenarios of Food Web dynamics in the Rocas Atoll's coral reef ecosystem (South Atlantic) under climate change

SESSION 19: OCEAN GOVERNANCE IN THE FACE OF CHANGE: CONFRONTING THE CHALLENGE OF REBUILDING FISH STOCKS, FISHERIES AND VIABLE COASTAL COMMUNITIES AND PREPARING FOR FUTURE CHANGE

Room 1

Thu 20 June Time Block 1 of 3

11:00 - 11:15 **Conveners**
Session introduction

11:15 - 11:30 **Prateep Nayak**
A three-dimensional perspective on creating viable fishing communities amidst a changing ocean

11:30 - 11:45 **Alicia Said**
Sustainability through transdisciplinarity: A framework for the Ocean's Sustainable Development Goal (SDG) in the context of small-scale fisheries governance

11:45 - 12:00 **Lisa Kerr**

	Climate Challenges to Fisheries Management in a Rapidly Changing Ecosystem
12:00 - 12:15	**Barbara Neis**
	Taking stock of research on gender, fisheries and aquaculture as we seek to improve ocean governance in the face of change
12:15 - 12:30	**Conveners**
	Question and answer period
Thu 20 June	Time Block 2 of 3
14:00 - 14:15	**Zach Koehn**
	Fishing for health: Is there alignment in the world's national policies for fisheries and aquaculture to health and nutrition?
14:15 - 14:30	**Louise Teh**
	Economic and social benefits of fisheries rebuilding: six Canadian case studies
14:30 - 14:45	**Courtenay Parlee**
	Access theory and marine fisheries: Integrating analyses of access to resources and to markets in the Newfoundland context
14:45 - 15:00	**Jack Daly**
	Deploying I-ADApT for an assessment of the Coastal Communities of Northern Newfoundland, Canada
15:00 - 15:15	**Nathan Stanley**
	The changing principles in Newfoundland and Labrador fisheries: A historical analysis
15:15 - 15:30	**Conveners**
	Question and answer period
Thu 20 June	Time Block 3 of 3
16:00 - 16:15	**Katia Frangoudes**
	Acceptability of aquaculture by local communities in Greece
16:15 - 16:30	**Eric Wade**
	Exploring the diversity of institutional arrangements in small-scale fisheries systems in the Wider-Caribbean Region
16:30 - 16:45	**Yinji Li**
	The future of Sakura shrimp fishery: a comparative analysis of two stories from Japan and Taiwan
16:45 - 17:00	**Devendraraj Madhanagopal**
	"Who" participate and "who" are not in the internal governance systems and "how" does it relevant to adaptation to climate change? Insights from the selected fishing villages in the Coromandel Coast of Tamil Nadu, India.
17:00 - 17:15	**Eva Royandi**
	Politics of management of marine and fisheries resources (study of power relation between fisherman groups in Palabuhanratu steam power plant area)
17:15 - 17:30	**Conveners**
	Question and answer period
Posters	
Session B	**Jack Daly**
	Vulnerability Analysis in Newfoundland, Canada Capture Fisheries Over the Last 60 Years

SESSION 20: OCEAN RECOVERY – STRATEGIES TO MITIGATE ANTHROPOGENIC PRESSURES AND SUPPORT MARINE ECOSYSTEM RECOVERY FOR A SUSTAINABLE FUTURE OCEAN

Room 5

Thu 20 June	Time Block 1 of 3
14:00 - 14:15	**Conveners** Session Introduction
14:15 - 14:30	**Thorsten Blenckner** Ocean health and recovery
14:30 - 14:45	**Charles Cadier** Challenges in Marine Restoration Ecology: How techniques, assessment metrics and ecosystem valuation can lead to improved restoration success
14:45 - 15:00	**Bettina Kleining** Are the European Nature Directives' legal expectations realistic as to the availability of scientific information needed to designate the marine Natura 2000 network?
15:00 - 15:15	**Mary Mackay** Who is affected most by a social norm nudge encouraging compliance behaviour in a recreational fisheries experiment and why?
15:15 - 15:30	**Karen Evans** The United Nations Decade of Ocean Science for Sustainable Development (2021-2030): achieving the ocean we need for the future we want.
Thu 20 June	Time Block 2 of 3
16:00 - 16:15	**Julie Reimer** A typology of area-based management tools for achieving the targets of Sustainable Development Goal 14
16:15 - 16:30	**Ulf Riebesell** Counteracting declining ocean productivity by artificial upwelling
16:30 - 16:45	**Jean-Noël Druon** Can we prevent fishing our living resource beforehand? The real-time dynamic protection of hake nurseries as a ready-to-use science to take action on overexploited species
16:45 - 17:00	**Fanny Noisette** Using marine macrophytes to mitigate global climate change
17:00 - 17:15	**Yanhui Zhang** Cost-efficient Solution of Coastal Wetlands Restoration: A Case Study of Xiamen Bay
17:15 - 17:30	**Bong-Oh Kwon** Evaluation of effective bioremediation methods on oil contaminated sand: A long- term outdoor mesocosm experiment
Fri 21 June	Time Block 3 of 3
09:00 - 09:15	**Lucie Buttay** An evaluation of management strategies to buffer the effect of mass mortality in early life stages of fish
09:15 - 09:30	**Cédric Léo Meunier** Global change vulnerability of North Sea plankton and associated ecosystem services: towards optimized management

09:30 - 10:30 **Conveners**
Final Discussion

Posters

Session B **Thomas Riedinger**
Behaviour and welfare of herring (Clupea harengus) and mackerel (Scomber scombrus) caught in purse seines

Session B **Jagad Wijoyo**
Study of layout of submerged breakwater in Panjang Island, Jepara

Session B **Aulia Aji**
Study of the effectiveness of submerged breakwater in Panjang Island, Jepara

Session A **Aulia Aji**
Mangrove Restoration and Rehabilitation : KeSEMaT Rehabilitate Mangrove Ecosystems Become Mangrove Education Center of KeSEMaT (MECoK)

Session A **Louise Copeman**
Latent effects of embryonic oil exposure on the growth, lipid storage and over-winter survival of juvenile polar cod (Boreogadus saida).

Session A **Nicolas Dupont**
Environmental effects on population annual mean length of polar cod (Boreogadus saida)

Session A **Angus Atkinson**
Challenges for sustainable monitoring and evaluation of the EU Marine Strategy Framework Directive in the Atlantic offshore waters: the iFADO project

Session A **Hiroki Fujita**
Mothocya parvostis Bruce, 1986 (Isopoda: Cymothoidae), infesting juvenile black sea bream, Acanthopagrus schlegelii Bleeker, 1854

Session A **Jaime Färber Lorda**
The vertical distribution of zooplankton in the OMZ of the Eastern tropical Mexican Pacific. Inter-annual Differences

Session A **Jaime Färber Lorda**
Morphological differentiation in krill of the Euphausia genus. From Antarctica to tropical waters.

Session A **Emilie Geissinger**
Overwinter growth and condition of juvenile Atlantic cod (Gadus morhua) in coastal Newfoundland

Session A **Carolyn Lundquist**
Tipping points in New Zealand coastal ecosystems

Session A **Clara Obregón Lafuente**
Network structure and information flow between fishery stakeholders: an interdisciplinary approach towards assessing communication pathways for management

Session A **Denny Nugroho Sugianto**
Identification of the Increase in the Air Temperature of the North Coast of Central Java as an Indicator of Climate Change (Semarang Station Climatology Data 1970-2017)

Session A	**Eduardo Erazo Acosta** Indigenous women of the Indigenous Regional Council of Cauca - Colombia, in the defense of water, epistemology's of Sumak Kawsay for the common good of humanity
Session A	**Ying Wu** Trophic interactions of mesopelagic fishes in the South China Sea: illustrated by stable isotopes and fatty acids
Session A	**Li Zhao** Influence of the Northern Yellow Sea Cold Water Mass on picoplankton distribution around the Zhangzi Island, northern Yellow Sea
Session A	**Yanchu Zhao** Seasonal variation of the abundance and biomass of picoplankton in the Sanggou Bay
Session A	**Yuan Zhao** Grazing Of Microzooplankton And Copepod On Microbial Food Web In Spring In Southern Yellow Sea, China
Session A	**Zhuoyi Zhu** Evidence of anthropogenic pressure on marine ecosystem from preserved sedimentary phytoplankton pigments
Session A	**Guillermo Ortuno Crespo** Global ocean governance requires usable baseline knowledge on migratory connectivity in the ocean
Session A	**Salma Begum** Mangrove Tourism : an overview in Bagladesh
Session A	**Sheveenah Taukoor** Multiple scenario analyses forecasting the impacts of sea level rise in Cape Town, South Africa
Session B	**Jianbo Han** Environmental occurrence of the novel PFOS alternatives (Cl-PFESAs) and their degradation potentials
Session B	**Anoop Das Karumampoyil** Is there any connection between a forest in mountain to marine fauna? The valuation of ecosystem services of the forests to the marine life
Session B	**Estelle Bigeard** Response of viruses to dust deposition in present and future ocean : Results from PEACETIME miniscosm experiments
Session B	**Franck Fu** Trace metals and nutrients fluxes and solubility during the Mediterranean PEACETIME cruise
Session B	**Lei Gao** Dynamics of dissolved and particulate organic matter in the Changjiang (Yangtze River) Estuary and the adjacent East China Sea shelf
Session B	**Shan Jiang** Nitrate circling in subterranean estuaries: reactions and influencing factors
Session B	**Faycal Kessouri** Ocean Modeling Supports Management Conversations on the Impact of Local Pollution

	Sources on Acidification and Deoxygenation in California
Session B	**Cecilia Laspoumaderes**
	Nutritional demands with increasing temperatures: more nutrients or more carbon in a warming world?
Session B	**Makhlouf Ounissi**
	Riverine and wet atmospheric inputs of nutrients into Annaba bay (SW Mediterranean)
Session B	**Guodong Song**
	Response of benthic nitrogen cycle to hypoxia of the Changjiang estuary
Session B	**Wenjin Lyu**
	Summer Turbulent Nitrate Fluxes and the Contributions to Primary Production in the East China Sea
Session B	**John Woods**
	Applying marine science to enhance life cycle assessment: a tool for supporting environmental decision making in policy

Session 21: Responding to policy makers: what can we do, what do we need? Bridging the methodological gaps for better transparency

Room 8

Thu 20 June	Time Block 1 of 2
16:00 - 16:05	**François Le Loc'h**
	Session Introduction
16:05 - 16:25	**Natalia de Miranda Grilli**
	Why is interdisciplinary ocean science still a challenge? A local perspective from Southeast Brazil
16:25 - 16:45	**Marie Le Marchand**
	Global warming impacts on Bay of Biscay fish communities by the arrival of southern species
16:45 - 17:05	**Rhoda Fofack-Garcia**
	Modelling the nexus Socio-Ecology in the governance of Marine Renewable Energies
17:05 - 17:10	**Conveners**
	Mini break for transition to speed talks
17:10 - 17:15	**Chloe Bracis**
	Improving confidence in complex ecosystem models: the sensitivity analysis of an Atlantis ecosystem model
17:15 - 17:20	**Lan Bo Zhang**
	Valuing the Coastal Ecosystem Service: A Case Study of Xiamen, china
17:20 - 17:25	**Hannah Bassett**
	Assembling Impact Pathways: an interdisciplinary framework for understanding potential effects of ocean deoxygenation on people and societies
Fri 21 June	Time Block 2 of 2
09:00 - 09:05	**Florent Le courtois**
	Session introduction
09:05 - 09:25	**Kristina Heidrich**
	Conflicting Goals and Best Strategies for Reaching Good Environmental Status in the

	Baltic Sea
09:25 - 09:45	**Clément Dupont**
	Exploring how information from maritime surveillance could contribute to MSP processes
09:45 - 10:05	**Laura Kaikkonen**
	How can ecological risk assessment inform marine resource governance? A case study for seabed mining
10:05 - 10:25	**Danai Tembo**
	Sustainable Strategies for Improved Implementation of Marine Living Resource Legislation
10:25 - 10:30	**Emilie Tew-Kaï**
	Session conclusion
Posters	
Session B	**Chloe Bracis**
	Improving confidence in complex ecosystem models: the sensitivity analysis of an Atlantis ecosystem model
Session B	**Lan Bo Zhang**
	Valuing the Coastal Ecosystem Service: A Case Study of Xiamen, china
Session B	**Hannah Bassett**
	Assembling Impact Pathways: an interdisciplinary framework for understanding potential effects of ocean deoxygenation on people and societies

SESSION 22: SAME, SAME, DIFFERENT: UNDERSTANDING VARIABILITY AND THE RELATIVE ROLES OF ENVIRONMENT, CLIMATE, FISHING AND TROPHIC DYNAMICS IN MARINE ECOSYSTEMS

Petit Théâtre	
Mon 17 June	Time Block 1 of 8
11:55 - 12:01	**Mariano Koen-Alonso;Alida Bundy;Paul Renaud**
	Introduction to the session
12:01 - 12:16	**Tyler Eddy**
	Future of nutrients, fish, and fisheries under climate change: a multi-model approach
12:31 - 12:34	**Eleuterio Yáñez**
	Projections of climate change and impacts on Chilean pelagic fisheries
12:34 - 12:37	**Caroline Ulses**
	Future projections of plankton stocks and carbon fluxes for different biological regimes of the Mediterranean sea
12:37 - 12:40	**Maria Grazia Pennino**
	Coupling novel modeling techniques to predict future scenarios and alternative management options for small pelagic species in the Northwestern Mediterranean Sea
Mon 17 June	Time Block 2 of 8
14:00 - 14:15	**Mariano Koen-Alonso**
	Drawing the short environmental straw? A comparison between the Newfoundland-Labrador Shelves and Barents Sea marine ecosystems
14:15 - 14:30	**Jamie Tam**
	How do differences in primary production relate to ecosystem status? A comparison of

	two sub-Arctic and Arctic ecosystems.
14:30 - 14:45	**Ulf Lindstrøm** Comparing cod-capelin dynamics in the Newfoundland-Labrador Shelves and Barents Sea ecosystems: A minimum-realistic bioenergetic-allometric modelling perspective
14:45 - 15:00	**Garry Stenson** Harp Seals: Monitors of Change in Differing Ecosystems
15:00 - 15:15	**Torstein Pedersen** Modelling uncertainty and changes in food web structure and ecosystem properties of the Barents Sea from 1985 to 2013
15:15 - 15:18	**Jamie Tam** Predicting cumulative effects of climate change and fishing on the Newfoundland and Labrador Shelves ecosystem
15:18 - 15:21	**Torstein Pedersen** Trophic levels estimates from stable isotopes and mass-balance models for the Barents Sea – how do they compare?
Mon 17 June	Time Block 3 of 8
16:00 - 16:15	**Stefan Koenigstein** Impacts of environmental variability, fishing and future climate change on marine food-web dynamics and human users in the Barents Sea
16:15 - 16:30	**Jean-Noël Druon** Satellite-derived productive fronts as a common proxy for marine ecosystem productivity across oceans: lessons learnt from a climate-dependent and fisheries-independent indicator
16:30 - 16:45	**Joel Llopiz** Long-term ecosystem dynamics on the Northeast US continental shelf with a focus on the trophic role of zooplanktivorous forage fishes
16:45 - 17:00	**Jerome Guiet** Physical regimes and energy flows through fish communities in the California Current Ecosystem
17:00 - 17:03	**Ming-An Lee** Operational adaption of grey mullet fishing fleet possibly influenced Climate variability in the Northwestern Pacific
17:06 - 17:09	**Yuheng Wang** A life history model of giant jellyfish Nemopilema nomurai and its application in the Yellow Sea
17:09 - 17:30	**Paul Renaud;Alida Bundy** Plenary discussion
Tue 18 June	Time Block 4 of 8
11:00 - 11:15	**Marta Coll** Simulating marine life and change: advancing food web modelling capabilities to analyse plausible global ocean futures
11:15 - 11:30	**Roshni Subramaniam** A food web model to evaluate climate change impacts and fisheries management for a large oceanic plateau in the Southern Ocean

11:30 - 11:45	**Kelly Ortega-Cisneros** Assessing the potential impacts of fishing and ocean acidification on the southern Benguela food web and fisheries
11:45 - 12:00	**Jean-Baptiste Jouffray** Parsing human and biophysical drivers of coral reef regimes
12:00 - 12:15	**Javier Porobic** An uncertain future: The impact of fishing on a highly vulnerable ecosystem, the case of Juan Fernández Ridge Ecosystem.
12:15 - 12:18	**Maria Grazia Pennino** Ecological basis to embrace temporal assessment and spatial management of the European hake (Merluccius merluccius) in the northern Iberian Peninsula
12:18 - 12:21	**Maria Grazia Pennino** Monitoring shifts in abundance of cephalopods in North Spain shelf ecosystems: A key in fisheries assessment
Tue 18 June	Time Block 5 of 8
14:00 - 14:15	**Stephanie Brodie** Pattern or Process: considering space, time, and the environment in species distribution models
14:15 - 14:30	**Elena Lloret** Main drivers of seasonal change in commercial species distributions of the Northwestern Mediterranean Sea
14:30 - 14:45	**Bérengère Husson** Take it to the limit: finding ecological boarders of fish distribution using quantile regression
15:00 - 15:15	**Rhian Evans** Seabird distribution and abundance in a region of rapid environmental change
15:15 - 15:18	**Eva Velasco** Understanding Cephalopods catch and discard rates from fishery-dependent and independent data in north Iberian waters.
Tue 18 June	Time Block 6 of 8
16:00 - 16:15	**Jennifer Rehren** Balancing or compensating your fisheries catches? Evaluating different fishing patterns using the EcoTroph approach
16:15 - 16:30	**Matthieu Veron** Temporal trends and drivers of Sardine condition in the Bay of Biscay over the last 14 years
16:30 - 16:45	**Mayya Gogina** Projecting climate change and eutrophication-induced effects on distribution of a key benthic invertebrate: <i>Saduria entomon</i> in the Baltic Se
17:00 - 17:03	**Fang Zhang** Predation selection and diet shift of Cyanea nozakii in the northern East China Sea
17:03 - 17:30	**Alida Bundy;Mariano Koen-Alonso** Plenary Discussion

Wed 19 June	Time Block 7 of 8
11:00 - 11:15	**Susa Niiranen** Future climate change challenges food web stability in an exploited marine system
11:15 - 11:30	**Morgane Travers-Trolet** Variability of fishing reference points for interacting species under climate change
11:30 - 11:45	**Marianne Robert** Marine species facing global changes in the Celtic sea and Bay of Biscay
11:45 - 12:00	**Pierre-Yves Hernvann** The Celtic Sea through time and space: what drives what in the ecosystem?
12:00 - 12:15	**Andres Beita-Jimenez** Spatiotemporal patterns of northern shrimp life-history traits and its relation to fishing and environmental variability
12:15 - 12:18	**Maria Grazia Pennino** Quantify the potential role of environmental fluctuations and changes in the small pelagic fish status of the northwestern Mediterranean Sea
12:18 - 12:21	**Karen Evans** The CLIOTOP science programme: building collaborations to develop understanding of dynamic marine ecosystems and the pathways for sustainable practices needed.
Wed 19 June	Time Block 8 of 8
14:00 - 14:15	**Guillaume Feuilloley** The impact of environmental changes on the primary production in the Gulf of Lions and links with small pelagic fish
14:15 - 14:30	**Elliot Sivel** Modelling Chance and Necessity to explore the possible dynamics of the Barents Sea ecosystem under climate and fishing pressures
14:30 - 14:45	**Barbara Muhling** Drivers of spatiotemporal variability in the forage base for pelagic top predators in the California Current
14:45 - 15:00	**Didier Gascuel** Toward a global decrease in biomass flow in marine food webs over the 21 st century?
15:00 - 15:03	**Tianfei Xue** Variability of the trophic structure in the Humboldt Upwelling System
15:03 - 15:06	**Marta Albo Puigserver** Historical changes in life-history traits of small pelagic fish in the western Mediterranean Sea along a latitudinal gradient
15:06 - 15:30	**Mariano Koen-Alonso;Paul Renaud** Plenary Discussion
Posters	
Session A	**Eleuterio Yáñez** Projections of climate change and impacts on Chilean pelagic fisheries
Session A	**Caroline Ulses** Future projections of plankton stocks and carbon fluxes for different biological regimes of the Mediterranean sea

Session A	**Marta Coll** Coupling novel modeling techniques to predict future scenarios and alternative management options for small pelagic species in the Northwestern Mediterranean Sea
Session A	**Jamie Tam** Predicting cumulative effects of climate change and fishing on the Newfoundland and Labrador Shelves ecosystem
Session A	**Torstein Pedersen** Trophic levels estimates from stable isotopes and mass-balance models for the Barents Sea – how do they compare?
Session A	**Ming-An Lee** Operational adaption of grey mullet fishing fleet possibly influenced Climate variability in the Northwestern Pacific
Session A	**Yuheng Wang** A life history model of giant jellyfish Nemopilema nomurai and its application in the Yellow Sea
Session B	**Maria Grazia Pennino** Ecological basis to embrace temporal assessment and spatial management of the European hake (Merluccius merluccius) in the northern Iberian Peninsula
Session B	**Maria Grazia Pennino** Monitoring shifts in abundance of cephalopods in North Spain shelf ecosystems: A key in fisheries assessment
Session B	**Eva Velasco** Understanding Cephalopods catch and discard rates from fishery-dependent and independent data in north Iberian waters.
Session B	**Fang Zhang** Predation selection and diet shift of Cyanea nozakii in the northern East China Sea
Session B	**Maria Grazia Pennino** Quantify the potential role of environmental fluctuations and changes in the small pelagic fish status of the northwestern Mediterranean Sea
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Session B	**Marta Albo Puigserver** Historical changes in life-history traits of small pelagic fish in the western Mediterranean Sea along a latitudinal gradient

SESSION 23: THE MULTIPLE PATHWAYS OF THE BIOLOGICAL CARBON PUMP: CURRENT UNDERSTANDING AND FUTURE CHALLENGES

Salle Méridienne

Wed 19 June	Time Block 1 of 6
14:00 - 14:15	**Bernard Quéguiner** Pelagic ecosystem functioning in the vicinity of the Kerguelen Islands (Southern Ocean): Towards and end-to-end approach
14:15 - 14:30	**Stephane Blain** Seasonal changes in Southern Ocean diatom community composition shed light on the link between diversity, carbon biomass and export.
14:30 - 14:45	**Karine Leblanc** Nature of the sinking particle flux during a late summer bloom around the Kerguelen plateau (MOBYDICK)
14:45 - 15:00	**Solene Irion** Diversity and contribution of pico- and nano-phytoplankton to the carbon uptake in contrasted areas of the Austral ocean
15:00 - 15:15	**Marine Remize** A Southern Ocean field sampling with in situ pump to study fatty acids contents and lipid production of phytoplankton and microzooplankton at the very first levels of marine food webs and their implications in Biological Carbon Pump.
15:15 - 15:17	**Cédric Cotté** Trophic pathways and transfer efficiency from phytoplankton to micronekton under contrasting productivity regimes in the Kerguelen Islands region (Southern Ocean).
15:19 - 15:21	**Stéphanie Jacquet** Go further in constraining C remineralization in the mesopelagic ocean: new insights into the barium tracer
15:21 - 15:23	**Angela Martin** The functional role of marine fish in carbon cycling and flux
Wed 19 June	Time Block 2 of 6
16:00 - 16:15	**Anna Belcher** Respiration rates in the Southern Ocean: A day in the life of mesozooplankton and micronekton
16:15 - 16:30	**Clara Manno** Threatened species drive the strength of the carbonate pump in the Scotia Sea (Southern Ocean)
16:30 - 16:45	**Joanna Ainsworth** Are mesopelagic microbial communities iron limited?
16:45 - 17:00	**Svenja Halfter** SINKING DEAD – How zooplankton carcasses affect POC flux in the subantarctic Southern Ocean before the start of the spring bloom
17:00 - 17:15	**Sebastian Böckmann** From the origin of Feces - The impact of krill and salp fecal pellets on iron chemistry and iron bioavailability to Southern Ocean phytoplankton

17:15 - 17:17	**Nicolas Djeghri** Jellyfish and Marine Snow: A First Glance
17:17 - 17:19	**Kyle Mayers** Trophic interactions between filter-feeding mesozooplankton and the Emiliania huxleyi virus
17:19 - 17:21	**Jia-Jang Hung** Biological Pumps of Carbon, Nitrogen and Phosphorus in a Large Tropical Marginal Sea
17:21 - 17:23	**Marc Garel** Heterotrophic prokaryotic activity and structure in the water column vs fast sinking particles
Thu 20 June	Time Block 3 of 6
11:00 - 11:15	**Stephanie Henson** Drivers of carbon export efficiency in the global ocean
11:15 - 11:30	**Matthieu Bressac** Upper mesopelagic bacterial remineralization, an in situ perspective across ocean provinces
11:30 - 11:45	**Nathan Briggs** Global drivers of variability in carbon flux
11:45 - 12:00	**Maria Villa-Alfageme** Global particle sinking velocity distribution: from the Arctic to the Southern Ocean
12:00 - 12:15	**Santiago Hernández-León** Active flux by zooplankton and micronekton: A gap in our knowledge of the biological pump
12:15 - 12:17	**Pritha Tutasi** Is active transport of carbon a significant component of the carbon pump in the eastern south ocean?
12:17 - 12:19	**Katty Donoso** Variability in C and N flow at lower trophic levels in the eastern south Pacific: the role of environmental zonation
12:19 - 12:21	**Mar Benavides** Microbial degradation of black carbon particles in Halong Bay (Vietnam)
12:21 - 12:23	**Leonardo Bertini** The reversibility of anthropogenically-forced change in biogeochemical drivers and deep carbon export in the North Atlantic.
Thu 20 June	Time Block 4 of 6
14:00 - 14:15	**Calum Preece** Particulate organic matter composition and distribution in the Twilight Zone
14:15 - 14:30	**Benoit Espinola** Neutrally buoyant sediment traps collect particles from further away than previously considered.
14:30 - 14:45	**Cécile Guieu** "Lithogenic carbon pump”: toward a quantification to its contribution to particulate organic carbon export in the ocean?

14:45 - 15:00	**Augustin Lafond**
	Late summer bloom community structure around the Kerguelen plateau (MOBYDICK)
15:00 - 15:15	**Chelsey Baker**
	Deep Ocean Carbon Sequestration in the Iceland Basin: is mesoscale spatial variability important?
15:15 - 15:30	**Matthias Münnich**
	The three-dimensional biological pump of Eastern Boundary Upwelling Systems: modelling studies of the California and Canary Upwelling Systems
Thu 20 June	Time Block 5 of 6
16:00 - 16:15	**Emmanuel Laurenceau-Cornec**
	The SNOWMAN: a new experimental device to improve our understanding of the Biological Carbon Pump through quantitative studies of aggregation kinetics and export time lag.
16:15 - 16:30	**Lei Wang**
	Anticyclonic Eddy Edge Effects on Phytoplankton Communities and Particle Export in the Northern South China Sea
16:30 - 16:45	**Gabriel Dulaquais**
	Refractory dissolved organic matter along the conveyor belt, sources, sinks and implications for carbon sequestration
16:45 - 17:00	**Jordan Toullec**
	Nutrient limitations during diatom growth Influence the copepod grazing and the carbon export
17:00 - 17:15	**Domitille Louchard**
	The imprint of the Amazon River on the phytoplankton community structure and carbon export in the Tropical Atlantic Ocean
17:15 - 17:30	**Natalia Llopis Monferrer**
	Contribution of siliceous Rhizaria (Polycystine radiolarian and Phaeodaria) to the ocean silica and carbon cycles
Fri 21 June	Time Block 6 of 6
09:00 - 09:15	**Wolfgang Koeve**
	Quantifying the ocean-to-atmosphere feedback of the biological carbon pump on IPCC timescales
09:15 - 09:30	**Thomas Gorgues**
	Modeled changes in the particulate carbon export efficiency in the North Atlantic due to diel zooplankton vertical migration.
09:30 - 09:45	**Alina Madita Wieczorek**
	Microplastics Disrupting the Biological Pump?
09:45 - 10:00	**Anastasia Tsiola**
	Dissolved organic carbon release due to viral lysis in an ultra-oligotrophic basin (Levantine, Eastern Mediterranean)
10:00 - 10:15	**Nathan Hubot**
	Effect of jellyfish-associated nitrifying archaea on f-ratio measurements

10:15 - 10:30 **Frederic Planchon;Clara Manno;Bernard Quéguiner;Emmanuel Laurenceau-Cornec;Anna Belcher;Stephanie Henson**
Concluding discussion

Posters

Session B **Solene Irion**
Diversity and contribution of pico- and nano-phytoplankton to the carbon uptake in contrasted areas of the Austral ocean

Session B **Cédric Cotté**
Trophic pathways and transfer efficiency from phytoplankton to micronekton under contrasting productivity regimes in the Kerguelen Islands region (Southern Ocean).

Session B **Sebastian Böckmann**
From the origin of Feces - The impact of krill and salp fecal pellets on iron chemistry and iron bioavailability to Southern Ocean phytoplankton

Session B **Joanna Ainsworth**
Are mesopelagic microbial communities iron limited?

Session B **Stéphanie Jacquet**
Go further in constraining C remineralization in the mesopelagic ocean: new insights into the barium tracer

Session B **Nicolas Djeghri**
Jellyfish and Marine Snow: A First Glance

Session B **Kyle Mayers**
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Session B **Angela Martin**
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Session B **Jia-Jang Hung**
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Session B **Augustin Lafond**

	Late summer bloom community structure around the Kerguelen plateau (MOBYDICK)
Session B	**Benoit Espinola**
	Neutrally buoyant sediment traps collect particles from further away than previously considered.

SESSION 24: THE SECOND INTERNATIONAL INDIAN OCEAN EXPEDITION (IIOE-2): MOTIVATING NEW EXPLORATION IN A POORLY UNDERSTOOD BASIN

Room 1	
Mon 17 June	Time Block 1 of 1
14:45 - 15:00	**Alain de Verneil**
	Impact of the Mesoscale on Carbon Chemistry in the Arabian Sea
15:00 - 15:15	**Cécile Guieu**
	Major impact of atmospheric iron on the productivity of the Arabian Sea
14:00 - 14:15	**Jean-François Ternon**
	Current-topography interaction at three shallow seamounts in the South-West Indian Ocean: impact on ecosystem productivity
14:30 - 14:45	**Benjamin Kürten**
	Seawater oxygen isotopes as geochemical tracers of water mass exchange between the Red Sea and the Indian Ocean
14:15 - 14:30	**Jérôme Vialard**
	Physical controls of Arabian Sea oxygen and primary productivity interannual variability and change
15:15 - 15:30	**Jerry Wiggert**
	The case for iron limitation in the Indian Ocean

SESSION 25: TOWARDS A COORDINATED GLOBAL MARINE BIODIVERSITY OBSERVING SYSTEM

Room 5	
Mon 17 June	Time Block 1 of 3
11:55 - 12:10	**Luis Felipe Artigas**
	Combining automated optical approaches for building an integrated platform for marine phytoplankton observation
12:10 - 12:25	**Xin Guo**
	Temporal and Spatial distribution of marine nanoflagellates' diversity and community structure in East China Sea
12:25 - 12:40	**Dominique Pelletier**
	Monitoring of fish communities and benthic habitats from unbaited underwater video techniques: lessons from a decade's experience
Mon 17 June	Time Block 2 of 3
14:00 - 14:15	**Lars Stemmann**
	Towards a global in situ monitoring of plankton using imaging systems: lessons learnt from the past 10 years of observation in Europe
14:15 - 14:30	**Arnaud Louchart**
	Addressing high frequency phytoplankton dynamics from by automated flow cytometry

	and multi-spectral fluorometry in the Eastern Channel – Southern North Sea.
14:45 - 15:00	**Maria Gasalla** Science support to fisheries or fisheries support to science? Proactive design of virtuous cycles for ecosystem essential ocean variables collection and analysis
15:00 - 15:15	**Gael Forget** Monitoring Marine Ecosystems Via Biogeochemical Profiling Float Arrays
Mon 17 June	Time Block 3 of 3
16:00 - 16:15	**Frank Muller-Karger** Defining the observing system for the world's ocean – from microbes to whales
16:30 - 16:45	**Cheng Tang** Fishery resource assessment in the Bohai Sea using water column image data from multibeam echo sonar
16:45 - 17:00	**Salma Begum** Towards the sustainability through understanding benthic community productivity of the Sundarbans mangrove ecosystem, Bangladesh
17:00 - 17:15	**Frank Muller-Karger** Building a Marine Biodiversity Observation Network (MBON)
Posters	
Session A	**Arianna Liconti** Science for the future: the use of citizen science in marine research and conservation
17:30 - 19:30	**Alexandre Epinoux** High-frequency monitoring of phytoplankton by automated flow cytometry: diel variability and spatial distribution at high resolution

SESSION 26: TRANSBOUNDARY FISHERIES MANAGEMENT IN CHANGING NORTH ATLANTIC AND PACIFIC OCEANS: TAKING STOCK, FUTURE SCENARIOS

Room 5

Wed 19 June	Time Block 1 of 2
11:00 - 11:25	**William Cheung** Matching the Time of Emergence of Transboundary Fish Stocks to Lead Time for Policy Response Under Climate Change
11:50 - 12:15	**Cecilia Engler** The International Law and Policy Seascape for Managing Shifting Species and Ecosystems
12:15 - 12:30	**Conveners** General discussion
Wed 19 June	Time Block 2 of 2
14:00 - 14:20	**David VanderZwaag** Are Transboundary Fisheries Management Arrangements in the North Atlantic Seaworthy in a Changing Ocean?
14:20 - 14:40	**Olga Koubrak** Are Transboundary Fisheries Management Arrangements in the North Pacific Seaworthy in Changing Oceans?

14:40 - 15:00	**Juliano Palacios-Abrantes** Challenges to Transboundary Fisheries Management in North America Under Climate Change
15:00 - 15:20	**Olav Sigurd Kjesbu** 40 years of Norwegian experience in management of transboundary fish stocks: lessons learned and how will climate change interact
15:20 - 15:30	**Conveners** General discussion

SESSION 27: WORKING IN THE SCIENCE-INDUSTRY INTERFACE: STRATEGIES FOR EFFECTIVE COLLABORATION AND PATHWAYS TO POSITIVE ENVIRONMENTAL CHANGE

Room 8

Mon 17 June	Time Block 1 of 3
11:55 - 12:00	**Prue Addison** Working in the Science-Industry Interface: Modes of Collaboration and Pathways to Positive Environmental Change
12:00 - 12:20	**Henrik Österblom** To science change – a curious dance between experimental ecologists and senior executives
12:20 - 12:40	**Sierra Ison** Linking marine science to action: the role and utility of Outcome Mapping
Mon 17 June	Time Block 2 of 3
14:00 - 14:20	**Aoi Sugimoto** “We collaborate, for sustaining happiness of rural community residents”: Some empirical evidence on the factors enhancing the participation of “Associated Population” into rural re-energize activities in Japan
14:20 - 14:40	**Sara Mynott** Combining ecological science and industry innovation to cut back on bycatch
14:40 - 15:00	**Julie Hall** Working with industry in the Sustainable Seas national Science Challenge in New Zealand
15:00 - 15:20	**Dave Reid** WKIRISH: Harnessing Fisher Knowledge. an Example of Positive Collaborative Research
Mon 17 June	Time Block 3 of 3
16:00 - 16:20	**Arnault Le Bris** Developing long-term collaborative relationships with the multiple fishing industry sectors in Atlantic Canada to achieve common objective of sustainable fisheries
16:20 - 16:40	**Raphaël Billé** Developing innovative financial mechanisms for Pacific islands conservation: opportunities and challenges
16:40 - 17:00	**Jan Bebbington** Working in the science-industry interface: understanding the private sector
17:00 - 17:30	**Prue Addison** Session Discussion

Posters

Session A	**Marie Morfin** Science-fishing industry collaborations to improve gear selectivity: feedbacks and future strategies
Session A	**Marianne Robert** Building better fish stock assessment and management through effective science-industry partnerships

XI. ABSTRACTS

Session 1: Adaptation in marine socio-ecological systems

Participatory system modelling for fisheries, food and culture to increase climate resilience on seafood availability in Tla'amin Nation

Authors: Patricia T. Angkiriwang, Ouchi S., Kenny T., Salomon A., Chan L., Cheung W.W.L.

Presenter: **Patricia Angkiriwang**

Fish and other seafoods are integral to the traditional diet and culture of many indigenous First Nations on the west coast of Canada. However, the availability and access of traditional foods for these communities have been declining, and shifting fish distributions due to projected climate change—among other factors—may pose further challenges to the food security, nutritional health and culture of coastal First Nations.
Through a collaborative effort with the Tla'amin Nation, we aim to identify and explore adaptation options to reduce potential climate risks on the Nation's fisheries and food system, and assess their effectiveness and possible trade-offs. We develop and apply a participatory modelling approach, first by co-organizing a workshop with legislators, community members, and experts from Tla'amin Nation to synthesize a shared multi-disciplinary complex systems understanding of factors and dynamics relating fisheries, environmental change, food security, culture and well-being. The resulting systems model will subsequently be used to test potential impacts of community-proposed adaptation options and strategies under various socio-ecological and climate change scenarios.
Ultimately, we hope the outputs from this study will help increase community resilience to human and climate impacts on fish availability in the area. This research highlights interdisciplinary systems framework approaches, with key components informed by community focus groups and participatory systems mapping workshops.

Social-ecological resilience in community-based setting: The case of coastal shrimp farmers in northwestern Sri Lanka

Authors: Iroshani M. Galappaththi, Eranga K. Galappaththi & Sarath S. Kodithuwakku

Presenter: **Iroshani Galappaththi**

The aim of this presentation is to share how coastal shrimp farming communities in northwestern Sri Lanka have built social-ecological resilience in the face of change. We studied five coastal communities in northwestern Sri Lanka using the social-ecological systems approach. We found that the various stressors and shocks that have contributed to the changes over the years include: ecosystem changes, shrimp disease outbreaks, changes in farming practices, and increased cost of production. As a result, the shrimp farmers have gone through a process of coping, adapting, and transforming to ensure the survival of their livelihood activities and the well-being of households/communities. They have come up with diverse responses by using their existing capital types—social, natural, economic, political, and human—and their willingness for collaboration through community cooperative work. Their individual responses well demonstrate their capacity to cope while their collective responses mostly demonstrate their adaptive and transformative capacities. Furthermore, the key to social-ecological resilience in this setting lies with their understanding of the stressors—types of stressors, potential impacts, and response options—and their commitment to find solutions as a collective group.

The role of social networks for adopting innovative production techniques as a response to environmental change

Authors: Eike Martina Holzkämper

Presenter: **Eike Martina Holzkämper**

Abrupt shifts in social-ecological systems affect the availability of natural resources and ecosystem services, with often severe consequences for ecosystem-dependent households and communities. Forced to adjust their livelihood strategies, the frequently poor users of natural resources adapt in different ways – bounded by the opportunities (or lack thereof) that their social networks generate.
This recently started PhD project will analyse coastal ecosystem user communities' adaptation strategies to abrupt shifts in their natural environment. In each of the envisaged case studies across the globe, coastal populations have experienced a shift in livelihood-relevant conditions of their coastal and marine environment. In Bangladesh, salinity intrusion causes traditional aquaculture and agriculture methods to fail. In India and Brazil, mussel fishers are faced with a local mass mortality of their respective target species. There is a need for new production technologies and their implementation, adapted to the now altered conditions in many coastal areas. This study identifies why some households engage with innovative techniques and others not. Applying a social network perspective, the proposed study will assess the character and dynamics of those social network structures that influence how affected coastal communities adapt to the changes.
This knowledge offers a better understanding of how to support coastal communities' transformation processes towards sustainability in ways that address, or at least do not exacerbate, poverty and inequality issues. The project will (1.) generate new knowledge on the relation between different social network types and environmental and social outcomes and the associated transition processes under conditions of abrupt change. It will (2.) open up avenues for identifying the role of social networks for transformative change on the global level by developing a model on how the structure of social networks relates to social processes relevant for adaptation to environmental changes. On the implementation side, results will (3.) show how to leverage communities' transition towards environmental and social sustainability in times of abrupt change by employing a network perspective combined with participatory approaches.

The fishing forecast: using perceptions to understand fishers' adaptation to future climate change

Authors: Katherine Maltby, Steve Simpson, Rachel Turner

Presenter: **Katherine Maltby**

Climate change is increasingly impacting fisheries globally, posing both risks and opportunities to those dependent on these changing marine resources. In order for fishers to capitalise on potential opportunities and minimise the negative effects of climate impacts, successful adaptation is crucial. Adaptation is a process which heavily depends on how individuals at local scales perceive future changes and can respond under risk.

This research presents findings from a study which focused on exploring fishers' perceptions of climate change and adaptation within a UK fishing community. Through interviews we examined fishers' climate change risk perceptions, their perceptions of future impacts on the marine environment and their fishing practices, and the constraints and limits to their adaptation. While scientific literature indicates that fisheries within the area face significant potential risks from future climate change, and despite fishers describing many future impacts which they associated and attributed to climate change, the majority of

fishers interviewed felt that climate change posed no or very little risk to their business or the wider industry. Fishers had a strong sense of being able to cope and adapt to future climate change, yet further analysis found that fishers differed in their adaptive capacity and their perceptions regarding what constrained their future responses and adaptation.
This work highlights the importance and complexity of exploring perceptions of climate impacts and adaptation. It demonstrates that despite awareness of impacts, this does not necessarily translate into a perceived need or willingness to prepare for and adapt to future impacts. Through examining fishers' perceptions, constraints to adaptation can also be identified. Insights from this study show that greater emphasis on examining how individuals understand and perceive future change and their future responses is needed to help inform policy and decision-makers developing fisheries adaptation plans and determine how to engage key stakeholders within these adaptation processes.

Assessing the status of climate adaptation in marine fisheries

Authors: Katherine E. Mills, Roger Griffis, Alan Haynie, Gretta Pecl, Andrew J. Pershing, and John Pinnegar

Presenter: **Katherine Mills**

There is increasing recognition and concern about the impacts of climate change on marine ecosystems, fish populations, and fisheries. Climate-related changes in the distribution, productivity, phenology, and diseases of fisheries-related species can have substantial consequences for the fisheries, communities and economies that depend on them. Fisheries and fishery managers affected by these impacts are beginning to respond in a variety of ways, and efforts to support adaptation in the fisheries sector are being developed. However, it is not clear where and how adaptation efforts are proceeding at the multiple existing institutional scales, and the cross-scale synergies and disconnects that may exist have not been well described. This talk will synthesize information on climate adaptation efforts in marine fisheries across multiple institutional scales - including individual fishers, communities, fishing industries, and fishery management systems - in rapidly changing ocean ecosystems of the United States, Canada, Australia, and Europe. To date, most examples of adaptation appear to be reactive coping measures within the fishing industry, scientific efforts to develop climate-relevant information to support adaptation, and some regional to national-scale planning initiatives. These examples demonstrate the capacity for adaptation in fisheries and an intention of many actors to support it. However, the actual implementation of adaptation measures within fishery management systems has been more limited to date, although several important examples are available. Climate adaptation in fishery management systems has tended to focus on improving information on what is changing or expected to change (e.g., current and projected shifts in distribution) and better accounting for climate-related changes in the stock assessment and the quota-setting processes. There appears to be less adaptation activity related to the allocation process. Our synthesis demonstrates that climate adaptation in marine fisheries is being observed and is advancing in some areas. However, in many cases, there is not a clear focus on adaptation, efforts are nascent, or efforts have not been fully implemented. Current imbalances in the progress of climate adaptation across institutional scales may create disconnects or barriers that limit the long-term viability of certain adaptation pathways. This synthesis provides an opportunity to identify and address those imbalances to ensure the availability of a wide range of climate adaptation pathways for marine fisheries in the future.

Differences in well-being among small-scale fisheries

Authors: Sara Miñarro, Victoria Reyes-García, Shankar Aswani, Samiya Selim, Eric Galbraith

Presenter: **Sara Miñarro**

To prioritize fisheries management objectives and maximize societal benefits from limited fishery resources it is important to comprehensively quantify the benefits human societies get from fisheries. With the world's ever-growing interconnectedness, this is especially relevant as fisheries become globalized at a fast pace. Thus far, this quantification has been mostly done in economic terms, omitting many of the intangible benefits obtained from fisheries and failing to predict fishers' behaviour in small scale fisheries. Subjective well-being has been proposed as a social indicator for sustainability and is regarded as a potential alternative measure of societal progress. The aim of this study is to understand how the fast integration in the global market economy changes the relation that fishing communities have with marine resources, whether a difference in behaviour exists, and how this effects their subjective well-being. We will show preliminary results from a subjective well-being field study from small-scale fisheries along a gradient of market integration in the Solomon Islands and Bangladesh. Using structured interviews, catch assessments and the Experience Sampling Method, we address the following questions: (1) does the experience derived from fishing change along fishers in a gradient of integration in the global market? (2) What is the relative importance of different well-being drivers along this gradient? (3) Is there a change in fishing behaviour? Our findings will help better inform fisheries management policies to holistically consider the benefits obtained from small-scale fisheries.

More than just a food: the role of pollock in social change and the construction of place in a fishing-dependent community

Authors: Chaewon Yoo

Presenter: **Chaewon Yoo**

Through the case of one fishing community which experienced the boom and bust of the pollock fishery, I will show how the community has changed in response to the shift in pollock fishery by providing the chronology of the community, basic social indicators, and the coping strategies. The case suggests that social, political and ecological factors together shape the social changes. Based on the analysis, I will argue that resource management and resilience at the community level alone are not enough to cope with the ongoing and upcoming crises of fishing communities. In addition to the practical issues, drawing on the geographical notion of place, I discuss how pollock played a central role in making Goseong as a place, by analyzing the pollock-related locale and sense of place. I will also show how marine species as pollock which often perceived as just food is connected to human lives in a different dimension.

SESSION 2: ARCTIC MARINE ECOSYSTEMS IN A CHANGING CLIMATE

From long-interval, late Holocene paleo-records to scenario-building for adaptive planning in future fisheries

Authors: Ben Fitzhugh , Poul Holm, Tom McGovern, Nicole Misarti, George Hambrecht, Jim Woollett, Jason Addison, Kana Nagashima

Presenter: **Ben Fitzhugh**

Understanding the future of marine ecosystems and planning for socio-economic resilience to that system requires an understanding of the range of variability possible, whether due to climate forcing, oceanographic processes, internal ecological dynamics, human forcing (or a combination). Models and instrumental data have made progress describing multi-decadal scale variability. Paleo-proxies suggest longer period modes as well. We will compare paleoclimatic, paleoceanographic, paleoecological records from the North Pacific and North Atlantic record over the past 1500 years, which suggest spatially structured variability at multi-century scales. Archaeological and historical archives illustrate significant human consequences of this variability for societal resilience. With these case studies in focus, we will then take a scenario-building approach to explore how such variability could affect future marine-based economies around the subarctic for the remainder of the 21st century. This paper is a collaborative product of ESSAS/PESAS, the North Atlantic Biocultural Organization (NABO), NorFish, and the Oceans Past Initiative (OPI).

Warming in the Barents Sea: ecosystem benefits and problems

Authors: Elena Eriksen, Anatoly Filin

Presenter: **Elena Eriksen**

The ICES Working Group on integrated assessment for the Barents Sea (WGIBAR) is a multidisciplinary group of scientists, seeking to describe the ecosystem state and changes. The Barents Sea has been experiencing dramatic changes during the last four decades from cold conditions during 1960-1980, an oscillating period with both warm and cold years during the 1980s and 1990s, to record warm temperature conditions and loss of half of the winter ice from 2000 onwards. The warming has been associated with increased net primary production, abundance of meso- and macroplankton and good fish recruitment. The biomasses of macroplankton, notably krill, increased up to 200 million tonnes and both pelagic and demersal fish were at high levels with cumulative biomass up to 12 million tonnes. The capelin stock collapsed twice during the recent warming most likely due to increased predation pressure at all life stages. However, good recruitment and beneficial feeding conditions allowed the capelin stock to recover fast and tolerate a high predation pressure from a record large cod stock between their collapses. The large cod stock extended its feeding area into the northern Barents Sea, where it overlapped both with capelin and polar cod, and preyed on alternative food items in addition to polar cod when capelin was at a low level. While there was increased biomasses of boreal species, the arctic species decreased in abundance and distribution. The WGIBAR meeting held in February 2019 will document decadal changes in the ecosystem and try to predict future development. These results will be presented at the IMBeR Future Oceans2 Conference.

The importance mesoscale processes and bio-physical coupling for Arctic ecosystem modeling and prediction

Authors: Wieslaw Maslowski, Younjoo Lee, Marina Frants, Jaclyn Clement Kinney, Robert Osinski

Presenter: **Wieslaw Maslowski**

The Regional Arctic System Model (RASM) has been developed and used to investigate critical processes controlling the evolution of the Arctic climate system, including marine biogeochemistry, under a diminishing sea ice cover. RASM is a fully coupled limited-domain ice-ocean-atmosphere-land model with biogeochemistry components in the ocean and sea ice. Its domain is pan-Arctic, with the atmosphere and land components configured on a 50-km or 25-km grid. The ocean and sea ice components are configured on rotated sphere meshes with four configuration options: 1/12-degree (~9.3km) or 1/48-degree (~2.4km) in the horizontal space and with 45 or 60 vertical layers. Several examples of key physical processes and biophysical coupling will be presented, that improve the representation of the past and present Arctic ecosystem. The impact of such improvements will be discussed with regard to reducing uncertainties, improving model predictive skill and advancing predictability of Arctic climate change, including its ecosystem, at time scales from synoptic to decadal.

Controlling factor of primary production in the “warmed” Arctic Ocean

Authors: Amane Fujiwara, Shigeto Nishino, Emmanuel Devred, Toru Hirawake, Takashi Kikuchi

Presenter: **Amane Fujiwara**

Sea ice reduction in the Arctic Ocean has accelerated in the early 21st century. In 2007, most of the multi-year-ice had disappeared and the area of seasonal ice zone has extended, with the consequence of increasing the duration and surface area for phytoplankton growth. As a result of these changes in sea-ice dynamics, annual primary production (APP) has pulsed for ~1.5 times in recent two decades. Since then, annual minima of sea-ice extent have reached similar levels with 2007, though the decreasing trend has decelerated compared to the early 2000’s. In this study, we aim at reassessing the inter-annual variability of primary production under this recent dynamic of sea ice reduction. This information is crucial to provide a scientific basis for ecosystem-based-management and decision-making in the Arctic Ocean. In the present study, we investigated the relationship between annual primary production and its potential controlling factors at the pan-Arctic scale using satellite remote sensing comparing before and after the drastic sea ice reduction event that occurred in 2007. Before this event, the duration of the open water period (OWP) was the main contributor to APP in most of the Arctic Ocean. OWP remains a strong driver of the increase in APP after 2007, though the magnitude of spring bloom and the annual median temperature became more important to explain the changes in APP in some regions. These results suggest that the interplay between the mechanisms driving the primary production are becoming more complex in a warmer Arctic Ocean.

FAMOS multi-model intercomparison of the pan-Arctic ice algal productivity on seasonal and decadal timescales

Authors: Eiji Watanabe, Meibing Jin, Hakase Hayashida, Jinlun Zhang, and Nadja Steiner

Presenter: **Eiji Watanabe**

Biogeochemical responses to the Arctic sea ice decline have become an important topic for a variety of communities. Ice algae are an important component of the Arctic marine ecosystem and carbon cycle. Generally, sea ice decline plays both positive and negative roles in ice algal biomass. For example, sea ice thinning enhances light penetration into the skeletal layer at the ice-ocean interface. On the other hand, reduction in net thermal ice growth restricts nutrient availability. Retreat of sea ice margin causes shrinking of ice algal habitat. Numerical modeling is a powerful tool to evaluate the impacts of sea ice decline on ice algal productivity on the pan-Arctic and decadal scales. In recent years, the modeling target region has been extended from landfast ice stations to the entire Arctic Ocean, and complex ice algal processes are now numerically formulated in various ways.

The present study addresses seasonal and decadal variations in ice algal productivity from 1980 to 2009, which were simulated by five pan-Arctic and global sea ice-ocean ecosystem models participating in the Forum for Arctic Modeling and Observational Synthesis (FAMOS) project. Relationships among ice algal productivity/biomass, sea ice concentration, snow depth, sea ice thickness, and nutrient contents in the sea ice column and the ocean surface layer averaged over four sub-regions (Chukchi Sea, Canada Basin, Eurasian Basin, and Barents Sea) are particularly focused on. The FAMOS models simulated reasonable seasonal cycles of the analyzed sea ice and ocean properties, whereas their amplitudes are partly different. The simulated ice algal biomass shows no common decadal trend probably because sea ice decline has both positive and negative impacts. More details with uncertainties will be reported.

A numerical analysis of the effects of contemporary sea ice loss on Arctic primary production

Authors: Timothée Bourgeois, Katja Fennel, Benjamin Richaud, Xiaofan Luo, Xianmin Hu and Youyu Lu

Presenter: **Timothée Bourgeois**

The Arctic Ocean is changing at a dramatic pace with the melting of multi-year sea ice as one of the most obvious consequences of global warming. The reduction in sea ice coverage induces changes in light availability, freshwater cycling and ocean surface exposure to wind stress that result in modulations of phytoplankton activity. At the pan-Arctic scale, remote sensing- and model-based studies suggest a contemporary increase of Arctic primary production but differ in the extent of this change at both Arctic and regional scales. Here we use the coupled physical-biogeochemical model NEMO-PISCES to study the contemporary changes of Arctic primary production. With a horizontal resolution ranging from 10 to 20 km, our model domain covers the Arctic Ocean and extends to 45N in the Pacific and to 25N in the Atlantic Ocean. Based on a multi-decadal simulation, our model results describe both pan-Arctic and regional interannual changes in the primary production. Our model results show a 22 % increase in the Arctic primary production inventory from 1998-2002 to 2011-2015, reaching 314 Tg C yr^{-1}. The main primary production increases occur in the Barents, Laptev and Chukchi Seas as well as along the coasts of Beaufort Sea. Although light availability is the main limiting factor for phytoplankton growth in our model, the frequency of nutrient limitation events increases during summer in some Arctic shelf seas in parallel to the long-term increase in sea ice retreat.

Factors regulating nitrification in the Arctic Ocean: the potential impact of sea-ice reduction and ocean acidification

Authors: Takuhei Shiozaki, Minoru Ijichi, Amane Fujiwara, Akiko Makabe, Shigeto Nishino, Chisato Yoshikawa, Naomi Harada

Presenter: **Takuhei Shiozaki**

Nitrification is susceptible to changes in light and pH and, thus, could be influenced by recent sea-ice reductions and acidification in the Arctic Ocean. We investigated the light and pH sensitivity of nitrification in a natural nitrifier community and the major regulatory factors of nitrification in the Arctic Ocean. Nitrification was active near the bottom in the shelf region (<60 m) and in the halocline layer (50–200 m) of the Arctic basin, where ammonium was abundant, but was low in the ammonium-depleted Atlantic layer (>250 m). The nitrification rate was negatively correlated with the pH suggesting that a reduced pH might not be the primary factor inhibiting nitrification in the region. However, in pH control experiments, nitrification rates significantly declined when the pH was manipulated to be 0.22 lower than the controls. Light control experiments showed that nitrification was inhibited by a light intensity above 0.11 mol photons m^{-2} d^{-1}, which was presumably the light threshold. A light intensity greater than the light threshold extended to the shelf bottom and upper halocline layer, limiting nitrification in these waters. Satellite data analyses indicated that the area where light levels inhibit nitrification has increased throughout the Arctic Ocean due to the recent sea-ice reduction, conceivably leading to a declining trend in nitrification. Our results suggest that both stronger light levels and a lower pH in the future Arctic Ocean could further suppress nitrification and alter the composition of inorganic nitrogen, with implications for the structure of ecosystems.

Nutrient and phytoplankton distributions associated with ocean circulation, eddies, and mixing in the Pacific Arctic Region

Authors: Shigeto Nishino, Amane Fujiwara, Yusuke Kawaguchi, Takuhei Shiozaki, Motoyo Itoh, Toru Hirawake, Michiyo Yamamoto-Kawai, Michio Aoyama, Naomi Harada, Takashi Kikuchi

Presenter: **Shigeto Nishino**

The Chukchi Sea and Canada Basin are areas in the Pacific Arctic characterized by northward advection and spreading of Pacific-origin water that transports nutrients into the Arctic Ocean, and thus plays an important role in phytoplankton distributions. In this study, we examined ship-based and mooring data to understand nutrient dynamics and its influence on phytoplankton distributions. In the southern Chukchi Sea, our data suggest that, in contrast to spring blooms that are caused by a nutrient supply with the advection of Pacific-origin water, autumn blooms there are maintained by regenerated nutrients from the bottom of the shallow sea where particulate organic matters are largely accumulated in autumn. On the other hand, large-scale ocean circulation controls nutrient distributions in the Canada Basin where sea ice reduction in recent years has changed the ocean circulation and thus impacts on the nutrient and phytoplankton dynamics. We found that oceanographic and biological responses to the sea ice loss are quite different between the Alaskan and Siberian sides of the region. On the Alaskan side, eddies also play an important role in the nutrient and phytoplankton distributions. However, on the Siberian side, data are still lacking and various biogeochemical processes should be clarified in future studies.

Surface patches of *Calanus* sp. and the seasonal advection of zooplankton into the Arctic Basin through the Atlantic gateway, Fram Strait

Authors: Sünnje L. Basedow, Arild Sundfjord, Wilken-Jon von Appen, Elisabeth Halvorsen, David McKee

Presenter: **Sünnje Basedow**

The largest contribution of oceanic heat to the Arctic Ocean is the warm Atlantic Water (AW) inflow through the deep Fram Strait. The AW current also carries Atlantic plankton into the Arctic Basin and this inflow of zooplankton biomass through the Atlantic-Arctic gateway far exceeds the inflow through the shallow Pacific-Arctic gateway. Here we quantify the inflow of zooplankton biomass through the Fram Strait during different seasons, including winter. Data were collected with high spatial resolution covering hydrography (CTD), currents (ADCP and LADCP) and zooplankton distributions (LOPC and MultiNet) from surface to 1000 m depth along two transects crossing the AW inflow during three cruises in January, May and August 2014. Long-term variations (1997-2016) in the AW inflow were analysed based on moored current meters. Water transport across the inflow region was of the same order of magnitude during all months (January 2.2 Sv, May 1.9 Sv, August 1.7 Sv). We found a higher variability in zooplankton transport between the months (January 51 kg C s^{-1}, May 34 kg C s^{-1}, August 50 kg C s^{-1}), related to seasonal changes in the vertical distribution of zooplankton. However, high abundances of carbon-rich copepods were observed in the AW inflow during all months. Surface patches with high abundances of *Microcalanus* spp., *Pseudocalanus* spp., *Oithona similis* and in particular *C. finmarchicus* clearly contributed to the advected biomass, also in winter. This advective zooplankton input might be especially important for mesopelagic planktivorous predators that were recently observed in the region, particularly during winter. The inflow of *C. finmarchicus* with AW was estimated to be in the order of 500 000 metric tons C y^{-1}, it is discussed with respect to population size and recent observations of large-scale surface patches in the upstream habitat in the Norwegian Sea.

Awakening of zooplankton below drifting sea ice after the dark Arctic winter

Authors: Anette Wold, Haakon Hop, Janne E. Søreide, Maja Karoline Viddal Hatlebakk, Amelie Meyer, Mikko Vihtakari and Allison Bailey

Presenter: **Anette Wold**

The seasonal development of zooplankton community was examined during the N-ICE2015 expedition in the Nansen Basin and over the Yermak Plateau from January to June 2015. This area in the Arctic is situated north of Fram Strait, the only deep-water passage between the North Atlantic Ocean and the Arctic Ocean, allowing water circulation between the two basins. During the expedition, the hydrography was dominated by northward flowing warm saline Atlantic Water at intermediate depth and southward flowing cold Arctic water in the upper 100 m. This region is characterized by high variability in the formation and break-up of sea ice from year to year, causing large variation in the timing of the ice algae and pelagic phytoplankton blooms. Consequently, the zooplankton living here have to adapt to variable environmental conditions. This study presents the development of the zooplankton community from winter to summer in relation to the hydrography and algal food availability.

The most pronounced change in zooplankton community throughout the season was the increased abundance of the large herbivorous copepods *Calanus finmarchicus* and *Calanus glacialis* as well as *Calanus nauplii* in surface water at the end of May and beginning of June. *Calanus hyperboreus* was present in lower numbers than the two other *Calanus* species in surface waters. However, it was present throughout the water column and due to its relative large size it contributed substantially to the biomass. The species composition and the abundance of zooplankton in the two deepest layers did not change much throughout

the season. The deep samples were dominated by smaller species such as *Oithona similis, Triconia borealis* and *Microcalanus* spp. as well as typical deep-water species such as *Heterorhabdus compactus*, *Gaetanus brevispinus*, and *Paraeuchaeta norvegica*.
The largest increase in *Calanus* nauplii and copepodites was observed just after a rise in temperature and reduced salinity in surface waters in late May (25th May), due to the presence of Atlantic Water at depth and a shallower mixed layer followed by a peak in chlorophyll a standing stock a few days later (31st May). Subsequently the zooplankton biomass increased with a total of 149 mg dry weight m-3 in the upper 50 m in mid-June of which the *Calanus* species comprised approximately 90 %. The springtime increase in biomass of *Calanus* spp. in surface waters was due to 1) the presence of relatively zooplankton-rich Atlantic Water, 2) new recruitment as well as 3) overwintering individuals ascending to the surface.
This study combined with other N-ICE2015 campaign publications is expected to become a reference for future zooplankton studies in the Arctic Ocean. The Atlantic Water inflow to the Arctic has been warming since the later 1970s, leading to reduced ice cover north of Svalbard, decreased surface salinity, as well as a northward expansion of Atlantic zooplankton, such as *C. finmarchicus*. These changes are expected to continue in the future and documentation of zooplankton composition, biomass and seasonal development is needed for modelling and predictions.

Atlantification of zooplankton in Arctic fjords, Kongsfjorden and Rijpfjorden, Svalbard

Authors: Haakon Hop, Anette Wold, Mikko Vihtakari, Arild Sundfjord, Malin Daase, Slawomir Kwasniewski, Marta Gluchowska, and Stig Falk-Petersen

Presenter: **Haakon Hop**

Zooplankton communities in Svalbard fjords are composed of Arctic and Atlantic species, reflecting different water masses and the magnitude of advection of coastal and Atlantic water (AW). Ocean warming during the last decade has caused increased heat transport in the West Spitsbergen Current, which flows along the west coast of Svalbard and continues on the northern continental slope as the AW Boundary Current. Consequently, boreal zooplankton species associated with AW have expanded their distributions and have become more abundant in the resident zooplankton communities. Increased Atlantification of Arctic fjords is evident on the west coast of Svalbard and models project that this will extend to the high-Arctic fjords on the north coast based on increased global warming.
Here, we present observations on the distribution, composition, abundance and the development of zooplankton from summer time series in Kongsfjorden (1996-2016) and Rijpfjorden (2010-2014), Svalbard. Inter-annual variations in species composition and abundance were related to changes in hydrography and occurred in an oscillating manner. In Kongsfjorden, increased advection of AW was characterized by higher abundances of Atlantic species, such as *Calanus finmarchicus, Oithona atlantica, Thysanoessa longicaudata* and *Themisto abyssorum*. Other krill species, particularly *Thysanoessa inermis*, increased in abundance during the warming period 2006-2007, mainly in the inner basin. In years with less impact of AW, higher abundance of *Themisto libellula* was recorded. The changes in environmental factors, however, did not clearly influence the abundance or biomass of the Arctic Calanus glacialis suggesting that conditions have not reached critical levels for this species. Some Atlantic species have become more abundant in Kongsfjorden's pelagic realm, suggesting that they benefit from the increasing temperature, and the total biomass of zooplankton has increased in the fjord implying higher secondary production.
Rijpfjorden (80oN 22o30'E), which faces the Arctic Ocean on the north cost of Svalbard, is a much colder system, but is influenced by the Boundary Current which occasionally sheds AW onto the shelf and into the fjord. The boreal *C. finmarchicus* and *O. similis* dominated in AW over the slope and on outer part of the shelf, whereas *C. glacialis* and neritic zooplankton (*Pseudocalanus, Parasagitta elegans* and *meroplankton*) dominated the cold water masses inside Rijpfjorden. Regardless, a large biomass of *C. finmarhicus* was

found inside the fjord. Rijpfjorden will likely change with climate warming in a direction to resemble Kongsfjorden during the cold years prior to 2006, with an expected increase in the contribution of boreal species.
Large amounts of *C. finmarchicus* are transported northwards towards the Arctic Ocean through Fram Strait annually, but it is estimated that only about 1/3 of this biomass continues en route north of Svalbard in the AW Boundary Current. Further east along the continental slope, the species contribution to total zooplankton biomass diminishes from 40 to 10%, and its reproduction becomes hampered by low temperatures and the late onset of the spring bloom. Future warming and reduced ice cover may lead to conditions that are more favorable with regard to survival of Atlantic expatriates in Svalbard fjords and the Arctic Ocean.

Spatial variations in taxonomic and functional diversity of zooplankton from boreal to Arctic seas

Authors: Slawomir Kwasniewski, Marta Gluchowska, Emilia Trudnowska

Presenter: **Slawomir Kwasniewski**

The advection of warm Atlantic water into the Arctic influences not only hydrography and sea ice conditions in the Arctic Ocean and the adjacent seas but also the Arctic marine ecosystems. Earlier efforts to characterize the response of zooplankton communities to the increasing influence of warm AW focused mostly on changes in taxonomic species richness, community structure or standing stock. Such an approach is probably not sufficient and does not provide information about all important modifications in functioning of biotic communities, caused by environmental changes. Using functional traits allows for more in-depth understanding of mechanisms and phenomena that structure biological diversity and functioning of biotic communities.
This study presents the results of research on spatial variability of species richness and functional diversity of zooplankton communities from boreal to Arctic seas. Data on zooplankton composition and distribution used in this study was collected in six fjords from 76 °N to 79 °N, located along a thermal gradient from temperate to Arctic marine domains, under the Polish-Norwegian DWARF project. Complementary data on zooplankton functional traits was compiled as a part of the Polish National Science Centre Tax4Fun project. The results show that in spite of changes in taxonomic composition, biological diversity and individual functional characteristics of zooplankton, the functional diversity of the communities occurring along the investigated ecological gradients of 20 ° latitude and 8 °C water temperature was relatively similar. It can be assumed that if the communities investigated have similar functional characteristics, maybe they also have similar resistance to environmental stress, thus, maybe they are able to replace each other in role they play in ecosystems, in a situation of ecosystem modification due to climate change. Our findings can be used in building scenarios of changes, and in constructing and tuning plankton components of ecosystem models, for pelagic realms of boreal and Arctic seas.

Climate change impact on Barents Sea ecosystem functioning and vulnerability

Authors: Raul Primicerio, Michaela Aschan, Magnus Aune, Marie-Anne Blanchet, Padmini Dalpadado, Andrey Dolgov, Elena Eriksen, Maria Fossheim, Andre Frainer, Lis Lindal Jørgensen, Susanne Kortsch, Ulf Lindstrøm, Mette Skern-Mauritzen, Laurene Pecuchet, Paul Renaud,

Presenter: **Raul Primicerio**

The Barents Sea ecosystem is undergoing rapid structural change driven by climate warming. Ecosystem alterations are particularly extensive in Arctic waters, where poleward distributional shifts of demersal and pelagic fish species bring about changes in species composition and community structure. The restructuring of Arctic marine communities modifies food web configurations and functional characterization, with implications for ecosystem functioning and vulnerability. We address climate-driven changes in ecosystem properties affecting ecosystem functioning and vulnerability, relying on trait-based methods and food web analyses applied to the Barents Sea Ecosystem Survey Data collected by the Institute of Marine Research (Norway) and PINRO (Russia). We find that, in Arctic waters, functional characterization is changing towards an increased importance of larger, more generalist pelagic feeders. These changes in functional characterization, associated with increased seawater temperature and reduced ice coverage, are accompanied by food web reconfigurations leading to increased connectance and decreased modularity. The observed changes affect ecosystem functioning, by e.g. modifying the degree of bentho-pelagic coupling. Ecosystem vulnerability is also being affected, with three of its main components, functional diversity and redundancy, and food web modularity, all displaying rapid and extensive change in Arctic waters. The documented changes in functional characterization and food web configuration, driven by climate warming, will lead to substantial alterations in the ecosystem functioning and vulnerability of this Arctic marine ecosystem.

Increasing Atlantic currents drive poleward expansion of temperate marine species in the Arctic Ocean

Authors: Laurent Oziel, A. Baudena, M. Ardyna, P. Massicotte, J-B Sallée, R. Ingvaldsen, E. Devred, L. Lacour, M. Babin

Presenter: **Laurent Oziel**

The European Arctic corridor (EAC) is strategically positioned between the North Atlantic and the Arctic Ocean (AO). It represents the main gateway for the Atlantic Waters (AW) towards the Arctic basins. These warm waters, flowing northward, carry with them heat, nutrients and organisms. Using satellite-derived altimetry observations, we first describe an unprecedented two-fold increase in AW current velocities over the last 24 years. More importantly, we reveal here that advective transport, and not only water temperature as previously assumed, drive the spatial dynamics of the coccolithophore E. Huxleyi, a 'sentinel' for temperate AW ecosystem. In this context, we prove that bio-advection is the major mechanism responsible for the recent acceleration of E. Huxleyi poleward intrusions in the EAC. Such poleward expansion clearly illustrates the undeniable biological and physical "Atlantification" of the Arctic Ocean. Shifts in the marine species assemblage, like the one altering the phytoplankton compartment, could potentially have dramatic effects on Arctic marine food web and biogeochemical cycles in a context of rapid climatic change.

Extreme climatic event drive immediate response of fish communities in the Barents Sea

Authors: Husson Bérengère, Lind Sigrid, Fossheim Maria, Primicerio Raul, Ingvaldsen Randi, Dolgov Andrey

Presenter: **Bérengère Husson**

The Arctic is experiencing the strongest warming on earth, and because of the decrease in sea ice import, the northern Barents Sea is particularly impacted. Recent studies have shown that the increasing warming trend in temperatures is occurring at the same time as a northward shift of fish communities in the whole Barents Sea. Extreme climatic events could accelerate those changes or trigger a shift in the ecosystem and should be investigated. We investigated the link between environmental conditions and fish communities during the last fifteen years. During this period, three years are characterized by record high temperatures and low ice coverage: 2006, 2012, and 2016. Data on demersal fish abundances in the whole Barents Sea were collected from bottom trawls during the autumn ecosystem surveys of 2004 to 2017. Exploration shows that fish densities reach the three highest values of the time series in 2006, 2012 and 2017. Changes occurred mainly in the south-west and north-east of the Barents Sea in 2006, again in the north-east in 2012, and in the whole northern part in 2017. Studying the processes occurring at the community scale allowed the detection of general emerging patterns in link with climate changes.

Rapid borealization of Arctic marine fish communities

Authors: André Frainer, Raul Primicerio, Andrey Dolgov, Maria Fossheim, Michaela Aschan

Presenter: **André Frainer**

Climate change affects species distribution, with observed rapid effects on the functional composition of Arctic marine fish and several other marine species across the globe. Using data from an extensive survey conducted over 400 stations across 14 years, and covering the entire Barents Sea, we show that marine fish Arctic communities are under a process of rapid borealization. First, community-based mean values indicate that boreal functional traits are increasingly becoming dominant in Arctic stations. Then, assessing community-level variance, we show that the Arctic region as a whole already possesses the traits that makes it resemble the boreal region. This is followed by an increased functional diversity in the region led mostly by the addition of traits related to predator and superior competitor species. The increase in functional diversity in the Arctic has clear consequences to its ecosystem functioning, including energy flow patterns and biomass accrual. This result is alarming and indicative of a change at an unprecedented rate. Assessments of species and functional composition are key to lay the foundation for sustainable economic policies, to adjust current harvesting practices, and to conserve areas of special interest. Thus, early warning signals of functional change as shown here are paramount for rapid and effective policy adaptation in light of rapid worldwide climate-driven changes.

On the role of higher trophic levels for long-term changes in ecosystem productivity: A modelling study in the North Atlantic/Arctic Ocean

Authors: Ute Daewel, Annette Samuelsen, Corinna Schrum, Çağlar Yumruktepe

Presenter: **Ute Daewel**

Here we implemented functional groups of fish and macro benthos to the fully coupled physical-biological model HYCOM-ECOSMO with the aim to understand the feedback mechanisms between lower and higher trophic level (HTL) production. Zooplankton is typically the highest trophic level simulated in marine ecosystem models with energy and matter transfer to HTLs realized through constant rates and as a loss term. The advantage of a more dynamic higher trophic level formulation is thus on the one hand the spatially and temporally dynamics of the zooplankton mortality. On the other hand it allows a dynamical estimate of matter and energy transfer and, hence, a process determined higher trophic level production estimate.
By employing the model ECOSMO E2E in the North Atlantic/ Arctic region for a multidecadal time period we aim to study the role of the advanced HTL formulations for simulating the ecosystem response and changes in the food web in the light of environmental changes. Thereby we specifically emphasize the role of macrobenthos for nutrient cycling in the shallow shelf seas of the area and changes to the spatio-temporal distribution of higher trophic level production and its impact on zooplankton dynamics. Finally we will discuss the model results with respect to recent and expected changes in the Arctic ecosystem.

Marine animal biomass shifts under 21st century climate change in Canada's three oceans

Authors: Faelan Prentice and Andrea Bryndum-Buchholz, Derek P. Tittensor, Julia L. Blanchard, William W. L. Cheung, Marta Coll, Eric D. Galbraith, Simon Jennings, Olivier Maury, and Heike K. Lotze

Presenter: **Andrea Bryndum-Buchholz**

At the temperate and polar latitudes of Canada's three oceans, climate change is expected to cause substantial shifts in marine species distribution and abundance. These changes will significantly alter marine ecosystem structure and function with associated implications for marine ecosystem services, marine fisheries, and fishery-dependent societies. Using outputs from six global marine ecosystem models within the Fisheries and Marine Ecosystem Model Intercomparison Project (Fish-MIP), that simulate ecosystem structure, dynamics, and production, we analyze projected spatio-temporal changes over the 21st century in Canada's Exclusive Economic Zones (EEZs) under contrasting emission scenarios.
Under the high emissions scenario (RCP8.5), our ensemble results suggested that by 2100 climate change will lead to a 26% increase in mean biomass within the Arctic EEZ, and a >20% biomass decrease in the Atlantic and Pacific EEZs. Projected biomass changes were reduced under a low emissions scenario (RCP2.6). Further, our model ensemble projected strong latitudinal changes in the Atlantic and Arctic marine ecosystems, which indicate the need of long-term and dynamic planning of conservation measures given the likelihood that species will shift towards polar water with climate change.
This study presents an important case study for climate change impacts on a northern country and its oceans using an ensemble model approach, in particular for regions like the Arctic Archipelago, where many areas are still inadequately represented by global Earth system and marine ecosystem models.

Modeling abundance of demersal fish in the Pacific Arctic under climate change: implications on future resource availability to fisheries

Authors: Irene D. Alabia, Jorge García Molinos, Sei-Ichi Saitoh, Takafumi Hirata, Toru Hirawake, and Franz J. Mueter

Presenter: **Irene Alabia**

The rising global temperature, with its associated impacts on ecosystem productivity, elicits changes in species abundance, distribution and subsequent resource availability. In the present study, we are exploring the projected changes in abundance of major demersal fish species in the Eastern Bering Sea from artificial neural network (ANN) models. These species-specific models were trained using the catch data from the NOAA summer trawl surveys and environmental covariates (i.e. winter sea surface temperatures and sea-ice concentration and depth) from 1993-2016. The fitted models were then used to generate future projections on species abundance by mid- (2051-2075) and late-century (2076-2100) periods under moderate (RCP 4.5) and high (RCP 8.5) climate warming scenarios. The spatial patterns and differences in species' relative abundances between the present (1993-2016) and future periods (mid- and late-century) were then examined to highlight the spatiotemporal changes in their projected potential availability to fisheries. The outputs from our analyses can facilitate discussion and provide insight into the anticipated changes between the current and future fisheries in the region under different climate scenarios.

Tracking long-term trends in trophic levels of Pacific cod through carbon and nitrogen stable isotopes

Authors: Nicole Misarti, Franz Mueter

Presenter: **Nicole Misarti**

Pacific cod (Gadus macrocephalus) have been an important subsistence resource in coastal Alaska for thousands of years, and continue to be an important commercial species in Alaska fisheries to this day. Recent declines in Pacific cod in the Gulf of Alaska have been a cause of concern for local fishing communities. This project compares changes in trophic dynamics and size of more than 420 individual Pacific cod over the last few thousand years using carbon and nitrogen stable isotope analysis coupled with fish size. Fish size is based on allometric relationships of premaxillas to live fish length. Pacific cod collected from middens have fluctuated in both size and trophic position over the last 4500 years (ANOVA; p-value ≤ 0.001). Comparisons with published longline fishery data collected over the last 40 years show that both the current size and trophic position of Pacific cod appear to be within the normal range of variation for the last few thousand years. In addition, diets of smaller fish may be more susceptible to climate and regime shifts, as there was no significant difference between the nitrogen stable isotope signature of fish greater than 70 cm in size while cod smaller than 70 cm had significant differences over time. Therefore studies focused on younger/smaller Pacific cod may be valuable for management purposes. This research is a first step toward creating long term baseline data sets, which could be very useful to fisheries management, conservation, and the economic well-being of communities reliant on the Pacific cod fishery.

Climate impacts on spawning habitat of Pacific cod (Gadus macrocephalus)

Authors: Benjamin J. Laurel, Lauren A. Rogers

Presenter: **Benjamin Laurel**

Pacific cod (Gadus macrocephalus) support large commercial fisheries in Alaska that are being challenged by loss of adult biomass on customary fishing grounds in the Bering Sea and Gulf of Alaska. Such losses raise new questions on how climate impacts spatial-temporal dynamics in spawning habitat and processes during the first year of life. Here we measure temperature-dependent hatch success in the laboratory and integrate these models with available temperature data from the Bering Sea and Gulf of Alaska to develop historical and contemporary indices of spawning habitat suitability for Pacific cod. These outputs were then compared to available time series of larval, juvenile and age-3 abundance to determine whether Pacific cod recruitment success was related to environmentally regulated changes in spawning habitat. Habitat suitability indices in the Gulf of Alaska suggest spawning was spatially reduced and restricted to earlier times of the year during El Nino events (1998, 2003) and the 'warm blob' (2014-16) compared to historical averages. Positive correlations were also found between the spatial-temporal extent of suitable spawning habitat and the annual abundance of pre-recruits (larvae and juveniles) as well as age-3 recruitment estimated in the stock assessment model. Preliminary analysis of spawning habitat in the Northern Bering Sea suggests increased suitability following the loss of sea ice and observations of increased adult biomass. The environmental plasticity of spawning phenology and match-mismatch consequences for YOY Pacific cod will be an important area of research to determine population dynamics of this species in the wake of continued warming and extreme temperature events in Alaska.

SE Bering Sea ice: the importance of location, amount, persistence and timing for the recruitment of zooplankton and pollock

Authors: George L. Hunt, Jr., Lisa Eisner, Mary Beth Decker, Sigrid Salo, Phyllis Stabeno

Presenter: **George Hunt**

Since the mid-1970s, there has been an interest in exploring the role of sea ice in the southeastern Bering Sea. Here we examine the impacts of sea ice on the recruitment of zooplankton and walleye pollock (Gadus chalcogramma). To understand the importance of the location of the sea ice, we examine eight sectors of the southeastern Bering Sea, four of which are in the outer shelf and four of which are in the middle shelf. For each sector, we determine the relative impact on recruitment of zooplankton and pollock of the 1) number of days with sea ice cover of ≥15%, 2) the last day in spring of sea ice cover of ≥ 15%, and 3) the mean sea ice cover between day 32 and day 60 (approximately February) for all years from 1979 to 2014. We used a stop-light approach to show that average sea ice cover from day 32 to 60 in the southernmost sector in the middle domain is the best predictor of both strong and weak year-classes of pollock as estimated by their recruitment to age-3, when accounting for spawner biomass in the age-0 year. The next most useful predictor is the average sea ice cover in the next sector to the north over the middle shelf. Similarly, the average sea-ice-cover in February in the same zone is a good predictor of copepods. We also examine the impacts of sea ice on jellyfish. The implications of our results are that, without sea ice present in winter over the southern middle shelf, the recruitment of some species of crustacean zooplankton and walleye pollock will be severely diminished in the eastern Bering Sea.

The effects of temperature and food quality on the lipid condition and trophic biomarkers of juvenile polar cod (Boreogadus saida) and co-occuring Alaskan congeners.

Authors: Louise Copeman, Benjamin Laurel, Carlissa Salant, Michelle Stowell, Ron Heintz, Johanna Vollenweider, Franz Mueter, Edward Farley

Presenter: **Louise Copeman**

The Arctic is undergoing dramatic environmental change with decreasing sea ice extent and increasing summer temperatures. August of 2017 in the Chukchi Sea was anomalously warm, nearly 5°C warmer than the previous 30 year average. Increased ocean temperatures are affecting North Pacific fish both via direct thermal effects on their physiology as well as through indirect changes to available food quality/quantity. We have used combined laboratory and field-based approaches to study the interactive effects of food and temperature on the lipid condition metrics and trophic biomarkers of multiple juvenile Alaskan gadid species. Laboratory experiments showed species-specific lipid accumulation rates in Alaskan gadids in relation to temperature. Further, condition metrics of age-0 polar cod (Boreogadus saida) and saffron cod (Eleginus gracilis) collected in the Alaskan Arctic during 2017 were compared to those from earlier field survey years (2012-2014). In both time periods, condition metrics based on lipid parameters were more sensitive than those based on morphometric measurements. Further, age-0 juvenile gadids showed interspecific differences in the spatial distribution of high lipid density fish. Polar cod were in the highest energetic condition in the northern ice-associated Hanna Shoal region, while saffron cod were in better condition in warm nearshore Alaskan Coastal Current waters. Fatty acid biomarkers indicate polar cod have a higher reliance on diatom and *Calanus*-based food webs than saffron cod. Data from the anomalously warm 2017 season indicate a decrease in lipid-based condition metrics in polar cod from the southern Chukchi Sea. These data will be discussed in relation to the importance of lipid storage to overwintering survival in the Alaskan Arctic. Collection of additional inter-annual data will be required to determine how temperature and food quality interact to explain the observed variation in juvenile polar cod lipid density. However, data from laboratory thermal experiments combined with evidence of declining lipid storage during warming ocean events, may indicate that the southern Chukchi Sea regions is warming beyond the thermal limits of polar cod.

Climate-driven change in Arctic zooplankton species composition could decrease feeding success of polar cod larvae

Authors: Caroline Bouchard, Dominique Robert, Louis Fortier

Presenter: **Caroline Bouchard**

Polar cod (Boreogadus saida) is a key species in Arctic marine ecosystems. The feeding success of larvae and age-0 juveniles is hypothesized to dictate recruitment. We investigated the relationships between diet and feeding success in polar cod based on the gut content of 1797 larvae and juveniles 4.5 to 55.6 mm standard length collected from 1993 to 2014 in four Arctic seas. Prey were identified to the lowest possible taxonomical level, measured, and their carbon content was estimated using taxon-specific allometric equations. Feeding success was defined as the ratio of ingested carbon to larval weight. Larval polar cod fed mainly on *Calanus* spp. nauplii (prosome length 0.2-0.5 mm) and acquired the capacity to capture lipid-rich *Calanus glacialis* copepodites (prosome length 0.8-3.3 mm) at a standard length of 9.6 mm. From that size up, feeding success was higher in individuals that had ingested one or more *Calanus glacialis* copepodite. For larvae < 15 mm, catching such a large prey is a relatively rare event (6.5% of larvae) but can represent a "jackpot" accounting for up to 80% of a stomach carbon content. As Arctic seas warms,

zooplankton communities are replaced by boreal assemblages dominated by small, lipid-poor copepods such as *Calanus finmarchicus*. Such changes in the prey field of larval polar cod could decrease the feeding success and subsequent recruitment of the species, with cascading effects on Arctic pelagic food webs.

Barents Sea polar cod in a changing climate

Authors: Frode B. Vikebø, Elena Eriksen, Mats Huserbråten, Harald Gjøsæter

Presenter: **Frode Vikebø**

The polar cod (Boerogadus saida) plays an essential role in the ice-associated Barents Sea food web, linking the lower (i.e. zooplankton) and higher (e.g. other fish, mammals, seabirds) trophic level. Since the early 2000s there has been a large scale distributional shift of boreal species into the Barents Sea owing to a rapid warming and unprecedented ice loss. Although the response of the endemic polar cod to the new dynamical state of the Barents Sea ecosystem is currently unknown, it is well known that their pelagic early life stages (ELSs) are associated with ice, in particular the egg stage shelter underneath the ice. In two recent papers we apply a coupled ocean/particle-trajectory model combined with in situ and experimental data and show how the Barents Sea seascape apparently support separated subpopulation with a low connectivity. Inter-annual variation suggests a rapid reduction of suitable spawning habitats. We quantify how the decaying spawning grounds to a lesser degree support the historic wider habitat of polar cod, considering both variability and trends. Furthermore, by including IBM modules for growth, survival and behaviour we also address increasing sensitivity to a changing environment and discuss potential changing resilience to climate and anthropogenic impacts such as petroleum and transportation.

Associations between seabirds and their prey in the northern Bering Sea during summer of 2017 and 2018

Authors: Bungo Nishizawa, Haruka Hayashi, Nodoka Yamada, Charlie Wright, Kathy J. Kuletz, Hiromichi Ueno, Tohru Mukai, Toru Hirawake, Yutaka Watanuki

Presenter: **Bungo Nishizawa**

In 2018, there was little sea ice in the northern Bering Sea (NBS). Numerous strandings of seabirds (mainly *Uria* spp.) along the coast of St. Lawrence Island and reproductive failure of seabirds breeding on the island were also observed in 2018. To determine the mechanism of these unusual events on seabirds in 2018 in the NBS, we compared boat-based at-sea data on seabird and their prey around St. Lawrence Island in the summer (July) of 2017 and 2018. Seabird density and biomass of potential prey (fish and zooplankton) were measured by at-sea seabird observations and scientific acoustic surveys (38- and 120-kHz transducers), respectively, during T/S Oshoro-maru (Hokkaido University) cruises in both years. At-sea seabird densities in 2018 (planktivorous divers: 5.6 birds/km^2, piscivorous divers: 4.8, surface omnivores: 7.0, short-tailed shearwaters: 0.8) were lower than those in 2017 (planktivorous divers: 9.2 birds/km^2, piscivorous divers: 13.1, surface omnivores: 10.7, short-tailed shearwaters: 10.7). Acoustically-determined biomasses of potential prey in 2018 (fish: 10.5 m^2/NM2, zooplankton: 1132) were also lower than those in 2017 (fish: 19.7 m^2/NM2, zooplankton: 2475). Strongest correlations between seabird density and acoustically-determined biomass of potential prey in 2017 and 2018 were observed at 3- and 30-km scales (among 0.3-, 3-, 10-, and 30-km grids), respectively, indicating that seabirds should search for a larger area (i.e. increasing search cost) in 2018 when prey biomass was lower. Satellite images of our survey region showed that sea

ice concentrations and spring (May) chlorophyll a concentrations in 2018 were lower than those in 2017. Our study suggests that ice-free area with no ice-associated phytoplankton blooms in the NBS may cause low biomass of secondary consumers and hence affect at-sea seabird density and their foraging behaviors.

Changes in female age distribution parameters of severely declining Greenland Sea hooded seals 1958-1999: Clues to ecosystem impacts on a large piscivore marine mammal?

Authors: Anne Kirstine Frie, Tore Haug

Presenter: **Anne Kirstine Frie**

Greenland Sea (GS) hooded seals are thought to have declined from about 1.3 million animals in 1945 to 80,000 in 2012. Most of the decline occurred before 1980, when the stock was reduced to 200,000 individuals. High commercial hunting pressures are assumed to be the main reason for this decline, but major ecosystem changes occurring within the hooded seal habitat may also have affected the stocks sensitivity to hunting. These changes include an unprecedented increase in commercial landings of several potential hooded seal prey species such as redfish, herring, cod, Greenland halibut, capelin and several other species, often leading to severe stock declines.

Hooded seals are large, deep diving animals foraging over the continental shelves off Iceland, the Faroe Islands, mainland Norway and Svalbard. Physical diet data are generally restricted to breeding and moulting patches in the pack ice off Northeast Greenland, where polar cod and the arctic squid Gonatus fabricii are the main prey. Data for Northwest Atlantic hooded seals, however, suggest that commercial species such as redfish, Greenland halibut, cod and herring may form significant parts of the hooded seal diet in offshore habitats, where GS hooded seals are estimated to spend about 60% of their time.

Due to the large reduction in hooded seal abundance, individual fitness indicators of GS hooded seals may have been expected to increase over the 1960s and 70s. However, analyses of mean age at primiparity (MAP) for GS hooded seals over the period 1958-1999 show a significant increase from around 5.0 years up to 1983 to 5.5 years from 1984 to 1999. At the same time female length-at-age and length at first birth decreased between the period 1958-75 and 1980-99, suggesting a reduction in resource levels. Unfortunately, available reproductive and morphometric data are too scarce for meaningful modelling of potential ecosystem impacts.

However, a highly significant ($P<0.01$) negative linear relationship was found between MAP and the proportion of 4 year-olds among the total number of 4 and 5 year-olds (P4_4pl5) in breeding samples, explaining 47.8 % of the annual variance. Based on this, we have used P4_4pl5 as a proxy for MAP to increase the annual resolution using large age distribution samples collected from breeding patches in the 1960s and 70s. This provided 25 years of data and a total sample size of 1479 breeding females over the period 1958-99. Based on these samples we model effects of a wide range of environmental variables on P4_4pl5 in GAM models with binomial errors. Ecosystem variables included in the analysis comprise available data on a range of physical parameters (sea temperatures, breeding ice parameters, storminess) and biological parameters (abundances of various prey species within different parts of the known foraging habitat and population sizes of potential marine mammal competitors). All parameters are investigated with a 1-4 year lag period.

Preliminary results show several significant relationships, but prey species abundance variables appear to be the most important and outweigh physical factors when included in the same model.

Expected Changes in the Physical, Chemical and Phytoplankton Environments in the Subarctic to Arctic Transition Zones in the Atlantic and Pacific Sectors of the Arctic

Authors: Ken Drinkwater, Naomi Harada, Shigeto Nishino, Melissa Cherici, and Benjamin Planque

Presenter: **Ken Drinkwater**

The RACArctic (Resilience and Adaptive Capacity of Arctic marine systems under a changing climate) Project within the Ecosystem Studies of Subarctic and Arctic Seas (ESSAS) program is a joint undertaking by scientists from Japan, the United States and Norway. Its aim is to synthesize information on how variability and anthropogenically-induced changes in advection, temperature, ocean acidity and ice dynamics in the Subarctic to Arctic transition zone may affect future marine ecosystems of the Pacific and Atlantic Arctic. The principal geographic focus in the Atlantic Sector is the Barents and Nordic seas, Fram Strait, and the Nansen Basin while in the Pacific Sector it is the Bering Sea, Bering Strait, the Chukchi and Beaufort seas. In this talk, we present the physical and chemical characteristics of the transition zones and their anticipated future changes under anthropogenic warming. The most robust changes include warming temperatures, reduced sea ice, decreased salinity, stronger stratification, increasing acidification and potential changes in circulation patterns. Impacts of these on phytoplankton and ice algal production and distribution are presented. Some low probably scenarios with high impacts are also included. Finally, we compare and contrast the changes in the Atlantic and Pacific sectors of the Arctic.

Prey resources, food webs, fish and fisheries in rapidly changing Subarctic and Arctic marine systems

Authors: Franz Mueter, Benjamin Planque, George Hunt, Irene Alabia, Sei-ichi Saitoh, Padmini Dalpadado, Lisa Eisner, Yutaka Watanuki, Toru Hirawake

Presenter: **Franz Mueter**

Climate change impacts are particularly pronounced at high latitudes, where warming temperatures, reduced sea ice cover, and ocean acidification affect Subarctic and Arctic marine ecosystems. We present some well-supported scenarios of how changes in the physical environment and in prey resources may affect commercial fish and shellfish populations and their associated fisheries in high-latitude systems. Predicted impacts include shifts in spatial distribution, such as the recent expansion of boreal species to the north in both the Barents and Bering seas; a shift from larger, lipid-rich zooplankton to smaller, less nutritious prey during warm years, with detrimental effects on small fish that primarily rely on high-lipid prey for overwinter survival, such as walleye pollock (Gadus chalcogrammus) in the Bering Sea; a shift from benthic dominated to pelagic dominated food webs in the Arctic; and reduced survival of juvenile crab in waters that are increasingly undersaturated in aragonite. Predicted changes in distribution and abundance are expected to result in disruptions to existing fisheries or the emergence of new fisheries. Some impacts may be irreversible or may be more severe or occur more frequently under anthropogenic climate change than impacts associated with natural variability, posing additional management challenges. To adapt in a changing climate, managers should also consider low-probability events that could have large impacts on fisheries resources, such as a shutdown of overturning circulation in the North Atlantic, the occurrence of Harmful Algal Blooms in the Arctic, or the emergence of new diseases.

Are Fishery Management Systems Prepared for Change? A Comparison of Alaska, Norway, and Japan from the RACArctic Project

Authors: Alan Haynie, Henry P. Huntington, Arne Eide, Amanda Faig, Alf Håkon Hoel, Mitsutaku Makino, Joji Morishita, Franz Mueter, Fujio Ohnishi, Benjamin Planque, Michael F. Sigler

Presenter: **Alan Haynie**

Climate change is altering the marine environment, especially in Arctic and subarctic latitudes. Climate change impacts fisheries management through diverse mechanisms, including spatial shifts that move target species across national borders and introduce new species into ecosystems. Growth and recruitment are also impacted. This paper is an element of the IMBeR and Belmont Foundation supported project, Resilience and adaptive capacity of Arctic marine systems under a changing climate (RACArctic). RACArctic synthesizes information from studies conducted by Japan, USA, and Norway to examine how variability and changes in temperature, ocean acidity, and ice dynamics in the Subarctic to Arctic may affect marine ecosystems and the communities that depend upon them.

It is widely recognized that the nature of management institutions impacts how well fisheries management systems can adapt. Norwegian, U.S., and Japanese systems are by many measures among the most resilient in the world. In an effort to understand how to ensure that marine resource management is prepared for a changing environment, we have examined several of the primary climate-related challenges faced by these three management systems. The Norwegian Barents Sea and U.S. Bering Sea contain large sustainably harvested fisheries while Japan manages many diverse and valuable fisheries. Japan also is a primary consumer of fishery products. We examine how the primary tools of the different management systems – including the ecosystem based management approach, catch shares, and bycatch protection measures – interact with these climate-related challenges.

Several key conclusions arise from this analysis. First, flexible rules allow fishers to adapt to environment and market changes, but some of the rigidities are protective tools (e.g., marine reserves and ecosystem protections) that may provide additional conservatism in a changing environment. Second, spatial shifts of stocks challenge successful management systems and will require improved international management institutions. Finally, fisheries management systems are connected through consumer markets and this integration will also impact the management needs of the future.

Particle flux change reflecting input of Pacific-origin water in the southwestern Canada Basin

Authors: Jonaotaro Onodera, Satoshi Kimura, Motoyo Itoh, Eiji Watanabe, Kohei Mizobata, Yuichiro Tanaka, Naomi Harada

Presenter: **Jonaotaro Onodera**

The transportation of shelf matters from the Chukchi Sea to the Canada Basin has potential for change of biogeography, marine ecosystems, and biogeochemical cycles. In order to monitor the relationship between particle transportation and physical oceanographic conditions, bottom-tethered moorings with a time-series sediment trap were deployed in north of the Barrow Canyon and the northern Hanna Canyon (Station NBC: 72°28'N 155°24'W, Station NHC: 73°18'N 160°47'W) from September 2015 to September 2017. Total mass flux of settling particles at shallower trap depth (160-265 m) reached 2,389 mg m^{-2} d^{-1} and 3,729 mg

$m^{-2} d^{-1}$ at Stations NBC and NHC, respectively. These flux values are one order higher than the previous data in the central Canada Basin and the Northwind Abyssal Plain probably because of the proximity to the shelf. The trapped particles are mainly composed of lithogenic matters (72wt% in all studied samples). Increase of biogenic particle flux was observed at both mooring stations from late October 2016 to January 2017. This event corresponds to the period for temporal lateral advection of Bering shelf water to 50-150 m depth at the mooring position. According to long-term monitoring data on physical oceanography in the Barrow Canyon (upstream of Station NBC), the warming event by input of Pacific-origin water for the late fall season was the first time throughout the mooring period from 2002. This event was probably caused by dominance of northward wind over the Chukchi Sea shelf in fall 2016. The unusual high flux of particulate organic carbon (POC) for the lateral advection event in this study contributed 45-63% of total POC flux at both stations during the second annual deployment period since September 2016.

Glacial meltwater effects on the carbon cycle of Scoresby Sund (Greenland), the world's largest fjord system

Authors: Miriam Seifert, Mario Hoppema, Claudia Burau, Anna Friedrichs, Jana K. Geuer, Uwe John, Torsten Kanzow, Boris P. Koch, Christian Konrad, Helga van der Jagt, Morten H. Iversen

Presenter: **Miriam Seifert**

Climate change induced mass loss of the Greenland Ice Sheet increases the amount of meltwater, which is mainly released into the numerous fjords along the coast of Greenland. Due to its low salinity and high silt load, meltwater can profoundly affect the biogeochemical cycling of carbon. We visited the world's largest fjord system, Scoresby Sund at the eastern coast of Greenland, and its northernmost branch, Nordvestfjord, in the summer of 2016 for investigating biogeochemical carbon cycling. The data reveal that meltwater limited the productivity by inhibiting the resupply of nutrients to the surface and by shadowing the upper part of the water column by the introduction of silts. These silts, though, increased the export of organic carbon to depth by ballasting the sinking organic particles. While the region close to the fjord entrance was influenced by shelf waters, the water column within Nordvestfjord was significantly modulated by meltwater input from a number of marine- and land-terminating glaciers. Our results show that there was a clear gradient from a productive system with efficient remineralization at the mouth of the fjord to a less productive system with a high carbon export towards the inner fjord parts. These results imply that Scoresby Sund can be seen as a hotspot of carbon burial.

Inter-annual variability of organic carbon concentration in the eastern Fram Strait during summer (2009-2017)

Authors: Anja Engel, Astrid Bracher, Tilman Dinter, Sonja Endres, Julia Grosse, Katja Metfies, Ilka Peeken, Judith Piontek, Ian Salter and Eva-Maria Nöthig

Presenter: **Anja Engel**

The Arctic Ocean plays a key role in regulating the global climate, while being highly sensitive to climate change. Temperature in the Arctic increases faster than the global average causing a loss of multiyear sea-ice and affecting marine ecosystem structure and functioning. As a result, Arctic primary production and biogeochemical cycling are changing. Here, we investigated interannual changes in the concentrations of

particulate and dissolved organic carbon (POC, DOC) together with biological drivers, such as phyto- and bacterioplankton abundance in the Fram Strait, the Atlantic gateway to the Central Arctic Ocean. Data were collected in summer at the Long-Term Ecological Research observatory HAUSGARTEN during eight cruises from 2009 to 2017. Our results suggest that the dynamic physical system of the Fram Strait induces strong heterogeneity of the ecosystem that displays considerable intra-seasonal as well as inter-annual variability. Over the observational period, DOC concentrations were significant negatively related to temperature and salinity suggesting that outflow of Central Arctic waters carrying a high DOC load is the main control of DOC concentration in this region. POC concentration was not linked to temperature or salinity but tightly related to phytoplankton biomass as estimated from chlorophyll-a concentrations (Chl-a). For the years 2009-2017 no temporal trends in the depth-integrated (0-100m) amounts of DOC and Chl-a were observed. In contrast, depth-integrated (0-100m) amounts of POC as well as the ratio [POC]:[TOC] decreased significantly over time. This suggests a higher partitioning of organic carbon into the dissolved phase. Potential causes and consequences of the observed changes in organic carbon stocks for food-web structure and CO_2 sequestration are discussed.

Impact of sea ice/snow distribution on the seasonal and inter-annual variability of ocean primary production and carbon export flux in Baffin Bay: a 1D modeling approach

Authors: Gaëtan Olivier, Laurent Memery

Presenter: **Olivier Gaëtan**

The main objective of the Green Edge project is to understand the impact of climate change on the evolution of Primary Production (PP) at different scales (from regional to pan-Arctic), with its repercussion on ecosystems, biogeochemical fluxes (in particular carbon export) and societies. In this general framework, based on 1D modeling, this study focuses on understanding the factors controlling and regulating the development of phytoplankton bloom at the edge and under the sea ice, accounting for more than 50% of the global Arctic PP. The coupled NEMO (circulation) –LIM (sea ice) -PISCES (carbon cycle) model is used to estimate the seasonal and inter-annual variability of PP and associated fluxes. Based on a 15-year 1D simulation forced by the CGRF-GDPS (2002-2017) dataset, the simulation is validated against in situ data gathered at the Green Edge ice camp, south of Qikiqtarjuaq Island. The discussion will emphasize the impact of the disappearance of the snow, as well as the melting of sea ice on the light and nutrient (stratification) availability driving the onset and the fate of the bloom. The impact of the timing and intensity of the bloom on the export production will be analyzed as well.

Effect of the anthropogenic nitrogen on Arctic amplification in present and future climate

Authors: Hyung-Gyu Lim, Jong-Seong Kug

Presenter: **Hyung-Gyu Lim**

In conjunction with increasing carbon dioxide (CO_2), human activities such as fossil fuel combustion, land use change, nitrogen fertilizer for agriculture, livestock, and human waste are also accelerating the creation of reactive nitrogen (Nr). The nitrification of Nr in the ocean transforms the inorganic nitrate, that disturbs oceanic nitrogen and related carbon cycles while it was controlled by natural biogeochemical cycles. While the general consensus has been that anthropogenic Nr modulates the oceanic biogeochemical stoichiometry, the impact of anthropogenic Nr on the climate warming is uncomprehended. Using an GFDL CM2.1, we investigate the impact of the anthropogenic Nr on the Arctic warming in the future climate (1% increase until doubled CO_2) by comparing idealized experiments of different sets based on external forcings of preindustrial and contemporary amounts of the atmospheric Nr and runoff Nr fluxes. During the saturated year of doubled CO_2 2071-2100, the impact of anthropogenic Nr fluxes generate the positive chlorophyll anomaly in the future Arctic Ocean where the limiting condition of nitrogen dominates for the phytoplankton activity. The shortwave absorption rate on the Arctic Ocean surface is reinforced by the less depletion of the Arctic nitrate inventory and associated positive chlorophyll response. Thus, the additional shortwave heating is generated by anthropogenic Nr fluxes, that enhances the previously suggested Arctic warming amplified by the biogeophysical feedback. This study firstly suggested the possible mechanism that the accelerating nitrogen cycle by human activities can influence on the Arctic climate change via the marine phytoplankton response and its biogeophysical feedback process.

The glacier-influenced coastal Svalbard waters as a habitat for protists and zooplankton

Authors: Emilia Trudnowska, Boehnke R., Kubiszyn A., Zajączkowski M., Blachowiak-Samolyk K.

Presenter: **Emilia Trudnowska**

Most of Svalbard coastal waters are strongly affected by the glacier retreat as an effect of progressing climate warming. The glacier plumes can be distributed over many kilometres in a form of “brown zones”, which has a substantial impact on many physical and ecological processes occurring in the Arctic marine ecosystems.
In this study we took an effort to characterize the environmental conditions (hydrography, turbidity, marine aggregates concentrations) in the glacial-influenced waters and to relate this to the abundance and species composition of phytoplankton, protists and zooplankton. The study was performed in fjords (Wijdefjorden, Rijpfjorden) as well as in coastal waters close to the glaciers that terminate on large Svalbard islands (Nordaustlandet, Edgeøya) in the summer of 2016. The high resolution automatic measurements of the turbidity sensor and the Laser Optical Plankton Counter (LOPC) were performed in order to analyse the size spectra and abundance of particles and marine aggregates within the water column. The LOPC platform was equipped with CTD and fluorometer sensors in order to analyse also the hydrographical and algal conditions. Additionally, to investigate nano- to mesoplankton taxonomic composition and abundance, traditional plankton samples via nets and Niskin bottles were collected.
We observed different influence of the glacier-derived waters in fjords compared to open sea terminating areas in the case of the turbidity gradients and the vertical and horizontal spread of marine aggregates. Moreover, well recognized gradients in water salinity and particles concentrations from glacier fronts towards open waters did not correspond to the changes in any of the biological components. The results provide a new data of particles and plankton concentrations and size structure in coastal waters near glaciers, which is essential knowledge for future estimations of Arctic coastal ecosystems functioning under rapid glacier retreat caused by the climate changes. Therefore these unique observations can constitute an important premise for predicting future changes scenarios on production and feeding conditions for marine biota.

Ecological plasticity – a key skill to survive in a changing Arctic, tested on *Calanus* – the basis of the high latitude marine food webs.

Authors: Trudnowska Emilia, Gluchowska M., Balazy K., Stoń-Egiert J., Brown T.

Presenter: **Emilia Trudnowska**

If we are to understand the actual and to predict the future functionality of north polar marine ecosystems, we definitely need to recognize the susceptibility of the key ecosystem components to the climate oscillations.
Copepods of the genus *Calanus* are the key components of zooplankton in the Arctic and Atlantic waters. Due to their high lipid content they are responsible for the sustainability of large stocks of fish, birds, and mammals. Although particular *Calanus* species are morphologically very similar, they have different life cycle strategies, centres of distribution and roles in the ecosystems. Therefore so far they have been highly valued as one of the best known biological indicators of the hydrographical-ecological regimes and consequently of the effects of the ongoing climatic changes. However, due to problems with proper *Calanus* species identification, the knowledge about their ecological plasticity and functioning in various oceanic conditions is still very limited.
The aim of the study is to verify the actual differences between C. finmarchicus and C. glacialis with regard to their ecological plasticity. Our hypothesis is that the studied species' traits (e.g. size, pigmentation, population demography, lipid content, diet) will differ depending on the fact if particular species inhabit the preferable water mass or exist in suboptimal conditions (due to temperature, competition). Therefore the study was performed both in the waters from each particular species originate from (the Atlantic domain for C. finmarchicus and the Arctic domain in the case of C. glacialis) as well as in the waters in which they coexist (inside Hornsund fjord, Spitsbergen).
The proper identification of species was related to their life strategies and ecological plasticity traits, i.e. population demography, gonad maturation, lipid storage and utilisation strategies, diet (analysed on the basis of fatty acids and stable isotopes). It is the first study to incorporate so many aspects (various species identification methods, including molecular tools, and crucial traits of life history strategies) in order to improve our taxonomical and ecological species recognition, which is regarded as the main prerequisite for predicting future ecosystem shifts in northern hemisphere.

Isfjorden Marine Observatory Svalbard: seasonal and long term trends in Arctic zooplankton communities

Authors: Malin Daase, Ksenia Kosobokova, Kasia Dmoch, Igor Berchenko, Denis Moiseev, Maja Hatlebakk, Barbara Niehoff, Ragnheid Skogseth, Jørgen Berge, Janne E. Søreide

Presenter: **Malin Daase**

Isfjorden is the largest fjord system in Svalbard, located at the west coast of Svalbard (78oN). The hydrography in Isfjorden ranges from boreal characteristics (Atlantic water masses, no sea ice) in the outer part to Arctic conditions in the innermost part of the fjord system (sub-zero water temperatures, seasonal ice over). Consequently, the zooplankton community consists of a mix of boreal and Arctic species with a dominance of boreal species in the outer part and Arctic species in the inner part. Isfjorden Marine Observatory Svalbard (IMOS) aims at capturing seasonal, annual and decadal changes in the plankton community. The presences of permanent research infrastructure in Isfjorden (Barentsburg, Longyearbyen) and the frequency of visiting research vessels make regular, year round sampling feasible – a prerequisites for maintaining long time series. In addition to new data collected within the framework of IMOS, we have also made an effort to compile and analyse zooplankton data collected in the fjord system over the last 20 years. Our data show that the seasonal variability in the Isfjorden zooplankton community composition is stronger than the interannual variability, highlighting the need of high seasonal resolution in Arctic time series to differentiate between natural variability and persistent changes in plankton communities. While boreal species may dominate the community in summer and autumn, Arctic species prevail in spring, suggesting that the Atlantification of the zooplankton community in Isfjorden is hampered by the long, dark and unproductive winter. Long term data on the population dynamics of dominant *Calanus* species show high flexibility and robustness in the Arctic C. glacialis, being abundant in both ice-free and seasonal ice covered regions of the fjord system, compared to C. finmarchicus, who predominately occurs in the warm, ice free area.

Overlooked Contribution of the Biological Pump to the Pacific Arctic Nitrogen Deficit

Authors: Hongliang Li, Jianfang Chen, Diana Ruiz-Pino, Jingjing Zhang, Haiyan Jin, Yanpei Zhuang, Youcheng Bai

Presenter: **Hongliang Li**

While most nutrients biogeochemical studies have found the phenomenon of nitrogen deficit and low ratios of nitrate/phosphate in the upper Pacific Arctic Ocean induced by sedimentary denitrification, it remains unclear whether the biological pump may also modulate nutrient properties of the Arctic seawater. Here, we show that nitrate concentrations of the Pacific inflow gradually decrease northward in association with notable biological utilization. The phytoplankton assimilation, in combination with efficient vertical nitrogen export via sinking particles, serves to preferentially remove nitrogen (relative to phosphorus) from upper waters, thereby further intensifying the Arctic nitrogen deficit. The magnitude of this biological pump removal of nitrogen from the water column may be as great as half the nitrogen loss ascribed to sedimentary denitrification. Our findings suggest that biological utilization of nutrients in the Chukchi Sea may significantly contribute to the conditions of nitrogen limitation and excess phosphorus in the Arctic and North Atlantic oceans.

SESSION 3: BIOGEOCHEMICAL AND BIOLOGICAL PROCESSES PROMOTED BY OCEAN MIXING

Progress report: Ocean mixing processes: impact on biogeochemistry, climate and ecosystems (OMIX)

Authors: Ichiro Yasuda, OMIX members

Presenter: **Ichiro Yasuda**

Plans and progress report will be overviewed for the 5-year Japanese project ‘Ocean mixing processes: impact on biogeochemistry, climate and ecosystem (OMIX)’ which were launched in July 2015. A new turbulence observing system using fast response thermistors was developed and contributed to widen microstructure measurements which begin to show basin-scale surface-bottom turbulence distribution in the western North Pacific. The data are helping to revise the model turbulence field. Those large numbers of in-situ turbulence observations and modelling including biogeochemical parameters lead to findings such as turbulence hot spots in the Kuroshio and the Oyashio and roles of turbulent fluxes of macro- and micro-nutrients on ecosystem. Microscale otolith stable isotope analysis is developed to elucidate the life history of chub mackerel. These results are now being synthesized to models with vertical mixing distribution and its 18.6-year period modulation, which could make clear how mixing impacts on ocean circulation, ecosystem, climate and their long-term variability.

Dense water formation in the Northwestern Mediterranean: from the physical forcings to the biogeochemical consequences

Authors: C. Estournel, P. Conan, P. Testor, F. D'Ortenzio, X. Durrieu de Madron

Presenter: **Claude Estournel**

One of the general characteristics of the Mediterranean is its oligotrophy that affects biological productivity. However, there are some areas where particular oceanographic and atmospheric conditions generate intense vertical mixing of the water column in winter. These convective areas are located in the northern half of the Mediterranean (Gulf of Lion, Adriatic Sea, Aegean Sea, northern Levantine Basin).

Dense water formation has important implications for the hydrodynamics, biogeochemistry and vitality of Mediterranean ecosystems. This process regulates the characteristics of the intermediate and deep water masses that contribute to the general circulation of the Mediterranean. It also injects massive amounts of nutrients into the surface layer, triggering large spring planktonic blooms and exporting organic matter and oxygen to the deep layers.

The Mediterranean is particularly sensitive to climate change. A reduction in dense water formation as indicated by some scenarios could dramatically affect the characteristics of water masses, nutrient balances and ecosystem functioning.

To better characterize and understand dense water formation in the northwestern Mediterranean and its biogeochemical consequences, a major experiment, DEWEX (DEep Water EXperiment), was carried out in 2012-2013 in the framework of the HYMEX, MERMEX, and NAOS projects. This one-year experiment combined data from oceanographic vessels, satellite images and various instrumented autonomous platforms (gliders, moorings and profiling floats).

These efforts provided a unique and comprehensive data set that allowed for an accurate description of the seasonal cycle of oceanic and biogeochemical components and is a valuable case study for the modelling community. The results allowed a better understanding of dense water formation and also revealed important dynamic processes at small scale.

The measurements revealed that convection during the winter of 2013 was particularly intense. The mixing reached the bottom at a depth of 2500 m and formed a significant amount of dense water, increasing the temperature, salinity and density of the bottom waters. The monitoring of the interannual variability of convection in the Gulf of Lions, as part of the MOOSE observation system, showed that deep-water formations occurred each winter between 2009 and 2013, making it a period of intense air-sea interactions compared to what was observed before and after.
The combination of in-situ, satellite measurements, and modelling made it possible to reconstruct the distribution of chlorophyll-a throughout the annual cycle in the different bioregions, defined by their maximum mixing depth. The extent of the area affected by convection strongly influences the intensity of the spring bloom. A 3-D high-resolution coupled hydrodynamic-biogeochemical model carefully verified with the DEWEX dataset was used to study phytoplankton dynamics and biogeochemical and physical carbon fluxes in three distinct regions of the western Mediterranean Sea. Despite seasonal variations, annual primary production in all three regions was similar. In the deep convection region, total organic carbon export transfer to deep waters (800 m) was 8 times higher than in the Algerian subbasin. The northwestern Mediterranean is therefore a source of organic nitrogen and phosphorus throughout the water column for the surrounding regions and a sink of nitrate and phosphate in intermediate layers.

The impact of Antarctic sea ice on surface mixing and primary production

Authors: Mark Hague, Marcello Vichi

Presenter: **Mark Hague**

Sea ice has long been recognised as playing an important role in biogeochemical processes. During the winter months it acts as the interface between ocean and atmosphere, modulating surface fluxes of heat and momentum, while in summer and spring melt waters significantly alter the vertical salinity profile. Hence, in all seasons sea ice strongly affects vertical mixing and therefore impacts the availability of both light and nutrients.
Since Earth System Models seek to represent these processes and their evolution in a changing climate, it is important that we identify and diagnose key shortcomings such models may have. While the relationship between sea ice and seasonal growth has received some attention in the Arctic, relatively few studies have investigated the unique Antarctic sea ice environment.
In a recent publication we outline the principal mechanisms controlling vertical mixing and seasonal growth (phenology) in the Atlantic Marginal Ice Zone (MIZ) of the Southern Ocean, focussing on CMIP5 models. We found that models tended to overly stratify the water column within the MIZ, leading to early growth when compared to satellite observations. We suggest that this could be linked to an inability of models to represent the exchange of heat and momentum within the MIZ. Such biases in phenology and mixing have important consequences for the representation of future climate, since both processes affect how carbon is cycled in the Southern Ocean.

Seasonal modulation of nutrients cycles and phytoplankton biomass by submesoscale circulation in the California Current System

Authors: Faycal Kessouri, Daniele Bianchi, James C McWilliams, Lionel Renault, Hartmut Frenzel, Curtis Deutsch

Presenter: **Faycal Kessouri**

Seasonal wind-driven upwelling supports phytoplankton blooms that turn the California Current into one of the most productive ecosystems of the ocean. This upwelling is confined to a narrow near-shore band that is poorly resolved by current physical-biogeochemical models. Further offshore, mesoscale eddies counteract the upwelling by removing surface nutrients through subduction. However, the impact of submesoscale motions on upwelling and subduction of productivity has not yet been quantified. Here, we present results from three sets of simulations with a regional physical-biogeochemical model of the California Current run at the resolutions of 4 km, 1 km and 300 m respectively. The 300m focuses only on the Southern California Bight (SCB). We will demonstrate the role of the submesoscale dynamics via three processes: First, submesoscale dynamics generated by increased frontogenesis during spring, controls up to 50% the vertical eddy transport of nutrients across the euphotic layer, reducing plankton productivity, and exporting biomass out of the euphotic layer during the post-upwelling period. Second, in the offshore oligotrophic region, submesoscale eddies intensify the vertical velocities in winter, driving injection of nutrients from enriched thermocline to the depleted mixed layer and maintain productivity in the deep chlorophyll depth. Lastly, we will demonstrate how submesoscale eddies emphasizing the generation of topographic wakes in Channel Islands (SCB) and promoting very high productivity all year around.

Deceleration of particle sinking by ocean surface turbulence

Authors: Yutaka Yoshikawa, Takahiro Mannen

Presenter: **Yutaka Yoshikawa**

Dissolved carbon in the ocean is absorbed into phytoplankton through photosynthesis. When the phytoplankton is died, it sinks as particle (called as marine snow). Associated with this sinking, carbon is transported into the abyssal ocean. This vertical transport process of carbon is referred to as biological pump, and is considered as one important pathway of carbon from the atmosphere into the abyssal oceans. Particles in the ocean tend to sink due to its own gravity, but fluid motion accelerates and/or decelerates their sinking speed. Previous studies showed that sinking speed of particles with less inertia such as phytoplankton in the ocean is neither accelerated nor decelerated by the turbulence (e.g., Maxey 1987); Turbulence accelerates some particle's sinking and decelerates the other particle's sinking, and net effects of the turbulence is nil.

In the present study, we performed numerical experiments to test the above result in the ocean mixed layer. Large-eddy simulations were performed to simulate wind-induced turbulence, and passive particles with its own settling velocity were deployed continuously and tracked. We found that turbulence can decelerates sinking speed of inertia-less particle, if the settling speed of the particle is similar to the characteristic turbulent flow speed, and if the particles start to sink within the mixed layer rather than from the ocean surface. This deceleration can be explained by vortex trapping (Stommel 1949): turbulent vortex traps the particles that start to sink in the vortex.

Response of lower trophic level ecosystems to decadal scale variation of climate system in the North Pacific Ocean

Authors: Maki Noguchi Aita, Kazuaki Tadokoro, Akira Kuwata, Taketo Hashioka, Naomi Harada

Presenter: **Maki Aita**

The changes related to interdecadal climate variations, such as the Pacific Decadal Oscillation and the 18.6–y tidal cycle, have been discussed in many marine ecosystem studies. By analyzing data from observation of nutrient concentrations, decreasing and increasing trends of nutrients in the surface and subsurface layers, have been reported in many studies. Changes have also been observed in the biomass of phytoplankton and zooplankton. To clarify variability of lower trophic level productivity and its controlling factor, we simulated changes in the marine ecosystem caused by interdecadal climate variability, using data from 1948 to 2009 to drive an ecosystem model, NEMURO, embedded in a global three-dimensional physical–biological coupled model, 'COCO-NEMURO'. Furthermore, we compared and verified ecosystem model results with observations of the species composition data collected by the Fisheries Research Agency (FRA) and Japan Meteorological Agency (JMA). Our model results showed that changes in biomass and nutrient concentration greatly differ depending on the region. According to our model results, sea surface temperature (SST) was very low during mid 1960s to mid 1970s, then SST increased after the mid 1970s to the end of 1990s in the western subarctic North Pacific. Changes in phytoplankton biomass was follow to this. However, the change in SST and phytoplankton and zooplankton biomass were contrary to this in the western subtropical North Pacific. To elucidate the mechanism that sustains marine ecosystems, we will also analyze focusing on primary producers and zooplankton to key link to higher trophic levels.

Short-term changes in carbon and nitrogen biomass of picophytoplankton over a 10-day period at a station off St. Helena Bay

Authors: Zimkhita Gebe, Coleen L. Moloney, Emma Rocke, Maya C. Pfaff

Presenter: **Zimkhita Gebe**

This study quantifies the contributions of three picophytoplankton groups (Synechococcus, Prochlorococcus and picoeukaryotes) in total picophytoplankton carbon biomass. It also looks to relate picophytoplankton biomass patterns to estimates of primary production, particulate organic carbon and chlorophyll. Informed by an investigation of spatio-temporal variability of picophytoplankton groups along four monitoring lines in the southern Benguela, a station off Elands Bay was identified for a short-term study of these targeted groups and other molecular and biogeochemical measurements. Sampling was conducted every day for ten days at the surface and at 10 m (15 m on the first day) and pre-filtered through a 200 µm mesh sieve. Flow cytometry was employed to enumerate the three targeted groups and the abundances were converted into carbon biomass. Nutrients were sampled simultaneously at the study site and analysed by the Department of Oceanography. Sampling days were categorized into three water types, unstratified water exhibited by a homogenous temperature and density in the water column from day 1 till day 4, stratification from day 5 to day 10 due to high temperatures at the sea surface causing stratification in the water column could further be distinguished by the presence of the thermocline coupled with a pycnocline to exhibit low-density stratification and high-density stratification above and below the pycnocline, respectively. Using total picophytoplankton biomass (sum of the three groups) principle component analysis plots were generated to assess total picophytoplankton biomass grouped according to water type and results showed that biomass for each water type was relatively different. Overlaying the negatively correlated nitrate (NO3), ammonium (NH4), and dissolved oxygen (DO) as an indication of photosynthesis in the water column, DO seemed to be driving picophytoplankton biomass in the low density stratified water type at both depths and taking up nitrate and ammonium in the high density stratified water types at 10 m. Biomass in the unstratified water seemed to not be driven by any of the correlated nutrients. An ADONIS test showed that picophytoplankton biomass varied significantly according to their inhabiting water types during the sampling period, with R2 = 0.501 and p = 0.001. An in-depth investigation using the data is still in progress.

Impact of submesoscale processes on phytoplankton community structure across oceanic fronts

Authors: Inès Mangolte, Marina Lévy, Stephanie Dutkiewicz, Oliver Jahn, Sophie Clayton

Presenter: **Inès Mangolte**

Although limited, recent observations suggest that submesoscale fronts act to structure phytoplankton communities. Here we use a modeling framework to explore a set of processes that could alter phytoplankton communities in fronts. The first process is the supply of nutrients by the vertical frontal circulation that could stimulate phytoplankton growth and favor «opportunist» species which are more rapidly responsive to local nutrient injections (active process). The second process is the lateral mixing of different communities at the scale of mesoscale eddies and fronts (passive process). The third process is the reaction of the existing community to these active and passive processes. We use a diverse ocean ecosystem model to investigate the contribution of these processes to the phytoplankton community structure. The ecosystem model is trait-based and resolves 35 phytoplankton phenotypes, differentiated by their biogeochemical functional and cell size (which sets their respective nutrient affinity, growth rates, light absorption, sinking rates and grazing). The physical model is a submesoscale-permitting, seasonally varying idealized representation of a two-gyre basin analogous to the Gulf Stream or the Kuroshio. We find that all three of the community structuring processes described above can be identified at different fronts in the model. We also find, that on average, diatom abundances are higher at submesoscale fronts, indicating a strong and consistently active response of opportunists to nutrient injections within these frontal features.

The Kuroshio Subsurface Water Intrusion onto the East China Sea continental shelf as traced by dissolved inorganic iodine species

Authors: Peng Zhou, Xiuxian Song, Yongquan Yuan, Wentao Wang, Lianbao Chi, Xihua Cao, Zhiming Yu

Presenter: **Peng Zhou**

The circulation systems and ecological environment of the East China Sea (ECS) are greatly influenced by the Kuroshio. The nutrient-rich Kuroshio Subsurface Water (KSSW) has been subject to considerable research attention, but the intrusion pathway, extent and variation of the KSSW over the entire southern ECS shelf are still debated. In in spring of 2014, autumn of 2014 and spring of 2015, the dissolved inorganic iodine species (DIIS) were determined, and hydrographic data were collected and analyzed in the southern ECS. Our study shows that a unique iodate-rich (>0.37 μM) and iodide-poor (<0.10 μM) water occurred at the bottom of the ECS shelf, and this water always exhibits cold, saline and dense characteristics. The characteristics of this water are similar to those of the KSSW and obviously distinct from other water masses in the ECS. The evidence from both the DIIS and hydrographic data suggest that the KSSW mainly intrudes onto the ECS shelf from northeast of Taiwan (25.5 °N) via upwelling. However, in addition to the main intrusion center northeast of Taiwan, the DIIS concentrations indicate that another weaker intrusion from the KSSW occurs at ~28 °N along the shelf edge. This phenomenon can not be observed via hydrographic data alone; in addition, the DIIS have good linear relationships with the hydrographic data during the KSSW intrusion. Thus, the DIIS can be used as complementary and effective tracers of the KSSW intrusion.

Based on the characteristics of the DIIS and hydrographic data, we determined the thickness of the KSSW intrusion (depth from the upper boundary of the KSSW intrusion to the seabed) at each station, which was used to draw the intrusion pattern of the KSSW on the ECS shelf. In spring of 2014 and 2015, the KSSW intrusion northeast of Taiwan flowed northwestward then bifurcated into a nearshore branch and an offshore branch at 27.5-28.5 °N. The nearshore branch flowed approximately northward and finally appeared in the subsurface layer within the 50-m isobath off the Zhejiang coast (north of 29 °N); the offshore branch flowed along the 100-m isobath and reached north of 29 °N. The KSSW intrusion northeast of Taiwan was obviously weaker in autumn than that in spring. In autumn, the nearshore branch was not observed, and the offshore branch reached only ~28 °N. The KSSW intrusion in the ECS shows significant seasonal variation. When comparing the KSSW intrusion in spring of 2014 and 2015, the KSSW intrusion northeast of Taiwan in spring of 2015 intruded northernmost off the Zhejiang coast in the nearshore area, but was weakest in the southern region (south of 28 °N), this may because the center of the KSSW intrusion northeast of Taiwan was shifted seaward. The KSSW intrusion in the ECS also has the feature of interannual variation.

Monsoon and El Nino regulated biological pump in the South China Sea based on long-term sediment trap mooring

Authors: Jianfang Chen, Martin G Wiesner, Hongliang Li, Lihua Ran, Jingjing Zhang

Presenter: **Jianfang Chen**

Ocean Margins play a key role in the marine carbon cycle. South China Sea (SCS) is among the biggest marginal seas in the world, the marine environment and upper ocean biological processes are largely controlled by East Asia monsoon and El Nino event. In this presentation we will discuss the seasonal and inter-annually variation of the biological pump at the five locations in the northern South China Sea based on multi-year observation of biological pump by time series sediment traps since 1987 up to now. Generally, the monthly averaged biogenic flux (CaCO3, Opal and POC) in the northern SCS exhibits strong seasonality with prominent peak in winter during northeastern monsoon period, attributed to a positive response of diatom growth to increased nutrient supply from the subsurface as a result of enhanced vertical mixing. On the contrary, strong stratification and the southwest monsoon induced basin-scale anti-cyclonic circulation resulted in low productivity in summer. On the other hand, higher biogenic fluxes could also induced by upwelling/meso-scale eddy and short-term events such as the Asian dust storms. The inter-annually variation of the biological pump in SCS was controlled by ENSO induced oceanographic variability in northern SCS, the most distinct consequences was low diatom and biogenic fluxes was observed during ENSO dominant period. Our results will compared with the previous reports on monsoon derived biological pump in the Arabian Sea and Bay of Bengal based on sediment traps by German and Indian scientists.

Seasonal and interannual variation of mesozooplankton community structure in the Oyashio and Kuroshio-Oyashio Transition waters, western North Pacific

Authors: Kazuaki Tadokoro, Yuji Okazaki and Hiromi Kasai

Presenter: **Kazuaki Tadokoro**

The Fisheries Research Agency has carried out monitoring on the A-line (http://tnfri.fra.affrc.go.jp/seika/a-line/a-line_index2.html) in the Oyashio (after OY) and Kuroshi-Oyashio Transition (after TR) waters since 1987. We investigated the seasonal and interannual variation of the mesozooplankton community structure in both waters based on 5 time cruises per year (January, March, May, July and October) from 2007 to 2017. Samples were collected by vertical haul of Norpac Net (45cm mouth diameter, 0.33 mm mesh size) from 0m to 150 m, except at a coastal station (0 m to 90 m). We classified observation stations into four communities as cold community-1 (CO1), cold community-2 (CO_2), mixed community of cold and warm (MIX), and warm community (WA) by using cluster analysis. MIX and WA mainly appeared in TR from throughout year. On the other hand, community structure represented seasonal change in OY. Although CO1 mainly appeared from January to March, cold CO_2 mainly appeared from May to July. From May to July, ontogenetic migrant species e.g. *Neocalanus* spp. appeared in OY and it is cause of the change of the community group in OY. In October, MIX mainly appeared in OY. It might be related the increase in the water temperature in the surface layer. Geographical change of the distribution of MIX also appeared. Northern limit of MIX shifted to north in the 2015 and the 2016 and it corresponded with increase of salinity and temperature in those areas. Our results indicated that the community structure of mesozooplankton seasonally and interannually changes related to the environmental changes and ontogenetic migration of mesozooplankton.

Mechanisms responsible for intraseasonal variations of the spring phytoplankton bloom

Authors: Keerthi Madhavan Girijakumari, Olivier Aumont, Marina Levy, Matthieu Lengaigne, David Antoine

Presenter: **Keerthi Madhavan Girijakumari**

Ocean color data reveal large surface chlorophyll (SChl) fluctuations at intraseasonal timescales in regions with a spring bloom. Here we quantify these fluctuations and relate them to physical forcing mechanisms in the deep winter convection zone located in the northwestern Mediterranean Sea. We use 8-day merged ocean color products, in situ data from the long-term time series BOUSSOLE and mixed-layer depths (MLD) from the MERCATOR reanalysis. We partition the SChl and MLD time series into three components: intraseasonal, seasonal and interannual timescales. Comparison of the different products at the BOUSSOLE site shows that the satellite and reanalysis products are reliable at the sub-monthly timescale. We show that intraseasonal variability explains nearly half of the SChl variability in this region. Importanly, we show that the spatial scales of intraseasonal variability are small (~100 km) and tied to intraseasonal fluctuations of the mixed layer depth at similar scales. Based on this result, we discuss the potential cause of these intraseasonal fluctuations.

Budget of dissolved oxygen in the western Mediterranean sea during the deep convective year 2012-2013

Authors: Caroline Ulses, C. Estournel, L. Coppola, P. Marsaleix, M. Fourrier, F. Kessouri

Presenter: **Caroline Ulses**

The aim of the DEWEX project was to investigate the impact of deep convection on biogeochemical fluxes in the northwestern Mediterranean. Three cruises and deployments of Argo floats allowed intensive observation of this region before, during and just after the intense deep convection episode of January-March 2013. In particular, observations suggest a rapid intake of atmospheric dissolved oxygen during the intense vertical mixing period, which greatly influenced the O_2 content in the entire water column. However, these observations, which remain punctual in time and space, do not make it possible to quantify the contribution of ingassing/outgassing, primary production/respiration and lateral import/export in the variation of O_2 inventory during and after the convective episode, as well as to understand the post-convection fate of atmospheric oxygen injected into the sea interior.
We use a coupled physical-biogeochemical model to perform a dissolved oxygen budget over the period September 2012-September 2013. After showing that the simulated dissolved oxygen concentrations are in good agreement with the observations, we analyze and quantify the hydrodynamic and biogeochemical fluxes of O_2. We show that the air-to-sea fluxes in the deep convection zone exceeded 500 mmol O_2 m^{-2} d^{-1} during the deepening of the mixing layer. We estimate that 15 mol m^{-2} of atmospheric O_2 was absorbed in the deep convection region during the convection process. The model shows that atmospheric dissolved oxygen absorbed was transferred under the euphotic zone reaching the deep layer of the zone (> 800 m). It was then gradually exported, notably, through the spreading of dense waters recently formed, to the south and west of the basin.
Recent hydrodynamic scenarios predict a decline in deep convection in this region by the end of the century. This could have important consequences on the ventilation of the Mediterranean for O_2 and the O_2 exchanges with the Atlantic Ocean that should be addressed in a context of low-oxygen zones expansion.

Hypoxia: A rising physical-biogeochemical coupled issue driven by the estuary-shelf-slope interactions in the East China Sea

Authors: Feng Zhou, Daji Huang, Fei Chai, Jiliang Xuan, Huijie Xue, Xiaobo Ni, Xiao Ma, Peng Xiu

Presenter: **Feng Zhou**

Hypoxia, as one of the attractive marine environmental issues, was observed off the Changjiang Estuary in the early 1960s and recently has been getting more severe in the recent decade in terms of both the minimum dissolved oxygen concentration and hypoxic extent. The consumption of oxygen is a result of massive phytoplankton blooms at this area, which are associated with considerable amount of both riverine and oceanic nutrients contributed mostly by the Changjiang River and the Kuroshio. This study aims at understanding how the cross-shelf exchange varies spatially and temporally, particularly at the shelf break, and also at understanding to what extent and how the exchange between the shelf break and the open ocean could affect the development of hypoxia, especially for the year 2006 when a significant amount of high salinity water and one of the largest extent of hypoxia were identified north of the Changjiang in the summer. The role of the Kuroshio intrusion will also be discussed in terms of two aspects: The first is how many Kuroshio-related nutrients are transported to the mid-shelf and the estuary, and their contributions to the phytoplankton blooms? The second is how much the low dissolved oxygen water from the shelf break is transported to the mid-shelf and the estuary, and thus reduces the concentration of DO before and during the period when hypoxia usually occurs? It was demonstrated from both observations and simulations that

in 2006 high saline water could be delivered to the north of the Changjiang River mouth (near 32ºN) as a result of stronger-than-normal cross-shelf exchanges at the shelf break and flows through the Taiwan Strait. The stronger intrusion in turn explains the northward shift of the hypoxic zone in the year. Sensitivity analysis also suggested that the hypoxia extent was affected by the change in nutrient concentration of the Changjiang as well as that of the Kuroshio. Increase in nutrient in the river discharge and the Kuroshio both led to an expansion of hypoxic water during the summer monsoon. The comprehensive investigation suggested that the effective way to relieve the hypoxia stress off the estuary is controlling the nutrient loading from the watershed.

Iron supply from the marginal seas to the North Pacific Ocean

Authors: Jun Nishioka, Hajime Obata, Ichiro Yasuda

Presenter: **Jun Nishioka**

Although the subarctic North Pacific is high nutrient low chlorophyll region, where phytoplankton growth is limited by iron (Fe) availability, the area has high bio-pCO_2 drawdown. The overall picture of the processes for supplying Fe and macro-nutrients, however, are still not fully understood. In this study, we compiled comprehensive observed data in the North Pacific in this 20 years, including the marginal seas and its island chains, and construct a dissolved Fe (DFe) dataset with nutrients and hydro-cast water properties. The dataset can withstand the analysis of the distribution of the chemical parameter on isopycnal surface. Firstly, we constructed 3D DFe diagram of the North Pacific including subpolar marginal seas by using the dataset. The isopycnal analysis indicates that the DFe rich water propagate from the Okhotsk Sea Intermediate Water (OSIW) to the wide area of Upper(U)-NPIW (26.6-27.0 $\sigma\theta$) in the western North Pacific, especially from 155 E to the west. Vertical distributions of DFe along isopycnal depth also indicate that source of DFe in the U-NPIW in the Oyashio region is mainly discharged water from the Kuril basin in the Okhotsk Sea. These results highlighted an importance of marginal seas and intermediate water formation for circulating micro- and macro-nutrients and controlling bio-pCO_2 drawdown in the subarctic Pacific.

Dynamics of the sediment plume over the Yangtze Bank in the Yellow and East China Seas

Authors: Jianrong Zhu, Zhifa Luo

Presenter: **Jianrong Zhu**

A distinct sediment plume exists over the Yangtze Bank in the Yellow and East China Seas (YECS) in winter, but it disappears in summer. Based on satellite color images, there are two controversial viewpoints about the formation mechanism for the sediment plume. One viewpoint is that the sediment plume forms because of cross-shelf sediment advection of highly turbid water along the Jiangsu coast. The other viewpoint is that the formation is caused by local bottom sediment resuspension and diffused to the surface layer through vertical turbulent mixing. The dynamic mechanism of the sediment plume formation has been unclear until now. This issue was explored by using a numerical sediment model in the present paper. Observed wave, current and sediment data from December 29, 2016, to January 16, 2017 were collected near the Jiangsu coast and used to validate the model. The results indicated that the model can reproduce the hydrodynamic and sediment processes. Numerical experiments showed that the bottom sediment could be suspended by the bottom shear stress and diffuse to the surface layer by vertical mixing in winter; however, the upward diffusion is restricted by the strong stratification in summer. The sediment plume is generated locally due to bottom sediment resuspension primarily via tide-induced bottom shear stress rather than by cross-shelf sediment advection over the Yangtze Bank.

Three-dimensional modeling of primary production, phytoplankton diversity and functional groups in the Canary Current System by remote sensing

Authors: Berrada Aicha, Benazzouz Aïssa, Demarcq Hervé

Presenter: **Aicha Berrada**

The Canary Current Upwelling System (CCUS), the second most productive upwelling system in the world is modulated by an exceptional seasonal variability in physical forcing conferring various geochemical characteristics. Previously computed in the Northwest African coast, using the VGPM of Behrenfeld & Falkowski 1997, productivity plays a major role in sequestering atmospheric CO_2. It has been suggested that Global warming increase likely the intensity of the trade winds and shows a strong response from primary production (PP), particularly in Morocco. To understand the variability of phytoplankton species, we are conducted to study the change in the phytoplankton composition and abundance. Historically few studied the phytoplankton variability, whereas the determination of phytoplankton species are undertaken on a yearly basis in Morocco.
The micro-phytoplankton is composed of diatoms, dinoflagellates, silicoflagellates, euglenophytes, coccolithophorids and raphidophytes. In Moroccan waters, 217 taxa of micro-phytoplankton have been identified in previous studies from Cape Blanc (21°N) to Cape Beddouza (32°30'N). A list of all taxa is published in Demarcq & Somoue 2015. The most abundant diatoms are *Chaetoceros* spp., *Leptocylindrus danicus*, *Leptocylindrus minimus*, *Pseudonitzschia* spp., *Thallassiosira* spp., *Melosira* spp. and *Nitzschia* spp. The most common dinoflagellates are *Protoperidinium* spp., *Alexandrium* spp., *Prorocentrum* spp. and *Gymnodinium* spp. Their relative abundance varies according to the depth and distance from upwelling centers, and according to season and region, mostly because of differences in the local intensity of coastal upwelling.
The description of phytoplankton groups using remote sensing-based observation (PHYSAT) combined with in-situ datasets would help to better understand the various processes involved in the modification of phytoplankton composition as well as in the productivity of the CCUS. A reconstruction of vertical distribution of biomass in response to natural forcing will be realized, as well as a bio-optical three-dimensional model of PP. Finally, the role of mesoscale will be studied from specific indices based on thermal frontal occurrence.

Session 4: Blue management and governance of marine resources

Supporting integrated coastal management implementation in Pacific Island Countries and Territories: challenges and avenues for progress

Authors: Raphaël Billé , Jean-Baptiste Marre

Presenter: **Raphaël Billé**

A second aim of this session is to assess the opportunities offered by Marine Spatial Planning, which is spreading throughout the world, for integrating environment into public policies and the ecosystem-based approach. Marine spatial planning offers indeed an attractive setting to combine different uses of marine resources within a single area through its aim to reconcile human uses and nature conservation. A specific focus of the session will be on the tropical regions where policies regulating marine and coastal environments are predominantly sector-based, thus hindering comprehensive understanding and relevant response design to challenges posed by the management of marine and coastal environments.

Connectivity across the seascape: challenges and opportunities in a tropical coast

Authors: Beatrice Padovani Ferreira, Camila Silveira, Ana Lidia Gaspar, Gil Strenzel, Leonardo Messias, Marcus Silva, Tereza Araujo, Sophie Bertrand and Mauro Maida.

Presenter: **Beatrice Ferreira**

This session will open the floor to present and discuss the challenges we need to overcome in the inter-sectorial collaboration efforts to transcend traditional regulatory limits, via a set of themes and case studies. Moreover, investigating the link between policy relevant knowledge and decision support tools will allow to weigh alternatives and balance marine spatial planning and governance options, keeping in mind their impact to the environment, including blue carbon, and on human communities throughout the decision-making process.

How to avoid MSP to become an ocean grabbing tool?

Authors: Queffelec Betty, Marie Bonnin, Solange Teles da Silva, Sophie Bertrand, Annie Cudennec

Presenter: **Betty Queffelec**

Marine spatial planning (MSP) is a new concept for managing human activities at sea. It aims at conciliating a variety of human uses, possibly in conflict between themselves, together with nature conservation goals. First proposed in developed countries, it is spreading all over the world supported by EU and UNESCO. While surely promising for organizing an increasing variety of activities at sea, its direct transposition to developing and emerging countries may trigger and favour an ocean grabbing process. Unbalanced power and representation of stakeholders in MSP design may overlook specific objectives, such as food security, while securing exclusive spaces for powerful economic actors, such as oil and gas exploitation. Here we propose a risk analysis of MSP to that extent and provide perspectives to get around this issue.

Towards evaluating the potential of marine biological carbon management

Authors: Maike Scheffold, Inga Hense

Presenter: **Maike Scheffold**

Although the potential of biological carbon management (further BioCM) is increasingly recognised, ideas for marine BioCM strategies are still vague. One reason for this is the prevailing view that only primary producers, which are hardly suitable for carbon management under existing policies, contribute to the long-term storage of carbon. In view of more holistic approaches that assume a possible contribution of higher trophic levels, this understanding has to be questioned and reviewed. Furthermore, the criteria for BioCM are likely to differ from those for marine ecosystem-based management. Both strategies could complement each other or even compete. The legitimation and applicability of marine BioCM strategies thus have to be evaluated by 1) understanding carbon pools and fluxes within the marine ecosystems, 2) assessing the carbon management potential for different marine functional groups and 3) studying the effects of marine ecosystem management on carbon storage. As a test case, we choose the Baltic Sea, which is particularly suitable, because it is characterized by a low taxonomic diversity, and ecosystem management plans exist. We will present a first idea on how to evaluate the potential of marine BioCM in the Baltic Sea.

Marine spatial planning and human-predator interactions. The case of shark risk in Réunion Island (Indian Ocean)

Authors: Ateret Shabtay, Plot Virginie, Potin Gael, Dargent Fleur, McClintock Will, Lagabrielle Erwann

Presenter: **Ateret Shabtay**

Expanding human activities are increasingly overlapping with established wildlife territory and, consequently, the mitigation of human-wildlife interaction risk is a growing environmental management issue. Among them, human–predator risk, refers to the negative impacts resulting from the interactions between potentially harmful large wild animals and people. Marine spatial planning (MSP) allocates spaces for human uses and environmental protection to achieve sustainable development and good environmental status by minimizing the negative impacts of human activities on ecosystems. However, MSP rarely considers marine wildlife as a threat to people. Réunion Island (Western-Indian Ocean) stands out as a case where marine wildlife risk (sharks) significantly affected sea users' behavior and activities. This was the consequence of a shark bite outbreak that started in 2010, with more than 20 cases of bites on humans, including 9 fatal. The increased risk produced controversies articulated around the human-sea-predator relationship and inflicted direct and indirect opportunity costs to the leisure-tourism activities. Today, shark risk reduction strategies in Réunion Island comprise a total ban on swimming and wave-based activities, shark culling operations, exclusion shark nets and underwater shark spotters. The MSP process in La Reunion initiated in February 2018 aims to integrate this uncommon human–predator risk component and respective management measures as part of a broader maritime strategy. To address this social demand confirmed by MSP stakeholders, we develop and test a participatory method to incorporate Human–wildlife conflicts into marine spatial planning.

Exploring an Australian Aboriginal blue carbon approach: cultural, environmental, and social ecosystem services

Authors: Sebastian Thomas

Presenter: **Sebastian Thomas**

The ‘blue carbon’ stored and sequestered in coastal habitats provides extensive and valuable ecosystem services including biodiversity, resilience to erosion and extreme weather events, nutrient cycling and pollution control, and provision of food and medicines. In Australia and elsewhere, these areas are also culturally significant to Indigenous Traditional Owners. Supporting conservation, restoration, and management of these coastal areas by Traditional Communities and Indigenous Corporations through carbon finance represents an opportunity to achieve important social and cultural outcomes through enterprise development and economic empowerment, as well as offering environmental benefits not limited to climate change mitigation and adaptation.

While Australian domestic climate policy has been dynamic at least through the last decade, ecosystem-based carbon management has been widely supported. In particular, traditional Indigenous savanna burning methods have achieved recognition of their carbon abatement outcomes through granting of offset certification. Major corporations not only support these savanna burning projects but pay premiums for offset credits that certify cultural, environmental, and social non-carbon benefits. Blue carbon is therefore a priority topic in Australia for federal and state governments, key corporate actors in the private sector, scientific and conservation communities, and it is increasingly of interest to Traditional Owners.

This paper provides an overview of carbon farming and specifically the state-of-the-art of blue carbon in Australia and its region, including current environmental, social, and economic research; state and non-state initiatives; and regional political, Indigenous, development, and commercial perspectives. Following this, we consider the Australian blue carbon case study in a wider critical context, highlighting how Indigenous Science and traditional knowledge can inform, guide, and complement blue carbon initiatives, and where traditional knowledge and practices may clash with the characteristics and assumptions of regulated carbon markets. Australian Aboriginal and Torres Strait Islander peoples have sustainably managed marine and coastal resources for millennia, and these traditions may offer valuable – if not necessary – insights for genuinely sustainable future coastal management.

By integrating modern market frameworks with ancient environmental knowledge, Indigenous blue carbon initiatives may be a path to realise regenerative and sustainable development through coastal conservation and restoration; empower and build participation of Indigenous people and organisations in the emerging carbon farming industry; and support Governments and corporations to meet carbon liabilities, climate change mitigation and adaptation responsibilities, and Sustainable Development Goals.

“No good planning without good training”: Blue Planning in Practice (BPiP), cross analysis of a comprehensive approach experimented over four continents

Authors: Marinez Scherer, Armelle Jung

Presenter: **Armelle Jung**

Oceans are facing serious concerns and coastal and marine management, as well as marine spatial planning, are urgent processes being currently developed all over the world trying to solution them. This imperative situation to find coordinate solution for management of the seas also creates some needs to have people prepared to do so with good knowledge and methodology in hands. Blue Planning in Practice (BPiP), as part of the Blue Solutions Program (GIZ, GRID-Arendal, IUCN and UN Environment) is an innovative and adaptive

training tool to experiment the all steps process to conduct a successful marine and coastal spatial planning. Especially focused on ecosystem-based approach, BPiP is designed to apply the several expectations from institutions and stakeholders such as policy makers, planners, government technicians, civil society, academics and the private sectors. The tool focuses on the identification of needs for the planning process, mapping and organization of stakeholders, inventory of current and future conditions, writing and approving a spatial management plan, implementation, regulation and monitoring, as well as revising and adjusting the plan. Recently the training was offered in several countries in South America (e.g. Brazil, Surinam, Ecuador), Asia (Myanmar), Africa (Senegal, Guinea, Equatorial Guinea, Namibia, Madagascar), and Europe (e.g. Cyprus, Turkmenistan) since 2017. Global feed back of the training is very positive and enthusiastic from the participants throughout the places it took place. The different trainings are being analyzed over geographical areas, socio economic context, and participant level; it shows the effectiveness of the participatory approach set up by BPiP. One of the most important issues of the course is the demonstration, in practice, of the different interests, conflicts and potential partnerships between the different stakeholders. Moreover, BPiP offers to be more than a technical course but is bringing participant to experiment the need for human change on global but also individual scale. One of the most challenging but compulsory condition for an effective marine spatial planning!

"Blue Amazon": the legal-political challenges for the implementation of marine spatial planning

Authors: Solange Teles da Silva, Tarin Mont`Alverne

Presenter: **Solange Teles da Silva**

Among the 17 countries recognized as megadiverse, only 3 have a more extensive coast than Brazil: Indonesia (54,716 km), Australia (25,760 km) and China (14,500 km). This can justify the interest in analyzing how Brazil, which coast extends for 7,500 km, reconciles the human uses of the oceans and the conservation of marine biodiversity. In Brazil the population is concentrated in the coastal areas and human activities have an impact on oceans and marine biodiversity, as well as on the way of living of traditional and local communities. For the benefit of the society, the effectiveness of the principle of participation in decision making on the use of marine resources and the appropriation of these spaces should be ensured. In this sense, the sustainable governance of the oceans can be analyzed from a specific perspective on the "Blue Amazon", a marine space that encompasses part of the tropical ocean and biodiversity. The aim of this paper is to contribute with information for the formulation of public policies that overcome a fragmented vision of the uses of marine spaces and resources and to promote their effective planning, identifying the institutional challenges in Brazil. Discussions on marine spatial planning (MSP) are still at an embryonic stage in Brazil - Bill no. 6.969 / 2013 on the marine biome has the definition of MSP - and in this sense the advances made in MSP in the European Union can inspire us in the present study. We first identified the legal-political instruments that may contribute to the development of Brazilian marine space planning, considering the current political moment of dismantling of environmental institutions initiated mainly from January 2019. In a second moment, we studied the degree of institutionalization of the coordination of public policies related to marine space and resources. In methodological terms, we observe that the degree of implementation of the principle of participation, integration and the ecosystem approach in sectorial norms involving economic and conservation activities in Brazil is still incipient. Therefore, although this analysis refers to the tropical ocean with its specificities, the principles that govern the planning of the European Marine Space can serve as an inspiring model to overcome the obstacles and built the bases for the sustainable management of the "Blue Amazon".

Environmental protection in Marine Spatial Planning: insights from the cross-analysis of legal and uses data

Authors: Philippe FOTSO, Joel Kamdoum Ngueuko, Sophie Bertrand, Sébastien Thorin, Marie Bonnin

Presenter: **Philippe Fotso**

The requirement to reconcile uses at sea with the protection of ecosystems is one of the essential objectives of the MSP. Defined as an analytical process geared towards sustainable distribution of maritime activities in space and time, implementation of MSP requires the use of several tools, including technical and legal tools. While GIS and decision support tools (DSTs) help unearth planning challenges through scenarios management in face of various constraints, the legal aspects of MSP stem from the multiplicity of international or national rules that organize user's rights over spaces and resources. The objective here is to highlight the link between uses and law in a MSP process, through a case study of marine and coastal area of the State of Pernambuco (Brazil). Mapping of various uses and activities is performed and coupled with the set of existing legal data and rules applicable to each use and activity in space. This cross-analysis allows uncovering what already works well and what may challenge the implementation of a MSP in the Brazilian ocean.

SESSION 5: "BUT WHY WON'T THEY USE MY SCIENCE?" IMPROVING THE IMPACT OF MARINE SCIENCE ON POLICY: ADVANCES IN THEORY AND PRACTICE

Accounting for Ecosystem Service (ES) in the marine environment: background, needs and possible implementation.

Authors: Laura Basconi

Presenter: **Laura Basconi**

Ecosystem services (ES) have been increasingly used in the assessment of ecosystem functioning and (even if it is still debated) even as metrics of the marine environment ecological status. To merge economical-ecological needs (alias sustainable economy) Marine/Maritime Spatial Planning (MSP) is being used to map marine ecosystems and to create operational tools for the management of the natural capital in an increasing economic activities scenario. Together, these two aspects are considered in an economic-socio-ecological framework which requires wide interdisciplinarity. However, to date, policy-makers are mainly advised by economists. Hence, should marine ecologists make their science suitable for policy-maker purposes, creating new metrics? Otherwise, should economists study the complex ecological systems and account for them with traditional economic tools? In my PhD project, the economic dimension of ES will be explored however ecological approach has been so far sceptic about environmental accountability even because direct ecosystem services are difficult to monetize. Direct ecosystem services are intended as ES delivered to humans without human mediation (e.g. recreation, aesthetic enjoyment) and so difficult to translate in monetary terms. The status quo of marine environment accounting is presented with issues and questions arise. Should ecologists in the Anthropocene and in a climate change context monetizes what should be protected by mere ethics?

Look who's asking! (Reflections on participatory research approaches)

Authors: Annette Breckwoldt, Priscila Lopes, Samiya Selim, Prateep Nayak, Paul Onyango, Alifereti Tawake, Joeli Veitayaki, Ingrid van Putten

Presenter: **Annette Breckwoldt**

In this research we reflect on the question of who is actually asking and setting the research questions in local community-based marine conservation and management efforts. After decades of efforts to foster participatory research, and many advancements in transdisciplinary research design, this question has still not lost its relevance. Research questions are often framed and formulated outside the actual geographical, social, cultural and ecological setting in which the research projects are supposed to be anchored. Even though research pathways have become more diverse, the direction of the information flow is still mostly one way. The slow progress in transforming academic and funding environments for true 'level-playing-field' research projects does not help this mono-directional research tendency.

Often within research collaborations involving international 'north-south/east-west' teams it remains worth asking a number of questions, such as who is asking the research questions? Who is framing the research questions? What are the local questions? Whose knowledge is used where (in which decision-making processes – and for whom)? What are the benefits for the resource users/managers/decision-makers of the countries where the research is taking place? Whose lens is used to undertake the data analysis, draw conclusions and write recommendations?

With a preliminary focus on marine protected areas, and showcasing examples from Bangladesh, Brazil, Fiji, India and Tanzania, the paper will shed light on the existing or non-existing overlaps between 'internationally' pressing research questions, and those questions that are of actual relevance for the local resource users, managers, policy-makers. The latter would involve questions that the local people and institutions would actually like to ask and need to ask (before being advised on the relevant questions from outside the relevant communities).

This partly self-reflective research is a result of a discussion started at the 2018 IMBeR Human Dimensions Working Group meeting in Stockholm. It will bring together and discuss international perspectives and data from a number of locally grounded marine conservation and management research projects. In this way it asks what can be done better, and how can the process of identifying the most relevant and meaningful questions be better understood and improved?

Bright spots at the marine science-policy-practice interface: the case (and need) for optimism

Authors: Christopher Cvitanovic, Alistair Hobday

Presenter: **Christopher Cvitanovic**

Effectively translating scientific knowledge into policy and practice is essential for helping humanity navigate contemporary environmental challenges. Accordingly, the past two decades have seen calls for scientists to find new ways of engaging more effectively with decision-makers, as well as demonstrate the tangible and real world impacts arising from their research. Achieving demonstrable impacts on policy and practice, however, is not easy, leading to the widespread adoption and institutionalisation of the mantra 'science-policy gap', which now dominates much of the public and academic discourse in this space. In this talk we will outline the case that the continued propagation of this mantra, which is largely fuelled by ongoing research effort focused on 'challenges' and 'barriers', is counterproductive to improving the relationship between marine science, policy and practice. Instead, we will present the case that a shift in the academic study of science-policy-practice interfaces is needed, towards the study of 'bright spots' –

situations whereby marine science has successfully influenced and impacted on policy and practice. Drawing on a range of case studies we will show how a shift in research towards bright spots can help improve the impact of environmental science on policy and practice in two ways. Firstly, it will help us move beyond the existing discouraging discourse towards a new mantra of hope – one that inspires optimism and action at the interface of science, policy and practice. Next, we will highlight the value of bright spots in identifying practical strategies for improving the impact of marine science on policy and practice.

Translating science to policy – bridging the gap in New Zealand

Authors: Gemma Couzens

Presenter: **Julie Hall**

New Zealand an island nation with an affinity for the coast. We have the 4th largest exclusive economic zone in the world and are a hotspot for marine diversity, including species found nowhere else in the world. However, most of our marine bird species and more than one-quarter of our marine mammal species are threatened with or at risk of extinction. Our coastal waters are degraded due to excess sedimentation, seabed trawling and dredging for fish and shellfish, marine pests, and excess nutrients carried down waterways.

Managing the cumulative effects that arise from human and natural stressors is one of the most urgent and complex problems facing coastal and marine decision makers today. In New Zealand, cumulative effects management is especially complicated by fragmented legislative regimes and institutions that struggle to deal with cross-scale interactions, chronic data scarcity, and high levels of uncertainty.

Concepts such as the ‘precautionary principle’, ‘best available information’ and ‘adaptive management’, have raised the bar in terms of science information needs for policy- and decision-makers. And as new activities, such as seabed mining, become more feasible in deeper waters, we need to keep bridging the gap between science, policy and practice.

Through the initiative of a government-funded research programme called the Sustainable Seas National Science Challenge, New Zealand has undertaken research to improve our understanding of, and management of the marine environment. A major success of the Challenge has been its unique opportunity to bring together different stakeholders including regional and central government agencies, industry, and Māori; with expertise ranging from marine ecology to policy implementation. The integration of different stakeholders into various research projects under the Challenge has greatly enhanced the uptake of science information by policy-makers and practitioners.

In this presentation I will talk about some of the initiatives that have been successful in translating science into policy, from the perspective of a policy-maker; and some of the challenges faced by policy- and decision-makers when using science.

Science 2 advice at ICES, an evaluation of the factors influencing the take up of new knowledge.

Authors: Mark Dickey-Collas, Simon Jennings, Kåre Nolde Nielsen, Nathalie Steins, Robert Thorpe, Eskild Kirkegaard

Presenter: **Mark Dickey-Collas**

ICES is recognised as an independent, high-quality advisory body by governments and it develops science and advice on meeting marine conservation, management and sustainability goals. It recently held a workshop to explore the factors that enable new and innovative science to be taken into the advisory process. Twenty-seven factors were identified and clustered into issues around (1) the behaviour, diversity and working practices of people involved in generating the new knowledge (2) the analytical approaches applied by scientists, and their accessibility, repeatability, quality assurance (3) the fitness for purpose of science in relation to advisory needs or priorities, and (4) the legitimacy of the science, as influenced by the extent of engagement between scientists and advisers, the strength of scientific consensus and trust in the impartiality and credibility of the scientists working in projects and expert groups. The uptake of science into advice from 27 projects and expert groups was evaluated.
The most important factors influencing uptake were the effectiveness of stakeholder engagement, the extent to which the diversity of people engaged in translation of science to advice spanned science, advice, advice recipients and knowledge brokers, and the salience of the science in relation to advisory needs and priorities. The workshop also considered it likely, that the full involvement of people who understand advisory needs and priorities is essential during both call development and the review of project proposals. For internal ICES expert groups the most important factors were the extent to which the advisory community is willing to accept and assimilate science subjects and the evidence base; the effectiveness, resourcing and relevance of stakeholder engagement in relation to product or advisory needs; and the clarity of, support for and durability of follow-up processes after terms of reference are completed.

Using science fuel to drive a change: a case study involving microplastics, whale sharks and stakeholders in the Maldives

Authors: Giulia Francesca Azzurra and Alina Madira Wieczorek, I. Zazeer, I. Shameel, J. Hancock, R. Rees

Presenter: **Giulia Donati**

Due to their remote location and increasing tourism, the Maldives struggle with their waste management. The environmental consequences of this are reflected in the results of a recent study reporting microplastics to be particularly abundant in this Archipelago. However, the Maldives also feel the great responsibility to protect their unique marine habitats, home to an astonishing biodiversity, including many threatened species. Among these, the emblematic and endangered whale shark (Rhincodon typus) is of high economic value as the opportunity of encountering it lures tourists from all over the world to the “island nation” and tourism has become the largest economy. In 2013, whale shark tourism in the small South Ari Atoll Marine Protected Area (S.A.MPA) alone has been valued at 9.4 million USD, corresponding to 3% of the global shark tourism. It would thus be prudent from an ecological and economic point of view to protect and preserve their habitats and achieve good environmental status. For this purpose, it is key to open the dialogue with the community and key actors alike by increasing the visibility of this environmental issue, which has nowadays reached global concern. Here, we aim to open the dialogue using findings of microplastic ingestion by whale shark. Contrarily to most areas of the world, whale sharks in S.A.MPA aggregate all year round. Their feeding strategy, filtering up to 614 m3/h of sea water, makes them particularly prone to microplastics ingestion. This is of concern as microplastic ingestion by other fish species has been shown to cause reductions in food uptake and predatory performance, and act as a vector of toxins, which can bioaccumulate and lead to endocrine disruption and hepatic stress. While there has been an initial effort to investigate microplastic interactions with whale sharks, to date, such research has been based on presence of plasticisers in their tissues. Through the analysis of faecal matter, we identified a non-invasive method to provide empirical evidence of microplastic ingestion by whale sharks. At present time, ten faecal samples were collected and we proceeded to the analysis of one initial sample from which ten microplastics were extracted. Using these findings, we aim to provide scientific evidence of the extend of microplastic pollution in the Maldives and its potential consequences for the unique marine species inhabiting these waters. Next, we will engage with stakeholders through a survey to create a shared problem framing. A series of workshops will follow and use insight-driven science communication to develop collaborative solutions between and within keystone actors. Lastly, through the help of a long-established NGO, we hope to empower and support stakeholders to implement their solutions, but also to contribute to their efforts when introducing new regulations for marine protection. Throughout the documentation of the project using videos, articles and interviews which will be shared on social media platforms will help to spread awareness, stimulate action and support marine ecosystem's conservation worldwide.

The problem isn't the managers: Managers can't use what scientists won't share

Authors: Nick Wehner, Raye Evrard, Allie Brown, John Davis, Mike Hay

Presenter: **Raye Evrard**

Ever since the paywalled academic publishing model was invented in the 1950s, readers and authors alike have been forced to pay publishers, who largely operate for a profit, to access scholarly research. While university libraries typically cover the costs for academics to access such works, those who work in the non-profit or civil-service sectors rarely have access to any paywalled journals. Thus, the majority of the ocean conservation research corpus remains so costly it is unavailable to the vast majority of the population. This is despite the fact that authors who publish with the largest for-profit publishers (Elsevier, Springer Nature, Taylor and Francis, Wiley, etc.) can make their work "Green" Open Access without paying the publishers any fees. In November 2017, OCTO launched MarXiv, a research repository to help scholars make their work legally and freely-accessible through "Green" Open Access. During MarXiv's first year of operation, over 400 authors of ocean-related papers were invited by OCTO to share their papers. Authors were sent up to three solicitation emails each with the subject line "Paper request". Of the authors contacted, 38% did not open a single request message, while only 26% of contacted authors successfully shared their papers. Based on our results, the adage, "you can email the author for a copy of their paper," is ineffective for the majority of the ocean research corpus. Until ocean scientists change their behaviors surrounding publishing and sharing, resource managers and others without academic journal subscriptions will continue to face barriers to discovering science, let alone using it.

Communication, collaboration, and transparency: Tailoring ecosystem science to inform fisheries management

Authors: Stephani Zador, Elizabeth Siddon, Martin Dorn

Presenter: **Stephani Zador**

Scientists have been providing contextual ecosystem information to federal fisheries managers in Alaska to support the quota-setting process for 25 years. This ecosystem information is supplemental to the stock assessment process and largely consists of ecosystem indicators that track physical and biological changes in the ecosystem. These indicators are integrated into ecosystem assessments presented annually to managers immediately preceding their review of stock assessments to discuss and set fisheries quotas. Lessons learned largely follow themes of communication, collaboration, and transparency. We have found that regular communication among scientists, managers, and fisheries practitioners of information tailored to specific needs increases uptake into management processes. For the process of informing annual quota decisions, the needs are ecosystem information that is timely and at relevant scales. To achieve this also requires collaboration, which is encouraged by trust in the management system and transparency. As an example, data contributors to the ecosystem assessments have their names associated with their contributions, such that they receive credit and value from participation in the management process. This results in a win-win situation, with scientists demonstrating application of their science to management, and managers benefiting from timely and informative data. But success in this process requires trust; for scientists, this requires that data will not be "scooped for publication" as their names are always associated with the data. In 2018, this type of collaboration built on trust allowed for communication of reports of strong impacts on the northern Bering Sea ecosystem, which did not freeze over during the preceding winter for the first time, to stock assessment scientists and fisheries managers before stock assessments were completed. The rapid availability of this information informed a re-evaluation of stock assessment assumptions regarding the geographic shift of fish stocks from the eastern to the northern Bering Sea. Also in 2018, several stock assessments included a new risk matrix that identified and ranked ecosystem, population dynamics, and assessment concerns. Developing the risk matrix was a collaborative effort among stock and ecosystem scientists to represent the best available science. These risk matrices increased the transparency of the rationale for reducing the quota below the maximum allowable. Summarizing myriad data into simple risk matrices allowed stakeholders to compare management recommendations among stocks, increasing their understanding of assessment concerns. The outcome was greater engagement in the development of management advice by stakeholders. In general, knowing our specific audience—stock assessment scientists, stakeholders, and fisheries managers—allows us to tailor to the quantity and type of ecosystem information delivered to best meet their needs. In this presentation, the themes of communication, collaboration, and transparency are applied specifically to groundfish fisheries management in Alaska but are also considered as broad themes that should be applied in other fisheries management systems.

A view from Philanthropy: The Lenfest Ocean Program Approach

Authors: Jason P. Landrum, Charlotte Hudson

Presenter: **Jason Landrum**

The Lenfest Ocean Program (LOP) is a grant-making institution with over a decade of experience supporting scientific research that informs marine resource management and conservation. We believe that scientific research is more likely to be used if decision-makers and stakeholders contribute to the process from the start. As both a funder and boundary organization, the LOP has the flexibility to encourage

coordination between researchers and practitioners prior to evaluating potential funding opportunities. To do this, program staff dedicate considerable time to investigate what information is needed to inform emerging policy issues, and then collaborate with scientific experts to co-design practical research projects that fill those knowledge gaps. This process stimulates stakeholder conversations and buy-in on the front-end, it helps shape the proposed research around users' specific information needs, and it clarifies potential pathways by which new information can inform specific decisions and/or decision-making processes.
From a philanthropic perspective, we believe our grant-making process results in funded projects that have a higher likelihood to produce useful, policy-relevant scientific information, thereby increasing our return on investment. During this session, we will introduce the LOP's approach to project development and describe the interactive engagement process that occurs between program staff and potential grantees. We will communicate the types of questions that staff use to select potential projects, and present case studies of projects that resulted in successful integration of science into decision-making and projects that failed to inform the intended audiences. Through this discussion, we hope to stimulate productive conversation and learn from other ongoing efforts that are advancing the use and impact of scientific research on marine policy and decision-making.

Building university-based boundary organisations that facilitate impacts on environmental policy and practice

Authors: Marie Löf, Christopher Cvitanovic, Albert V. Norstroem, Mark S. Reed

Presenter: **Marie Löf**

Responding to modern day environmental challenges for societal well-being and prosperity necessitates the integration of science into policy and practice. This has spurred the development of novel institutional structures among research organisations aimed at enhancing the impact of environmental science on policy and practice. However, such initiatives are seldom evaluated and even in cases where evaluations are undertaken, the results are rarely made publicly available. As such there is very little empirically grounded guidance available to inform other organisations in this regard. To help address this, the aim of this study is to evaluate the Baltic Eye Project at Stockholm University – a unique team consisting of researchers from different fields, science communicators, journalists and policy analysts – working collectively to support evidence-informed decision-making relating to the sustainable management of the Baltic Sea environment. Specifically, through qualitative interviews, we (1) identify the impacts achieved by the Baltic Eye Project; (2) understand the challenges and barriers experienced throughout the Baltic Eye Project; and (3) highlight the key features that are needed within research organisations to enhance the impact of science on policy and practice. Results show that despite only operating for three years, the Baltic Eye Project has achieved demonstrable impacts on a range of levels: impacts on policy and practice, impacts to individuals working within the organisation and impacts to the broader University. We also identify a range of barriers that have limited impacts to date, such as a lack of clear goals at the establishment of the Baltic Eye Project and existing metrics of academic impact (e.g. number of publications). Finally, based on the experiences of employees at the Baltic Eye Project, we identify the key organisational, individual, financial, material, practical, political, and social features of university-based boundary organisations that have impact on policy and practice. In doing so this paper provides empirically-derived guidance to help other research organisations increase their capacity to achieve tangible impacts on environmental policy and practice.

Roles and impacts of science and interactions with stakeholders and decision makers in decision-support to fisheries management: sharing experiences and practices from an inter-disciplinary collective of researchers

Authors: Claire Macher, Denis Bailly, Marta Ballesteros, Michel Bertignac, Francesco Colloca, Mike Fitzpatrick, Katia Frangoudes, Dorleta Garcia, Marloes Kraan, Rich Little, Loretta Malvarosa, Simon Mardle, Arantza Murillas, Lionel Pawlowski, Manuelle Philippe, Ra

Presenter: **Claire Macher**

Implementation of Ecosystem Based Management in fisheries has favoured the integration of knowledge and disciplines and the engagement of stakeholders in the processes supporting management decision-making. Scientists contribute to this integration and engagement through research projects involving participatory approaches with stakeholders, and/or through the provision of advice within institutionalized decision support systems. It is however not trivial to operationally define the role and impact of scientists in such processes. This was the aim of a workshop held in January 2018. The workshop brought together biologists, economists and social and political researchers from Europe and Australia, involved in management decision-support processes and in participatory research in fisheries. Experiences and views across case studies, disciplines and projects were shared. Based on a review of the context and content of, and lessons learnt from concrete experiences in supporting fisheries management, the role and impact of scientists in decision-support processes was explored. Workshop participants underlined the diversity of scientists' roles and the need to understand how and to what extent some roles may lead to better decision-support. Increasingly, scientists facilitate trans-disciplinary approaches integrating academic and non-academic knowledge to support management decisions. The need to develop networks which can review, expand and ultimately institutionalize transdisciplinary research platforms was identified, as well as the need to establish a community of practice in this area. Such a community of practice could promote systematic cross-study and cross-scale comparisons, which should generate actionable knowledge for fisheries management decision-support.
Keywords: decision-support process, fisheries management, participatory approach, stakeholder engagement, inter-disciplinary, trans-disciplinary approaches, role of science.

Science-based evidence in support of management of coastal (marine protected) areas

Authors: Dominique Pelletier, et al.

Presenter: **Dominique Pelletier**

In coastal areas, Marine Protected Areas (MPA) are important instruments to influence the spatial and temporal distribution of ever increasing anthropogenic pressures on ecosystems. Over the last two decades, many coastal MPA were established in response to national and international conservation policies and agendas. MPA management takes place at local scale, but within the scope of national policies. Whether or not conservation management goals are reached must thus be assessed locally, to guide management interventions and evaluate management plans, and also nation-wide and at international level. Moreover, periodic assessments are also needed for other purposes, e.g. in Europe, the Marine Strategy Framework Directive.
Underpinning these assessments lies the need for consistent monitoring and assessment methods, and for scaling-up tools. In this paper, we focus on science-based assessment of coastal areas, particularly in MPA. Based on several research projects involving collaboration with MPA managers and environmental management bodies, I highlight ingredients that proved to be key for a better appropriation of science by

managers. These projects occurred over the last fifteen years in several regions and ecosystems, including coral reef oversea territories, the Mediterranean and the Atlantic, and concerned several types of MPA, ranging from the small marine reserve to the large Marine Park. Among these ingredients, I will address project scoping, methodologies for fostering transdisciplinarity and inclusiveness, allocation of resources for the joint involvement of both scientists and managers, communication of science, and operational outcomes. I will also illustrate the dynamic interplay between scientists' and managers' expectations, and the issue of a sustainable uptake by end users of new approaches and tools.

What can we learn from the use of ICES scientific advice on fishing opportunities by decision-makers when setting EU total allowable catches (TACs)?

Authors: Ashley Wilson

Presenter: **Ashley Wilson**

Managing fisheries sustainably and accordance with established policy objectives is highly dependent on scientific advice. Decision makers use scientific advice and evidence to varying degrees when agreeing management measures to control fishing mortality and to restore fish stocks to desired levels e.g. through the setting of fishing opportunities.

In the EU, the Common Fisheries Policy (CFP) provides a framework for fisheries management. One of the central and well-defined objectives of the CFP is to apply the precautionary approach to fisheries management and to ensure that exploitation of living marine biological resources restores and maintains populations of harvested species above levels which can produce the maximum sustainable yield (MSY) – Article 2(2).

The International Council for the Exploration of the Sea (ICES) provides authorities with scientific advice on the sustainable management of fisheries and other human activities that affect marine ecosystems. Most relevant to the setting of TACs in the EU are ICES fish stock assessments and quantitative advice on fishing opportunities. These are based on the ICES framework for advice, which aims for consistency with international agreements and policies, and responds to the policy needs of ICES Member Countries, and multinational and intergovernmental organisations.

According to the CFP, managers should establish measures using the 'best available scientific advice' – and in a manner consistent with the requirements of the CFP objectives. Our research looks at EU decision making since the reform of the policy in 2013, and the extent to which decision makers adhered to ICES scientific advice on fishing opportunities when setting TAC limits in European waters of the north-east Atlantic. We observe that between 2013 and 2017 the majority of TACs were set exceeding scientific advice for catches/landings, even though there was an increase in the number of TACs set not exceeding scientific advice since 2014. In 2018 and 2019, just less than half of TACs were set exceeding scientific advice. These trends, and the large number of TACs still set higher than scientific advice, suggest that well-established science is being reinterpreted, used partially, or ignored. Why might this be the case?

The talk will outline the points during the EU's decision making at which scientific advice is used, and/or reconciled with, policy and political processes. We will discuss the key moments in the process of TAC setting where decisions often diverge from scientific advice, and highlight any potential or publicly stated rationale for this, with examples and observations about why this occurs (e.g. authorities' perception of advice and the use of alternative scientific evidence).

The talk will also outline common transparency and accountability issues that often make it difficult to evaluate comprehensively when and/or why well-established fisheries science is used, or not used, by decision makers (e.g. stock and TAC area mismatch).

Finally, the talk will propose possible science and/or policy focused solutions that might help address these specific issues. Insights may be relevant to scientists and policymakers wanting to improve uptake of established science and integration of new science into policy.

Transdisciplinarity in Fisheries: Are We on Track?

Authors: Milena Arias Schreiber, Alicia Said

Presenter: **Alicia Said**

Transdisciplinarity is a new word à la mode at least in the ocean and fisheries context. The practice of transdisciplinarity in sciences (like medicine) and engineering has been around for some time. The concept is also referred to, without calling it as such, in the seminal paper, the 'Tragedy of the Commons' by Garret Hardin. We argue that fisheries governance requires the involvement of all relevant stakeholders in the identification of the issues and in the understanding of the problems. Integration of the knowledge and the sciences from all relevant disciplines is also required for the co-design and the co-implementation of solutions or the pathways, and, in principle, these two aspects are supported by both the natural and social science spectrums. However, the extent to which these key aspects of the transdisciplinary perspective occur in practice is questionable. In fact, the low participation of social scientists in fisheries science conferences and likewise the low participation of natural scientists in social sciences conferences attest to this. Here, we present results of a comparative analysis of the last World Fisheries Congress (Busan 2016) and the World Small-Scale Fisheries Congress (Chiang Mai 2018) and assess the extent to which the transdisciplinary perspective was incorporated in the papers presented at these two world congresses. We discuss the reasons for the poor scientific collaboration, the barriers for integration, and the consequences on fisheries and ocean sustainability.

How to bridge the gap between the scientific community and indigenous knowledge bearers : Opportunities for marine policy and practice.

Authors: Aliou Sall, Cornelia E Nauen

Presenter: **Aliou Sall**

The goal of this paper is threefold. First, it describes the growing distance between the world of research and the custodians of endogenous knowledge, a process going on for a little over a decade in the fisheries of the ecoregion of the Sub-regional Fisheries Commission (Mauritania, Senegal, Cape Verde, Gambia, Guinea Bissau, Guinea and Sierra Leone). This lack of contact between researchers and the leaders within artisanal fishing communities creates a significant negative impact in the form of a perpetual challenge what can be agreed upon in favour of sustainable management of resources, on which many communities depend for their social, economic and cultural well-being. Under the auspices of FAO and other international institutions concerned with the future of the oceans in general, and sustainable fisheries in particular, states have adopted more technical and legal instruments for sustainable fisheries (Code of Conduct for Responsible Fisheries, the Ecosystem Approach to Fisheries (EAF), National Pirogue Registration Programme (PNI) in Senegal). Recent and ongoing research is confirming findings already presented at the 2002 Dakar Symposium on half a century of change in West African fisheries, ecosystems and societies.

Despite efforts by States to regulate fisheries through different reforms and the interesting scientific results about the degradation of marine ecosystems, it is still difficult to enforce the management measures and bring these research results into the fishing communities. We assume that a main driver leading to such a situation is related to the lack of communication between scientists and the stakeholders.

Secondly, the paper examines the process by which this gap - which translates also into a growing difference between the two forms of representation of knowledge about the marine world - is maintained and develops momentum. Greater specialisation in the sciences means that any specialty can only represent and cover a small segment of the complexity of the social-ecological system. The implication is that decision

makers in the fishing industry at whatever scale or in government need to consider a broader spectrum in balancing often contradictory factors and trade-offs.
Finally, some proposals are put forward for closing these gaps through effective collaboration between "Conventional Research", "Policy Makers" and "Dignitaries of Endogenous Knowledge" in favour of better policies and practice towards the objective of sustainable fisheries. The term critically engaged science has been coined for the mode in which scientists recognise that different types of knowledge need to come together and that "stakeholders" in society are impact experts. Transdisciplinary and action modes of doing research with involvement of practitioners are promising avenues to close the gap. Care must be taken to allot enough time to develop a common language and ensure mutually respectful relations for such approaches to be successful.

Multi-objective zoning for biodiversity and aquaculture in the Adriatic-Ionian region

Authors: Chiara Venier, Jennifer McGowan, Stefano Menegon, Elena Gissi, Andrea Zanella, Daniel Depellegrin, Alessandro Sarretta, Andrea Barbanti, Hugh Possingham

Presenter: **Chiara Venier**

Spatial decision-support tools can be used for scenario analysis and guide decision-makers towards transparent and knowledge-based spatial planning. Their application for multi-objective zoning in marine socio-ecological systems is beneficial for supporting the on-going Maritime Spatial Planning (MSP) process. We consider the sustainable development of aquaculture as one of the main maritime activities for sustainable Blue Growth in the Adriatic Ionian Region. The objective of this research is to conceptualize a strategic multi-objective zoning process for aquaculture expansion and biodiversity protection (seabed habitats, marine mammals, seabirds and turtles species distribution, nursery and spawning areas of commercially important fish species) in the Emilia Romagna Region (Italian Northern Adriatic Sea). This area is characterized by the highest productivity of mussels in Italy and is also intensively used by several maritime industries. The projected growth of the Blue Economy is likely to result in an increase of conflicts and impacts on sensitive environments. The decision support tools Marxan and Marxan with Zones are applied to develop alternative planning scenarios and compare solutions in terms of potential impacts on human activities. To do so, we i) build an aquaculture suitability distribution for important commercial species using a multi-criteria analysis that considers environmental, biological and socio-economic factors; ii) prioritize biodiversity using Marxan, while testing how different considerations of human impacts influences priorities (e.g. minimizing the area, number of maritime activities, distance from ports, aquaculture suitability); iii) simultaneously prioritize aquaculture and biodiversity using Marxan with Zones, while minimizing the impact of the number of maritime activities in the Emilia Romagna Region. We compare our scenarios using a novel nearest-neighbour statistical analysis for Marxan's outputs to understand similarities and differences among scenarios. We conclude that an integrated multi-objective zoning approach, which simultaneously plans for biodiversity and aquaculture, will support more efficient, and therefore more effective strategies for Blue Growth objectives in the AIR.

ODATIS: a single gateway to French in situ marine and coastal data to facilitate data access

Authors: Sabine Schmidt, Gilbert Maudire, Joël Sudre, Gérald Dibarboure, the ODATIS CDSs

Presenter: **Sabine Schmidt**

The past few decades have seen a marked acceleration in the number of marine and coastal observations, both by using in situ measurements or remote sensing. For example, high-frequency monitoring of physical-chemical parameters (temperature, salinity, fluorescence, dissolved oxygen, among others) has become an essential tool to assess the natural and human-influenced evolutions of coastal waters, and the societal or management implications. The number and variety of acquisitions require now efficient tools to make available of the research community such large amounts of data.
ODATIS, the French portal for marine data launched in December 2017 (www.odatis-ocean.fr), has the ambition to become an essential tool for the community to describe, quantify and understand the global ocean and its evolution across disciplines: physic, chemistry, biogeochemical cycles, marine ecosystems. An easier and widespread access to marine data is indeed of crucial importance to address climate and environmental issues, in particular in coastal regions directly affected by human activities. ODATIS is part of the European and international initiatives such as Copernicus, SeaDataCloud and Emodnet.
ODATIS relies on a network of data and service centers (CDS) supported by the main French research organizations concerned by marine sciences: CNRS, CNES, Ifremer, IRD, SHOM and Université Marines. The first task of ODATIS is to catalog all the data and to facilitate data extraction. The catalogue offers several data access tools: a search service with selection filters, a data description service (with two options: "Preview" and "Complete"), a visualization service, and the possibility to download data directly or via the local partner portals. The second task is to develop processing tools for handling such large amounts of data, and to generate products from observations for policy-makers, practitioners and academics, and. Through examples, we will illustrate the interest of ODATIS.
CDSs: Data and Service Centers

Marine ecosystem services trade-off assessment: a methodological approach to inform maritime spatial planning

Authors: Elena Gissi, Elisabetta Manea, Davide Di Carlo, Stefano Menegon, Denis Maragno, Francesco Musco

Presenter: **Chiara Venier**

Strategic natural resource management is of central interest for long-lasting and sustainable socio-economic development, especially in the marine realm, where ecosystem services (ES) and trade-offs assessment is backward compared to land-based studies. Marine Spatial Planning (MSP) represents an opportunity to spatially allocate human uses at sea to favour socio-economic development, supporting the sustainable use of its resources. In the Adriatic Sea, which is a severely used and highly ecologically valued marine area, the need for informed and balanced measures of resource exploitation is urgent and claims for MSP to meet both conservation and socio-economic regional objectives. This study proposes a method to understand and assess potential trade-offs between multiple ES. The study takes as example the relationship between the supply of multiple supporting ES and the provisioning ES related to fishery activity, recognized as pivotal among the diverse uses in the area. The method supports the identification of pair-wise trade-off relationships between ES. The spatial analysis depicts areas revealing high ES delivery potential and heavy fishing activity that could lead to the impoverishment of the capacity to provide the delivery of ES due to environmental damage. The results are discussed in order to support the elaboration of spatial management measures in order to cope the fishing industry needs and conservation. Our study highlights the necessity in including ES trade-off assessment in MSP to explore potential conflicts between economic activities and the delivery of multiple ES because of marine environment integrity.

SESSION 6: DESIGNING THE QUILT OF SUSTAINABLE OCEAN GOVERNANCE

Ecosystem Approach

Authors: Alida Bundy

Presenter: **Alida Bundy**

Review of Ecosystem Approach in relation to Integrated Management

EBM mandates and implementation

Authors: Mark Dickey-Collas

Presenter: **Mark Dickey-Collas**

Ecosystem-based management (EBM) requires a degree of coordination across countries that share ocean ecosystems, and among national agencies and departments that have responsibilities relating to ocean health and marine resource utilization. This needs political direction, legal input, stakeholder consultation and engagement, and complex negotiations. There is a common perception that within and across national jurisdictions there is excessive legislative complexity, a relatively low level of policy coherence or alignment with regards to ocean and coastal EBM, and that more aligned legislation is needed to accelerate EBM adoption. The Atlantic Ocean Research Alliance (AORA) created a task group comprised of an interdisciplinary mix of lawyers, social scientists, and natural scientists from Canada, the USA, and the EU. The task group characterized, compared, and synthesized the mandates that govern marine activities and ocean stressors relative to facilitating EBM in the North Atlantic. Formal mandates were identified across jurisdictions and, where possible, policy and other non-regulatory mandates. Irrespective of the detailed requirements of legislation or policy across AORA jurisdictions, or the efficacy of their actual implementation, most of the major ocean pressures and uses posing threats to ocean sustainability have some form of coverage by national or regional legislation. Still, numerous impediments to effective EBM implementation arise. These relate to the lack of integration between agencies and departments, a lack of adequate policy alignment, and a variety of other socio-political factors.

Precautionary Approach

Authors: David VanderZwaag

Presenter: **David VanderZwaag**

Review of Precautionary Approach

Social-ecological Systems approach

Authors: Eddie Allison

Presenter: **Eddie Allison**

Review of Social-ecological systems

Resource limitations, uncertainty and power plays: lessons from exploring a systems-based approach to ocean governance in the Benguela Large Marine Ecosystem

Authors: Astrid Jarre

Presenter: **Astrid Jarre**

Representing highly unequal, developing societies, the coastal countries of the Benguela Large Marine Ecosystem – South Africa, Namibia and Angola - have committed to implementing an 'ecosystem approach' to fisheries, defined in line with FAO guidelines. The three- dimensional view taken for the implementation of an ecosystem approach to fisheries has been beneficial with regards to other sectors (e.g., oil/gas, shipping, mining, tourism) operating in the marine environment, thus pointing to the "ability to achieve" as a necessary part of an ecosystem approach. There are two other integrated approaches to governance that are supported by active research in the Benguela region: integrated coastal zone management, and marine spatial planning. However, despite good overall marine governance legislation, effective implementation of any of these system-based approaches has been hindered by capacity problems and overall weak government institutions. Naturally extreme interannual variability, ecosystem regime shifts and climate change make medium-term predictions in the ecological subsystem highly uncertain, impacting the economies of industrialised fisheries and coastal livelihoods alike. In addition, uncertainties in global markets (where industrialised fisheries in southern Africa consider themselves to be price-takers), political uncertainty with regards to allocation of long-term rights, IUU fishing and organized crime in coastal fisheries (such as those for rock lobster and abalone in South Africa), and overburdened juridical systems (where even larger offences slip through) make things worse. Moreover, attempts to draw all stakeholders into governance and management processes are hindered by lingering historic inequalities, resulting in high levels of distrust on part of the historically and currently underprivileged members of the social-ecological systems of the Benguela. Working in this context requires a dedicated focus on conflict resolution and trust building in the long term. Any intended systems-based approach must not only take relationships into account, it must prioritise relationship-building as both a necessary condition and a tool. It is unclear from where the human and economic resources for these necessary initiatives are to be secured. While spatialised approaches to the management of multiple human activities in the ocean currently appear to be the preferred solution globally from the perspective of technical interactions of multiple sectors, much better results will be achieved - in any new system-based paradigm - through a considerably better integration of multiple dimensions regarding people and their ability to achieve if governments are to improve sustainability in the northern and southern Benguela subsystems. Since current weak government departments continue to operate in silos, marine management power will need to be transferred to new institutions: these will include (not be led by) relevant government departments and all stakeholders. Considerable social learning will be needed for such institutions to function, and for ocean governance in the Benguela to move towards sustainability.

Governing the ocean and coastal commons

Authors: Derek Armitage

Presenter: **Derek Armitage**

Ideas from social-ecological resilience, transformations and the commons have entered debates and discussions about ocean and coastal governance. Here, I reflect on how these approaches point to some important 'ingredients' that further complement and extend existing insights from the ecosystem-based and integrated management literatures. Some of these insights include the importance of multi-level and networked governance, the need for more attention to social learning and knowledge co-production, the importance of rights in providing a foundation for equitable ocean governance, as well as discourses of agency and power. Examples and cases from different contexts around the world will be used to highlight these ideas in practice.

Social licence for marine protected areas: A Tasmanian case-study

Authors: Rachel Kelly

Presenter: **Rachel Kelly**

Protected areas are considered one of the most important and valuable tools for conserving biodiversity and protecting natural habitats. Despite increasing evidence on the benefits of marine protected areas (MPAs) for biodiversity conservation and improving socio-economic conditions for local communities, designation and governance of MPAs has proved problematic. Understanding and improving social licence for marine protected areas is expected to reduce conflict and contestation and improve likelihood of MPA 'success'. Social licence is a concept that reflects community views and expectations on the use and management of natural resources, including the ocean. This presentation will outline the role social licence can play in improving MPA governance and management capacities, using Tasmania, Australia as a case-study. In 2014, as a result of historical opposition and a lack of social licence for MPAs, the Tasmanian State Government issued a moratorium on MPAs. We apply both qualitative and quantitative research methods to understand the current status of social licence for MPAs in Tasmania. We identify causes and events and which resulted in a lack of social licence and discuss how social licence for MPAs can be created and improved, aiming to further current understanding of social acceptance and support for marine conservation initiatives (e.g. marine spatial planning, co-management approaches) globally elsewhere.

Marine Spatial Planning

Authors: Maria Grazia Pennino

Presenter: **Maria Grazia Pennino**

The Marine Spatial Planning (MSP) is a relatively new approach to marine management. Actually, the first MSP workshop was held by UNESCO in 2006 in Paris, which makes this a recent movement considering the slow inertia and complexity to develop, establish and implement such a management system. However, since the beginning of its formulation there has been worldwide agreement on the need for such an approach. It is widely accepted that the MSP could be considered as a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that usually have been specified through a political process. In the last decade, various methodologies and conceptual and policy frameworks were developed to independently construct MSPs sometimes diverging from theoretical ideals. This presentation will focus on identify the most appropriate definition of the MSP, presenting its evolution with timeline, and its connection with all the others conceptual frameworks (e.g. Social-Ecological Systems Approach, Ecosystem Precautionary Approach, Integrated Management and Co-management) that are moving marine researchers nowadays with the common objective to attempt to find a balance economic and social development in addition to the environmental conservation of marine resources.

Integrated Management: Does it provide the pattern for the quilt of ocean Sustainability?

Authors: Robert Stephenson

Presenter: **Robert Stephenson**

This paper summarises the concept and uses of Integrated Management in order to provide the basis for comparison of concepts as they relate to the quilt of sustainable oceans governance.

The challenges and opportunities of integrating coastal management; a study of the New South Wales social-ecological systems approach

Authors: Kate Brooks

Presenter: **Kate Brooks**

Coastal and marine management in New South Wales (NSW) Australia has been dominated by ecological and economic approaches, implemented through multiple government agencies with overlapping jurisdictions and implementation effects. Further to a review of marine park management in 2012, the significant impact that social expectations, perceptions and values have on the success of these management programs, was recognised. In response, the government implemented the Marine Estate Management Act (MEM Act) in 2014, to integrate management of the marine estate.

Prior to the MEM Act, coastal infrastructure and estuarine management were governed as terrestrial activities remote from marine management - despite increasing awareness of the interconnectedness of these systems - and largely on an ecological basis cognisant only of economic impacts. Consequently, the primary challenge was not only the collaboration of four government departments to create a common vision for what they were collectively tasked to achieve, but consideration of, and accountability for, community values and expectations, in that vision and its implementation.

This paper discusses the multiple governance challenges for the NSW Marine Estate Management Authority (MEMA). Specifically, it explores the multiple challenges of governance related to: integrating planning and implementation processes of previously largely siloed government departments; to achieve equitable governance approaches for resource allocation between commercial / recreational fishers and recreational users of the coastal zone; recognition and integration of Aboriginal interests and knowledge into current processes; and, ensuring local government and community understanding of, and involvement in, the new approach, while ensuring ecological sustainability.

Agreement on a common methodology for achieving the MEMA vision, in a manner that addressed perceived deficiencies to marine coastal management identified by the NSW community in the 2012 review,

was the key to delivering one integrated plan of management for the coastal zone. Previously it had been managed by separate and, at times, potentially conflicting or duplicating, plans of management for marine and terrestrial coastal environments . MEMA adopted a social-ecological systems approach, in the two key elements of the framework utilised, being; establishment of community values (social and economic) associated with, and perceived threats and benefits to, the marine estate ; and the TARA (Threats And Risks Assessment) that was applied to the values and benefits identified in the community survey to identify a hierarchy of management priorities across government departments.
This paper focuses on the internal governance challenges of implementing the directives of the MEM Act, in the context of a social-ecological approach, the successes and the challenges that remain.

Session 7: Ecological feedbacks in the Earth System

How does varying the metabolic response of organisms to warming influence global particulate organic carbon export?

Authors: Emma Cavan, Stephanie Henson, Ross Corkrey, Philip Boyd

Presenter: **Emma Cavan**

Under future warming Earth System Models (ESMs) project a decrease in the magnitude of downward particulate organic carbon (POC) export of up to 12 % by 2100, suggesting the potential for ocean carbon storage will be reduced. Limitations caused by a lack of empirical data, mean the metabolic response of organisms to warming in ocean biogeochemical models typically varies only between heterotrophs and autotrophs, if at all. However, the few observations that do exist have shown other differences in temperature sensitivity exist; organisms residing in cool waters are more sensitive to temperature change than those in warmer waters, i.e. cool water organisms will experience a larger change in metabolism as the oceans warm. Metabolic processes such as microbial respiration are important in controlling the magnitude of POC exported from the upper ocean, and thus varying temperature sensitivity of microbes may influence POC export. Combining satellite data, metabolic theory and ESM outputs (RCP 8.5) we show that when increasing the temperature sensitivity of microbes in cool regions (< 13 C in line with empirical data), the projected decline of POC export globally by 2100 almost doubles, from 12 to 23 %. This suggests that current model projections of future POC export that do not account for biogeographical or functional group differences in metabolic response to warming, could be vastly underestimating the decline in the ocean's ability to store carbon. We also examine the appropriateness of applying a constant (across temperature) Q10 function (e.g. the Eppley curve for phytoplankton growth), and show Q10 varies as a function of temperature and taxa domain. We then discuss the observational data that is needed to update ocean biogeochemical models, to hopefully better simulate the future ocean's organic carbon cycle.

Comparison of two model approaches for describing phytoplankton adaptation to temperature

Authors: Inga Hense, Elisa Schaum, Aike Beckmann

Presenter: **Inga Hense**

We compare two different model approaches to model adaptation of phytoplankton through trait value changes. Both consider mutation and selection (MuSe) but differ with respect to the underlying conceptual

framework. The first one (MuSe-IBM) explicitly considers a population of individuals that are subject to random mutation during cell division. The second is a deterministic multi-compartment model (MuSe-MCM) that considers numerous strains of the population and where mutations are treated as a transfer of biomass between neighboring strains (i.e., a diffusion of characteristics in trait space). Focusing on the adaptation of optimal temperature, we show model results for different scenarios with different changes in environmental temperature and shapes of thermal reaction norm. For all cases, the differences between MuSe-IBM and MuSe-MCM are found to be negligible. Both models produce a number of well-known and plausible features. While the IBM has the advantage of including more mechanistic (i.e., probabilistic) processes, the MCM is much less computationally demanding and therefore suitable for implementation in three-dimensional ecosystem/biogeochemical models.

Can diatoms thrive in low silicic conditions?

Authors: Nmor Stanley, Lawal-Are O.A., Elegbede, I.O.

Presenter: **Stanley Nmor**

A preliminary assessment of stoichiometric ratio of elemental nutrient and their role in phytoplankton community structure in the upper neritic water of Lagos Lagoon, South-Western Nigeria was conducted. Monthly water samples (February – July 2016) were analysed for nutrient concentration using in-situ and discrete estimate measurement from the Laboratory. Examination of the nutrient profile showed a generally low concentration of Nitrate, Phosphate, and especially Silicate (< 1 mg/L). This low nutrient level resulted to the low abundance of phytoplankton species experienced (1570 cells) but a moderate diversity spanning across 5 taxonomical division. Community composition of phytoplankton was majorly dominated by diatoms accounting for 60% of the diversity. However, a single species of dinoflagellate (Prorocentrum sp) appears to be have the highest total abundance (cell count ~ 390). This might suggest some nuance shift in community structuring due to nutrient condition. Stoichiometric nutrient analysis of N:P:Si ratio shows that silicate appear to be the most limiting nutrient, thus an effect on the phytoplankton community. While the shift from a diatoms dominated community to dinoflagellate was less dramatic, we hypothesize scenarios which could have resulted to the success of diatom despite the limiting condition of silicate, chiefly among them include their inherent adaptive capacity as well as a tentative case for cellular size restriction allowing for rapid utilization of silicate whilst least effectively grazed by primary consumer.

The relative importance of phytoplankton light absorption and ecosystem complexity for the climate system

Authors: Rémy Asselot, Frank Lunkeit, Philip Holden, Inga Hense

Presenter: **Rémy Asselot**

While the complexity of Earth system models with respect to marine biota has increased over the years, the relative importance of biological processes in driving climate relevant mechanisms such as the biological pump and phytoplankton light absorption is still unclear. In particular, the effect of few versus many biological processes in ecosystem models on the global energy and heat budget has not been studied in detail. We have investigated the relative importance of ecosystem complexity and phytoplankton light absorption for climate studies. To shed light on the role of biologically mediated feedbacks, we performed model runs with the EcoGENIE Earth system model, with different degrees of complexity in the resolution of the marine ecosystem. Increasing ecosystem complexity has an impact on the carbon cycle, more specifically on the export production of particulate organic carbon and thus on the atmospheric CO_2. Phytoplankton light absorption modifies the sea surface temperature and the oceanic circulation affecting therefore the atmospheric temperature. But increasing ecosystem complexity and phytoplankton light absorption do not have the same impact on the climate system. We determine which processes are particularly relevant for the climate system and should thus be taken into account.

The bottleneck of marine ecological feedbacks on atmospheric pCO_2

Authors: Wolfgang Koeve, Angela Landolfi, Paul Kähler, Andreas Oschlies

Presenter: **Wolfgang Koeve**

The biological carbon pump (BCP), i.e. the production of organic matter in the surface ocean, its export to and degradation in the ocean interior, contributes significantly to the surface-to-deep marine inorganic carbon gradient and hence provides an important control on atmospheric CO_2 and climate on long time scales. The strength of the biological pump (i.e. the amount of respired carbon stored in the ocean interior) may change if either the export of organic matter, the flux attenuation in the ocean interior or the residence time of respired carbon in the ocean interior changes. For the transient period of human-induced climate change (e.g. 1850 to 2100), current models suggest that the strength of the biological pump actually increases despite a decrease in export production, as is evident from a decrease in ocean oxygen and an increase in apparent oxygen utilization. This transient change in biological pump strength, however, does not translate 1:1 to a respective carbon exchange with the atmosphere. Using an Earth System model of intermediate complexity we show that the erosion of the surface ocean CO_2-buffer capacity, a direct effect of the uptake of anthropogenic CO_2 by the ocean, is a gate-keeper of the CO_2 flux attributable to changes of the biological pump. For different CO_2-emission scenarios, the effective atmosphere-ocean carbon flux attributable to BCP-change is 2-5 times smaller compared to what might be expected from the change in BCP strength. We propose that the buffer capacity erosion affecting all atmosphere-ocean carbon fluxes provides a general bottleneck of marine ecological feedbacks on atmospheric pCO_2 under transient climate conditions.

The reversibility of anthropogenically-forced change in biogeochemical drivers in the North Atlantic. Can we still go back to pre-industrial levels?

Authors: Leonardo Bertini, Jerry Tjiputra

Presenter: **Leonardo Bertini**

Are pre-industrial levels really a thing of the past? With the advancement of Earth System Models (ESMs) and a better understanding of the intricacy of the ocean carbon cycle, it is possible to simulate how biogeochemical drivers would respond to different mitigation scenarios on global scales, thus making the future of our oceans become less opaque, helping tailor decisive policies to safeguard resources and our well-being.
This study's approach is based on analysing the projected outputs from one of the Coupled Model Intercomparison Project Phase 5 (CMIP5) models, the Norwegian Earth System Model (NorESM), which performs an idealized scenario of increasing atmospheric CO_2 (1% yr^{-1}) from pre-industrial levels for 140 years followed by another 140 yr of a reversing atmospheric CO_2 trend (decreasing at 1% yr^{-1}) returning to the preindustrial level. The model continued to run for another 200 years so that long-term responses could also develop and be studied. The annual rates of increase and decrease in CO_2atm follow the standard

protocol of the Carbon Dioxide Removal Model Intercomparison Project (CDR-MIP). Prior to this run, the model was spun-up by 900 years, reaching a near-equilibrium state with a mean CO_2atm of 284.7 ppm. Our analyses assess the biogeochemical responses simulated by this rapid warming and cooling climate change scenario, focusing on determining their time-scales as well as the persistence of the anthropogenic signals and the extent of projected reversibility. The overall goal is to look at how these projected changes would affect the ocean carbon cycle at particular domains of the North Atlantic (NAtl) and how this would ultimately affect ecosystem services and deep ocean life, which is particularly sensitive to changes in pH, dissolved oxygen, vertical export of carbon, carbon compensation depth, and aragonite saturation states. The preliminary results for the NAtl pH Time of Departure (ToD), which can be defined as the moment the time series departures from intrinsic pre-industrial fluctuations (i.e. those driven by non-anthropogenic forcing) have shown that the mesopelagic interior (depth= 500 m) is expected to experience the effects of ocean acidification in ToD=13±4 yr, reaching its lowest pH in Tlowest=151±7 yr after the start of the ramp up (decreasing from pH=8.14 to 7.61). An increase in pH levels again (Tlag) is only seen 11±7 yr after the start of the mitigation phase. A recovery (Trcvr) in the mesopelagic NAtl is expected 476±46 yr after the start of the ramp up, when stabilized pH levels are predicted to be, on average, 0.17% lower than the mean pre-industrial pH. On the other hand, the base of the epipelagic zone (depth= 200 m) is expected to experience the effects of ocean acidification even sooner (ToD=6±1 yr) reaching its lowest pH 155±10 yr after the start of the ramp up, decreasing from pH=8.15 to 7.56. Our focus is now on determining how the Particulate Organic Carbon flux (POCflux) to the NAtl deep ocean is affected by this mitigation scenario, analyzing changes in its magnitude, timescales, and reversibility trends.

An observation-based, objective classification of plankton functional types for use in climate and Earth System models

Authors: Meike Vogt, Fabio Benedetti, Luana Krebs, Colleen O'Brien, Damiano Righetti

Presenter: **Meike Vogt**

Marine ecosystem modules included in global climate and Earth System Models have often been criticized for the fact that they are at the same time too simple, thus not including key organism groups and interactions, and too complex, given the lack of parameters to describe the biogeography, physiology and ecology of the represented plankton groups. In recent years, novel observational data sets with a fine taxonomic resolution have become available that allow for the objective classification of observation-driven plankton functional types based on biogeographic, ecological or functional criteria, and the evaluation of marine ecosystem models against these data. We show that novel statistical clustering methods used in combination with extensive observational data sets are successful in determining a minimal number of functional groups based on ecological niche or functional trait characteristics for multiple phyto- and zooplankton groups, and also in the identification of each cluster's key environmental drivers and ecological niche characteristics. The number of species clusters differs between groups, with mesozooplankton and calcifying phytoplankton requiring a finer taxonomic resolution than the silicifying diatoms. We further show that ocean biomes with similar marine ecosystem structure and biogeochemical function can be determined based on a limited subset of the full marine plankton diversity, thus suggesting that the simplification of biological complexity in models can be successful at reproducing large scale ecological and biogeochemical structure. We argue that future models should include a minimal number of plankton functional types defined based on objective data analysis, with novel imaging and metagenomic data sets containing a wealth of information to be exploited for the development of the next generation of Earth System and climate models.

The impact of variable phytoplankton stoichiometry on projections of primary production, ocean carbon uptake and trophic cascades in the global ocean

Authors: Lester Kwiatkowski, Laurent Bopp, Olivier Aumont

Presenter: **Lester Kwiatkowski**

Ocean biogeochemical (OBGC) models are integral components of Earth System Models (ESMs) used to project the evolution of the ocean carbon sink, as well as potential changes in the physical and chemical environment of marine ecosystems. In such models the stoichiometry of phytoplankton C:N:P is typically fixed at the Redfield ratio. The observed stoichiometry of phytoplankton however, has been shown to considerably vary from Redfield values due to plasticity in the expression of phytoplankton cell structures with different elemental compositions. The intrinsic structure of fixed C:N:P models therefore has the potential to bias projections of the marine response to climate change. We assess the importance of variable stoichiometry on twenty-first century projections of net primary production (NPP), food quality and ocean carbon uptake using the recently developed PISCES-QUOTA ocean biogeochemistry model. PISCES-QUOTA projects similar twenty-first century global NPP decline (7.7 %) to current generation fixed stoichiometry models. Global phytoplankton N and P content or food quality is projected to decline by 1.2 % and 6.4 % over the twenty-first century respectively. The largest reductions in food quality are in the oligotrophic subtropical gyres and Arctic Ocean where declines by the end of the century can exceed 20 % and result in trophic amplification of plankton biomass declines. Using the change in the carbon export efficiency in PISCES-QUOTA we estimate that fixed stoichiometry models may be underestimating twenty-first century cumulative ocean carbon uptake by 0.5-3.5 % (2.0-15.1 PgC).

The abundance and biogeochemical role of fish in the ocean

Authors: Daniele Bianchi, Eric Galbraith, David Carozza, Jerome Guiet

Presenter: **Daniele Bianchi**

Fish and other consumers are major components of marine ecosystems, yet their role on the cycles of nutrients, carbon and oxygen is still poorly known. This lack of knowledge is particularly severe given the profound alterations caused by industrial fisheries. Here, we use an inverse modeling approach, synthesizing fish harvest reconstructions and stock assessment data in combination with a process-based ecologic-economic model, to estimate the pristine biomass of harvested fish in the ocean, its historical reduction by fishing, and the associated changes in biomass cycling rates. Our results indicate a global pristine biomass for commercially harvested fish of 3.3±0.5 Gt, that collectively consumed biomass at a rate of 9.4±1.5 Gt y^{-1}, equivalent to 1.2% of the available primary production, and reaching up to 6% of in cold, fertile shelf seas. Fish egestion supported approximately 2.4% of particle production and export from the upper ocean, with contributions up to 5% in subtropical and tropical waters, and significant implications for deep carbon export. We estimate that, by the 1990s, this biomass had been halved, and the associated cycling rates reduced by a third. These results suggest that the global fishery may have had a significant direct impact on the cycling of organic matter and nutrients in the marine ecosystem, which is currently not accounted for in Earth System Models.

The marine size-spectrum and human effects on oceanic systems

Authors: Ian Hatton, Eric Galbraith

Presenter: **Ian Hatton**

The size-spectrum is the observation that ocean ecosystems exhibit a near inverse size-frequency distribution that has long been hypothesized to encompass all marine organisms. This means that from bacteria to whales, the total biomass is constant across all logarithmic size classes. Despite the fundamental importance of this pattern for aquatic ecology, and many areas of applied ocean science, from fisheries to global change, it has never been formally tested in the oceans across the full size range. Here we bring together data from numerous sources to test the regularity of this pattern in ocean communities. We propose simple models that could help explain this distribution and discuss how this possibly universal marine pattern has importance for setting conservation targets and its use as a framework for studying human effects on ocean functioning.

Integrating humans into a global model of the marine wild-capture fishery: small-scale fishing by coastal communities

Authors: Kim Scherrer, Eric Galbraith

Presenter: **Kim Scherrer**

The global wild-capture fishery is an illustrative example of a coupled human-ecological system. Fishing is an important component of the coupled system, as it may alter the resilience, size-structure and functioning of marine ecosystems. It also provides human benefits. However, in most large-scale oceanic models, this interaction between humans and the marine system is missing. Previous work on modeling fishing has imposed observed or reconstructed fishing pressure, or represented fishing dynamically as driven by economic motives, but much fishing effort occurs for reasons other than monetary profit. Humans may also fish because it is a meaningful activity that provides food and employment. Such different motives for fishing likely result in different dynamical interactions between humans and the marine system, and different outcomes for human well-being. This study explores how alternative motives for fishing could be represented in a global model that resolves both the marine ecosystem and fishing, and that is compatible with conducting multi-decadal simulations in an Earth System modeling environment. Specifically, we develop a way to model simplified small-scale/subsistence fishing undertaken by the human coastal population, thus linking the fishing activity in the ocean to human communities on land. This representation of small-scale fishing can potentially interact with industrial profit-driven fishing, and raises interesting hypotheses about the potential for long-term sustainability and the benefits that humans can obtain from marine ecosystems.

Human influence on the nutrient cycling by the global commercial fish community

Authors: Priscilla Le Mézo, Eric Galbraith, Daniele Bianchi

Presenter: **Priscilla Le Mézo**

Fish assimilate and recycle essential elements throughout the course of their lives. Elements are retained in the fish body to build new biomass or to be stored, or excreted or egested back to the water, with possible effects on ocean nutrient cycling and thus primary productivity. Human activities can alter this link between fish and nutrient. Through fishing activity, fish are removed from the ocean worldwide, potentially modifying the nutrients cycling by the global fish biomass, but assessing this effect has been hampered by the difficulty of quantifying the global fish biomass. Here we quantify the role of commercial marine fish in the cycling of nitrogen, phosphorus and iron in the global ocean, with and without the presence of fishing activity, by using a global size-spectrum model of commercial marine fish biomass.
Our results demonstrate that the amount of nutrient stored in pristine fish biomass was particularly significant compared to the ambient nutrient concentration in seawater in the nutrient-poor regions of the world: the North Atlantic for phosphorus (up to 60%), the oligotrophic gyres for nitrogen (up to 200%) and the iron-limited regions for iron (up to 20%). In the global ocean, cycling by commercial fish biomass accounted on average for less than 6% of the primary productivity demand for N and P in productive areas, and for Fe in iron-limited regions. Relative to the export of N, P and Fe, fish egestion can account up to 10% in the oligotrophic gyres of the world. Iron contained in fish egested material also represent a non negligible part of Fe export in HNLC regions, up to more than 30% in the equatorial Pacific. The magnitudes of these fluxes suggest that fishing activity may have significantly altered nutrient cycling in some areas, and suggest that online coupling of fish with biogeochemical models, including interactions with sinking particles, are warranted.

SESSION 8: ECOSYSTEM-SOCIAL INTERACTIONS IN MARGINAL SEAS

New challenges for Marine Ecosystem Based Management-- A Lesson from Macro-algae Bloom

Authors: Song Sun, Xiaoxia Sun, Tian Yan, Rencheng Yu

Presenter: **Song Sun**

In the Summer of 2008, the world's largest green macroalgae blooms (green tide) caused by Ulva prolifera occurred in Qingdao, a city at the west coast of the Yellow Sea and the host city of 2008 Olympic sailing events. The green tide caused damages to the tourism, marine transportation and brought environmental problems. The "green monster" led to the costs of billion of Chinese Yuan while ten thousand of people were involved in combating the green tide. Since then, green tide has been visiting the west Yellow Sea every summer, bringing big troubles to the central and local marine environment managers.
In the last ten years, one of the popular topics is that where the massive Ulva prolifera come from, what cause the green algae bloom, and the most important: who should take responsibility of the green algae bloom, so it is not only a scientific problem, but social and concern local governments. Scientist must tell people the truth and the systematic solution to prevent or reduce the damage of the green algae bloom. on the other hand, some people do not scientist to reveal the truth, because it will affect the local economy and some people should take responsibility, they will continue to ask scientist offer “more data and details”, it is a new challenge for the ecosystem based management, because the problem occurred in one area, but it affect other areas, to prevent and reduce the affection, it need investment and cost a big money. From

2015-2018, a comprehensive “Green Tide” Project has been conducted to find out the origin in Shandong and Jiangsu provinces. This project focus on the disaster mitigation of green tides (induced mainly by Ulva prolifera) in the south Yellow Sea. Significant progress has been made on the mechanism of formation and the strategy of mitigation of the green tides in multidisciplinary studies, during which more than 20 cruises in the South Yellow Sea were conducted and multiple research methods applied, including on-site investigation, satellite remote sensing, and simulation experiment, etc. The results show that the massive floating U. prolifera could be traced back to the offshore aquaculture areas in Subei Shoal, North Jiangsu. A proposal how to prevent the green algae bloom happen in Qingdao was submit to the central government before the Shanghai Cooperation Organization summit, this proposal was accept and carried out along the coast of Yellow Sea, it was very successful; it is a lesson for the Ecosystem Based Management, challenges and solutions.

Towards a common framework for marginal seas socioecological research: case studies from Norwegian and Chinese coastal systems

Authors: Richard Bellerby, Phil Wallhead, Jie Liu, Halvor Dannevig, Jiangzhong Ge, Su Mei Liu

Presenter: **Richard Bellerby**

Continental marginal systems are undergoing rapid change following human activity and climate change. Interdisciplinary research on continental margin systems, with strong integration of stakeholder knowledge and feedback, is necessary in order to deliver local and regional scientific knowledge at the relevant scales for ecosystem service optimization and management. Accordingly, IMBER and Future Earth Coasts are supporting a working group which has the goal of developing a framework for sustainable development of resources and advising governance regimes to facilitate sustainable governance, facilitating equitable sharing of margin resources, and evaluating alternative research approaches and partnerships that address major margin challenges. This presentation will discuss case studies for Norwegian and Chinese marginal seas, where co-production through stakeholder engagement has enhanced local understanding of climate change and ocean acidification effects and ecosystem management.

Environment status under the impact of eco-aquaculture—A case study in Sanggou Bay, the western Yellow Sea

Authors: Su Mei Liu, RuiHuan Li, ZhiMing Ning, WenQi Xu, Jing Zhang, JianGuang Fang

Presenter: **Su Mei Liu**

Marine aquaculture is increasingly an alternative to provide a growing human population with high-quality protein. However, aquaculture of high value species relies on external food supplies and has a negative impact on water quality. Where aquaculture is to be embedded in coastal ecosystems, the inter-connections between production systems and the environment must be thoroughly understood. Although culture of seaweeds, which can reduce nutrient loadings to the environment from fish aquaculture, has not been attractive in many countries as algal products typically have a low value, combining different species in aquaculture systems could provide more profit and concomitant ecological benefits.
Sanggou Bay is located on the eastern tip of Shandong Peninsula, the western Yellow Sea and is well known in the field of marine aquaculture, especially in integrated multi-trophic aquaculture (IMTA). Overall, >100 km^2 of the 163 km^2 bay area are used for aquaculture, producing >24□104 tons/yr of seafood including

more than 30 important species such as kelp, scallops, oysters, abalone and sea cucumbers using various culturing methods such as long-lines, cages, bottom sowing and enhancement. Compared with other bay for aquaculture, nutrient levels are still low in Sanggou Bay, while nutrients composition and phytoplankton community have been changed. Large quantities of DIN and PO43– were removed from the bay through seaweed and bivalve harvesting. The benthic nutrient fluxes and total organic carbon of sediment in the IMTA system in Sanggou Bay were significantly lower than those in monoculture areas due to the efficient recycling of organic matter in the IMTA system. Implementation of IMTA in Sanggou Bay has been successfully practiced since the late 1980s, improved economic benefits, maintained environmental quality, created jobs.

Taking Stock: Status and Trends in East China Sea fisheries

Authors: Louise Teh, Tim Cashion, William Cheung, U. Rashid Sumaila

Presenter: **Louise Teh**

The East China Sea (ECS) Large Marine Ecosystem (LME) is one of the most important fishing grounds in the west Pacific, and is bordered by 4 large fishing nations – Mainland China, Korea, Japan, and Taiwan (China). Fisheries play a crucial food, economic, and cultural role in ECS countries; hence the sustainability of ECS fisheries resources and marine habitats is paramount to the future social-economic well-being of the region. As the most productive of China's four seas, the ECS is consequently also of significant importance to global fisheries, given China's leading role in worldwide marine fisheries production. However, intense fisheries development and exploitation over the past 4 decades has depleted fisheries stocks and changed the structure of ECS marine ecosystems. At the same time, rapid economic development and urbanisation in ECS countries has resulted in high levels of coastal pollution and habitat destruction and loss, thereby exacerbating the effects of overfishing. Inshore fisheries resources are largely depleted, leading to serious livelihood consequences for the estimated ECS fishing population of around 1.4 million, the majority of whom are engaged in small-scale fisheries.

At the national level, all ECS countries have implemented management measures to rebuild fisheries; however, overcapacity is still a persistent issue for the region's fisheries. Moreover, despite multiple bilateral fisheries management agreements between China, Japan, and Korea, ongoing territorial and political disputes inhibit multilateral management of the region's fisheries. The lack of cooperative, multilateral management is a large barrier towards sustainable management of the ECS' commercially important fisheries stocks, many of which are migratory and move between the exclusive economic zones of ECS countries. The future of ECS fisheries also faces uncertainties arising from climate change, which has already been associated with shifts in species distribution and hence affected the spatial distribution of fishing effort.

While the fisheries of individual ECS countries have been extensively documented, there is a gap in recent studies which provide a cohesive assessment about the status and socio-economic importance of fisheries at the Large Marine Ecosystem level. This study fills the existing gap by reviewing the recent socio-economic, governance, and biological status of, and threats to, ECS fisheries at the LME level. This allows us to identify the societal and ecological consequences of continued fisheries unsustainability in the ECS. By doing so, this study aims to provide an impetus for encouraging multilateral cooperation in ECS fisheries management in order to reduce present threats, rebuild fisheries, and manage future social-ecological and environmental risks. This is essential in order that ECS marine ecosystems are resilient and fisheries resources can continue to support the region's human, social, and economic well-being into the future.

Fisheries management toolbox: A fishers' self-assessment scheme to identify visions and next actions toward sustainable development of coastal communities

Authors: Shion Takemura, Mitsutaku Makino, Hidetomo Tajima, Hiroyuki Miyoshi, Hideo Saito, Tomoki Yamane and Shigeru Mukai

Presenter: **Shion Takemura**

Japan is one of the world's largest fish-eating countries with a long history, but recently stable supply of marine products and sustainable development of coastal communities are urgent issues due to various changes in both natural environment and society. In Japan, administrative agencies and local fishers are engaged in various efforts for resource management and fishing village development through close dialogue and discussion. In order to promote dialogue and discussion with stakeholders for sustainable fisheries, new tool is required for fishers to evaluate their own activities and to utilize their self-assessment results for the visions and next actions toward sustainable development of coastal communities.
Objectives of this study are to introduce a concept and methodology of Fisheries Management Toolbox (FMTB), which is self-assessment scheme for fishers and to discuss the practical solution in Shimonoseki city, Yamaguchi prefecture.
2. Methods
2.1 Fisheries Management Toolbox
In 2009, Japan Fisheries Research Agency developed a theoretical version of FMTB. It is a kind of theoretical catalogue of various management measures. But the theoretical FMTB was not user (fishers) friendly, therefore more practical version of FMTB was developed . Furthermore, various activities related to coastal community development were also added to FMTB, and its' framework was also expanded to sustainable developments of coastal communities.
2.2 Fishers' group discussions
Group discussions were conducted for four fishers' groups in Shimonoseki-Gaikai area, Shimonoseki city, Yamaguchi prefecture, western Japan. In these group discussions, facilitators explained about good practices of innovative fisheries management activities to fishers using by FMTB. Then, fishers and facilitators discussed about fishers' activities, their problems, and ideas of improvements within each fishers' group. Finally, we identified visions and next actions toward sustainable developments beyond the fishers' group.
3. Results and Discussion
Each fishers' group identified the condition of fishing ground, their present activities, their problems, and ideas of improvement during the group discussion. This result indicated that FMTB allowed to identify not only present activities and their problem but also local resources such as fish species, human resources, fishers' techniques, and food cultures in four fishers' groups.
In addition, common activities, problems, and local resources among four fishers' groups that operated various fishery types in different locations were identified. Based on these commonalities, we identified visions and next actions that should be implemented in cooperation across the fishers' group. These results showed that FMTB promoted dialogue and discussions with stakeholders to identify visions and next actions toward sustainable development in Shimonoseki-Gaikai area.
Further research is necessitated an assessment on the changes of fishers' activities before and after the implementation of the fishers' group discussions in order to clarify the effectiveness of FMTB in the promotion of sustainable fisheries.

Managing dive ecotourism in the Western Gulf of Thailand

Authors: Thamasak Yeemin, Makamas Sutthacheep, Wichin Suebpala, Sittiporn Pengsakun, Wanlaya Klinthong, Charoenmee Chamchoy, Laongdown Jungrak, Supawadee Hamanee, Chainarong Ruangthong

Presenter: **Thamasak Yeemin**

The Gulf of Thailand is a large marine ecosystem located in the western part of the South China Sea, a marginal sea of the western Pacific, where coral reefs are important treasures for marine tourism. However, the degradation of coral reefs has been reported due to natural and anthropogenic disturbances such as coral bleaching, coastal development and urbanization etc. Dive tourism with improper management also generates negative impacts and delays natural recovery process of degraded coral reefs. In this paper, we propose the management measures for dive ecotourism in Chumphon Province, the Western Gulf of Thailand using a transdisciplinary approach. The ecological, socio-economic, and tourism surveys were conducted to gather relevant information i.e. ecological data, socio-economic, and tourism development. The results reveal that three key considerations should be focused to manage dive ecotourism in the Western Gulf of Thailand including a) developing new dive sites, b) controlling number of divers and diving activity, c) increasing environmental awareness of stakeholders. Developing new dive sites may help reduce pressures from the main dive sites such as Ko Samui, Ko Phangan, Mu Ko Ang Thong in Surat Thani Province, Pattaya in Chonburi Province, Phuket Province, etc. where the number of tourists during the peak season is always greater than its tourism carrying capacity. Our surveys indicate that as many as fourteen coral communities and nine underwater pinnacles in Chumphon Province can be potentially developed and promoted to attract tourists from the main dive sites. Although the current number of dive tourists in Chumphon Province is still below its tourism carrying capacity, the number of tourists would be rapidly increased in the future due to tourism promotion. Precautionary measures should be established to control the number of tourists within the carrying capacity. Also, we suggest ecotourism concept with multisectoral collaboration as well as enhancing stakeholders' conservation awareness, particularly divers, dive operators, and fishers, should be applied to ensure the sustainability of ecological integrity and social-economic viability. This study provides an integrated baseline information to support sustainable ecotourism management along with coral reef conservation in Thailand.

Multiple threats to Western Baltic cod fishery

Authors: Xochitl Cormon, Steffen Funk, Stephanie Haase, Saskia Otto, Rene Plonus, Jörn Schmidt, Heike Schwermer, Rudi Voss and Christian Möllmann

Presenter: **Xochitl Cormon**

Western Baltic social-ecological system (SES) is, since the last fifteen years, the stage of anthropogenic and environmental changes inducing substantial social and economic consequences. Interactions between the different components of the system need to be disentangled to understand current crisis.

We first reviewed current knowledge of Western Baltic cod fishery SES core components, as cod is the most important commercial species in this area. We gathered relevant qualitative and quantitative data to describe each of them. Relevant variables were chosen to describe each core component: (1) changes in abiotic features and trophic interactions, and their potential consequences, were reviewed to understand the resources system; (2) stock-recruitment dynamics were investigated to understand changes in resource unit productivity; (3) recent changes in regulation and stock assessment quality were evaluated to understand governance efficiency; (4) social and economic attributes and expectations in terms of sustainability of the different users of the system were reviewed. In a second part, we discuss ecological-social interactions under growing environmental and anthropogenic stressors.

This review highlights gaps in knowledge of Western Baltic cod SES functioning, and the ecological-social interactions of the system. It also provides insights about climate change, environmental changes and multiple management measures, effects on the Western Baltic cod productivity, its associated fishery and the resulting conflicts. Finally, the study highlight needs and future directions to support a comprehensive management of the system and achieve an ecologically and economically sustainable exploitation of Western Baltic cod stock.

Ecosystem-based management under a changing environment via outputs from coupled marine physical and biogeochemical models and participance of stakeholders

Authors: Jie Liu, Richard G.J. Bellerby, Jianzhong Ge

Presenter: **Jie Liu**

As human pressures on the natural environmental increase through the Anthropocene and simultaneously, our demand for marine ecosystem services grow, it is paramount that adequate tools needs to be developed for good marine ecosystem governance and management. The development of such governance and management requires an understanding of the constituent physic-chemical, biological and socio-economic systems, as well as their connectivity. The efficient and relevant development of coastal management protocols could only be realized when there forms a comprehensive understanding of how the ecosystem changes with the changing environment. To realize the goal, both coupled marine physical with ecosystem models and involvement of stakeholders are needed.
Coupled marine physical and biogeochemical ecosystem models are of fundamental importance in fortifying assessment, management and policy support. Outputs from physical FVCOM (Finite-Volume, primitive equation Community Ocean Model)/ ROMS (Regional Ocean Modeling System) coupled with biological ERSEM (European Regional Seas Ecosystem Model) for both Norwegian and Chinese marginal seas are to be analyzed to develop scenarios for the scale, rate and phenology of critical drivers of organism and ecosystem function.
The natural scientific information about sustainable development of marine ecosystem services concerning how they change in a changing environment would only be ideal but not be meaningful if the social and economic expectations of the stakeholders, who live on take benefits from ecosystem services, are not considered. So we will need to provide targeted knowledge of ecosystem functioning and services changes to different stakeholders, meanwhile, to adjust models analysis according to their needs, thus to help them adapt to global change.

Response of nutrient compositions affected by human activities in the lower Yellow River （Huanghe）

Authors: Wu Nian, Liu Su Mei, Zhang Gui Ling, Zhang Hong Mei

Presenter: **Wu Nian**

The Yellow River was once the second largest sediment transport river in the world, however, the water discharge and sediment load have deeply influenced by the water-sediment regulation events and decreased recently, resulting in the nutrient transport patterns obviously shifted which sensitively impacted by intensive anthropogenic activities and have significantly affected the adjacent Bohai ecosystem. While, how nutrient concentrations specifically influenced by the societal and governing responses are unclear at present. Therefore, nutrient concentrations and fluxes in the lower reaches of the Yellow River were investigated using biogeochemical observations carried out during 2001-2018. The average concentrations of the nutrients were 302±75 μM for DIN, 31.1±31.9 μM for DON, 107±33 μM for DSi, 0.33±0.21 μM for DIP, 0.29±0.11 μM for DOP, in which DOP concentrations increased from 2009, even reached up to 95% in the TDP, while there were decreasing trends of dissolved inorganic nutrient concentrations and fluxes, which could result from the decrease in evaporation/precipitation, water and sediment load, fertilizer application, atmospheric nitrogen oxide emission and weathering intensity in the Yellow River Basin. And from 2014 onward some extremely low nutrient concentrations occurred which could be caused by the uptake of phytoplankton during the low water discharge and suspended particulate matter (SPM) period. With the development of economy and under the implementation of national environmental protection policies, the urbanization has intensified and the industrial structure has greatly changed in the middle-lower reaches of the Yellow River Basin, combined with the reduction of inorganic nutrient concentrations and fluxes in the river, the eutrophication might gradually decline.

Small-scale fisheries and tourism: a two-faced charade?

Authors: Ana Helena Bevilacqua, M. Grazia Pennino, Rachel A. de Lima Costa, Ingrid van Putten, U. Rashid Sumaila, Adriana R. Carvalho

Presenter: **TBD**

We investigate the socioeconomic dependence on fisheries in eight coastal communities with and without tourism and its direct or indirect impacts on these fishing communities. A combination of production and economic information jointly with fishers'(social) indicators were applied to test dependence on fisheries. Overall, the economic income from fishing was significantly different between communities that rely or not on tourism, mostly due to differences in revenue, net income and profit from fishing. Fishing was the only source of income (100%) for most fishers in non-tourist communities and for 41% of the fishers in tourist places. Regardless if a fisher lived or not in a tourist place, his/her fishing experience and the CPUE from targeting more expensive species for the tourist market defined his/her economic dependence on fisheries. Also, the more experienced fishers showed a higher chance of depending only on fishing income: for each additional year of experience, their dependency increases by 1.03 times. Ideally, the benefits of tourism should be shared across the community where it is practiced, avoiding fishers' displacement. Tourism should also be done without increasing pressure on the ecosystem services it depends upon to avoid moving the concerns from an economy that depends only on one sector (i.e. fisheries) to an unsustainable environment-centred one.

Session 9: Food web dynamics and contaminants: interactions with global environmental change and implications for food security

Contribution of nuclear applications to study the transfer of contaminants in marine organisms and to promote seafood safety.

Authors: Peter Swarzenski, Marc Metian

Presenter: **Roberta Hansman**

Marine pollution is often seen as a major concern today due its negative impact on organisms and can be a substantial risk to seafood consumers. Moreover, environmental stressors to marine ecosystems are numerous and can range from locally sourced contaminants (e.g. land-based pollutants) to global stressors (such as gradual rise in temperature and the acidification of the ocean). This can have consequences on marine biodiversity, on seafood safety, and on food security.
To better understand contamination kinetics in marine organisms and to assess potential contamination in downstream seafood consumers, a suite of nuclear applications can be optimized using experimental aquaria. This is a very powerful approach that allows identifying the susceptibility of fish and seafood that may become contaminated by pollutants. In particular, the assessment of contaminant bioaccumulation and retention rates in organisms in a changing environment (e.g. higher temperature, lower pH and/or lower dissolved oxygen) using high-efficiency gamma spectrometry.
Furthermore, nuclear applications can also be used to investigate contamination risk of fish and shellfish consumers. For example, it can help understand the transfer of inorganic contaminants from the fish or shellfish to consumers using radiotracers with in vitro digestion methods.
Major advantages of radiotracer techniques over conventional techniques are their very high sensitivity and discrimination capacity: it permits the measurement of bioaccumulation kinetics of several elements at realistic (viz. low) environmental concentrations in a single experiment. Some radiotracer techniques enable the non-destructive analyses of contaminant levels in living organisms.
This paper identifies how nuclear techniques can help study current and future threats to marine realm or people feeding from sea.

Better knowledge on food web structure and functioning can help improving stocks and ecosystems management

Authors: Marianne Robert and Dorothée Kopp, Dorothée Kopp, Marianne Robert, Hervé le Bris, Jonathan Rault, Pierre Issac, Margaux Denamiel, Louise Day Lionel Pawlowski

Presenter: **Marianne Robert**

This presentation will synthetize the mains results and perspectives of the EATME project which aimed at better understanding the food web structure and functioning to inform stock and ecosystems management in the Celtic sea. Over the thee years of the project, more than 1000 stomachs of the then most important commercial species and 1200 muscles samples (from top predators to primary consumers) for stable isotope analysis were collected in November on board the EVOHE scientific survey in the Celtic sea. This important sampling effort has allow characterizing the spatial structure of the food web from shallow area to the slope of the continental shelf. Trophic ecology of the main commercial fish species were compared using both stomach content analysis and stable isotope as complementary tools. We identified the main competitions for food resources between top predators and better understand co-occurrences conditions between the two species of anglerfish. This data were also used to better inform diet matrix of ecosystem models such as Ecopath with Ecosim using a new methodology to integrate information coming from various sources (stomach content, stable isotope and literature). Finally, a more management oriented model of SMS type (Stochastic Multi Species) is still under development. In the future, such model could help in understanding how management objective and rules might be affected by taking into account species interaction in mixed fisheries (Multi species FMSY ec …).

Ecosystem regime shifts affect the bioaccumulation of essential and non-essential hazardous metals in coral reef-associated mesopredatory fish

Authors: Magali Sabino, Nicholas Graham, Tessa N Hempson, James PW Robinson, Paco Bustamante, Carine Churlaud, Nathalie Bodin

Presenter: **Nathalie Bodin**

As highly diverse and productive ecosystems, coral reefs offer numerous ecological goods and services, in particular for small island states that rely mainly on marine resources. Yet, they are also facing increasing anthropogenic pressures including global warming, overfishing and contaminant inputs, resulting in critical damage to coral reefs and in extreme cases regime shifts to macroalgae. Located in the western Indian Ocean, the reefs of the inner Seychelles have experienced two recent major bleaching events (1998 and 2016), with mean losses of 50-90% coral cover. Although many areas show signs of coral recovery, other reefs shifted to stable macroalgal-dominated reefs, which are likely to provide fewer ecosystem services and fewer ecological and nutritional benefits for many associated organisms, including humans. For instance, regime shifts in Seychelles' reefs led to shortened reef-associated food chains with mesopredators, targeted species of local small-scale fisheries, being less abundant and having lower trophic levels (nitrogen stable isotope values) and food-derived energy stores (tissues' lipid concentrations) in macroalgae systems. Here, we investigated the effects of coral reef ecosystem regime shifts on the bioaccumulation of essential and non-essential hazardous trace minerals in the mesopredatory bluespotted grouper, Cephalopholis argus. Trace minerals together with carbon and nitrogen stable isotopes were measured in the muscle of 60 C. argus collected from three coral-dominated sites and three regime shifted macroalgal-dominated sites. Using generalized additive models, we show the influence of habitat on trace mineral bioaccumulation, with fish size, and trophic position having an effect on their concentrations, depending on the mineral considered. We thus bring insight into the effects of habitat variation on mesopredatory fish mineral composition and the consequences for food security in small island states

Modelling ecosystem responses to contaminants within the Atlantis framework

Authors: Heidi R. Pethybridge, Elizabeth A. Fulton

Presenter: **Heidi Pethybridge**

Atlantis is an end-to-end ecosystem model that includes integrated spatial and dynamic representations of the biophysical system, human use, and adaptive management. This includes hydrodynamic flows, primary producers, habitats, food web components, and major industries and long-term drivers (e.g., climate, population, and industrial development). Representations of contaminant interactions in Atlantis, including

physical dispersal and movement through the food web, is currently rather simple with improvements underway. This includes additional representations of acute (mortality) effects and chronic (behavioral) outcomes to ecosystem structure and function. Current efforts are focused on incorporating a better mechanistic understanding of the bioaccumulation processes and obtaining more accurate parameter estimates. An Atlantis model requires not only site-specific data (e.g., contaminant concentrations in water, sediment, and marine biota) for forcing and assessment but also parameter values for physicochemical properties (e.g., chemical uptake or elimination rate constants). Transports and footprints that define spill dynamics are most often produced by biogeochemical and particle tracking models. Persistent contaminants such as copper, mercury and oil (largely parameterized based on polycyclic aromatic hydrocarbons) have already been traced in Atlantis to look at ecosystem responses to localized incidents. This presentation will synthesize how contaminants are traced in Atlantis and what ecological insights can be provided to support science-based decisions that minimize environmental impacts of contaminant events (e.g., oil spills) and enhance habitat recovery.

Using mercury stable isotopes to unravel methylmercury source origin and distribution in Tuna from the South Western Pacific Ocean

Authors: David Point, Anne Lorrain, Patrick Houssard, Valérie Alain, Jeroen Sonke, Laura Tremblay-Boyer, Jeremy Masbou, Christelle Lagane, Heidi Pethybridge, Elodie Vourey, Jean Marie Munaron

Presenter: **David Point**

In the tropical Pacific Ocean, tuna contribute significantly to the livelihoods, food and economic security of many island nations. Tuna fisheries from the South Western Pacific Ocean (WCPO) account for a significant fraction of the world tuna catches representing a landing value of several billion US$. In this remote Pacific region, methylmercury (MeHg) oceanographic profiles indicate that MeHg production occurs mainly at depth. In addition, mercury concentrations in bigeye (BET), albacore (ALB) and yellowfin tuna (YFT) increase in the following order YFT<ALB<BET. This species-specific pattern is assumed to reflect a relative difference of foraging depth among the three-tuna species, with YFT occupying a more epipelagic habitat compared to mesopelagic BET. At the species level, spatial gradients have also been observed with increased mercury concentrations in southern latitudes (10°S-20°S) relative to the equatorial regions (0°-10°S), and BET exhibits the strongest latitudinal gradient. To investigate if changes in foraging ecology, and/or differences in marine MeHg biogeochemistry and sources contribute to the geographical trends observed, mercury stable isotopes (δ202Hg, Δ199Hg) and additional trophic tracers (δ13C, δ15N) were conducted on selected YFT, ALB, and BET samples (n=122), and on prey items (n=17).
Recent reviews indicate up to >20 ‰ mass dependent isotope fractionation (MDF) for δ202Hg. All Hg biogeochemical transformations and transfer studied thus far, i.e. volatilization, methylation, demethylation, reduction, oxidation, complexation induce measurable MDF. Interestingly, Hg is among a small group of elements (S and O) for which mass independent isotope fractionation (MIF) has been observed, especially for its odds isotopes 199Hg and 201Hg. The origin of Hg MIF (Δ199Hg or Δ201Hg) in nature is predominantly related to aquatic Hg abiotic photochemistry. Mercury MIF signatures of bioavailable MeHg are then transferred and preserved along the food webs. Mercury MIF in pelagic fish was also used to evidence decreasing marine Hg photodegradation with depth.
In the WCPO, mercury Δ199Hg signatures decrease in the order YFT>ALB>BET, and confirm that differences in foraging depth is likely the main ecological factor influencing mercury concentrations among the three-tuna species. This species specific Δ199Hg pattern is similar to the trend obtained for the same species in the Northern Central Pacific Ocean. The latitudinal differences in BET and YFT mercury concentrations from the WCPO appear to be linked to a significant shift in Hg MDF (δ202Hg), with heavier signatures at southern latitudes (10°S-20°S) relative to the equatorial regions (0°-10°S). On the contrary, mercury Δ199Hg values are relatively similar between these two regions at the tuna species level. These results suggest that tuna

from the WCPO may be exposed to MeHg of different origin, reflecting either spatial variations in marine mercury biogeochemistry and/or shifts in baseline Hg sources

Global-scale analysis of trophic interactions in co-occurring tropical tuna using stable isotope analyses

Authors: Lydie I.E. Couturier, Bodin Nathalie, Diaha Constance, Sardenne Fany, Pethybridge Heidi, Houssard Patrick, Allain Valérie, Roupsard François, Sanchez Caroline , Menkes Christophe, Ménard Frédéric, Gillikin David, Lorrain Anne

Presenter: **Lydie Couturier**

Tropical tuna fisheries are of vital importance to many developing countries as they heavily depend on these industries for food security and national income. Knowledge on trophic interactions among species present in these fisheries is essential to understanding food-web dynamics supporting tuna populations and how these may alter with climate-driven changes and intensive fishing activities. Using stable isotope data compiled under IMBER-CLIOTOP framework, we investigated the trophic interactions of four co-occurring tuna species including the yellowfin tuna *Thunnus albacares* (YFT), the bigeye tuna *Thunnus obesus* (BET), the albacore tuna *Thunnus alalunga* (ALB) and the skipjack tuna *Katsuwonus pelamis* (SKJ). We used Bayesian analyses of isotopic niche metrics to examine the spatial variation of niche size and overlap among these species across 5 regions in tropical oceans (including the east central Atlantic, western central Indian, western central Pacific and South-western Pacific regions). We showed that interactions among these same species can differ across oceans, and between neighbouring oceanic regions (i.e. western Pacific regions). Trophic niches of BET, ALB and YFT were significantly smaller in the Atlantic and Indian regions compared to Pacific regions. Proportional overlap of trophic niches among species varied significantly across regions. YFT and BET had significantly larger niche overlap in nearly all Pacific regions (prop>0.4) compared to the Atlantic and Indian regions (prop<0.2). SKJ niches overlapped strongly with those of YFT in the Indian and Pacific regions (prop>0.5) while ALB and BET niche overlap was highest in Pacific regions (prop>0.6) compare to the Indian region (prop<0.3). Area-averaged chlorophyll-a concentration data indicate that niche sizes and the degree of overlap among species may be related to productivity regimes. Our findings suggest that resource partitioning and foraging behaviour of tropical tuna species may be linked to intrinsic conditions of oceanic regions such as strong seasonal upwelling events. This study successfully applied isotopic niche metrics to detect spatial variation in trophic interactions at a global scale.

Trophic flow structure of a neotropical estuary in northeastern Brazil and the comparison of ecosystem model indicators of estuaries

Authors: ALEX SOUZA LIRA, François Le Loc'h, Ronaldo Angelini, Frédéric Ménardd, Carlos Lacerdaa, Thierry Frédou, Flávia Lucena Frédou

Presenter: **Alex Lira**

We developed an Ecopath model for the Estuary of Sirinhaém River (SIR) Northeastern Brazil, a small-sized system surrounded by mangroves, subject to high impact, mainly by the sugar cane and other farming industries in order to describe the food web structure and trophic interactions. In addition, we compared our findings with those of 20 available Ecopath estuarine models for tropical, subtropical and temperate

regions, aiming to synthesize the knowledge on trophic dynamics and provide a comprehensive analysis of the structures and functioning of estuaries. Our model consisted of 25 compartments, of these, thirteen among invertebrate and fishes had the trophic level values by Ecopath correlated to nitrogen values (δ15N) with aim of evaluating and validating the model. The average trophic transfer efficiency for the entire system was 11.8%, similar to the theoretical value of 10%. The Keystone Index and MTI (Mixed Trophic Impact) analysis indicated that the snook (Centropomus undecimalis and Centropomus parallelus) and jack (Caranx latus and Caranx hippos) are considered as key resources in the system, revealing their high impact in the food web. Both groups have a high ecological and commercial relevance, despite the unregulated fisheries. The trophic levels estimated by the Ecopath model were highly and positively correlated with the δ15N values for the different species analyzed (Pearson's correlation coefficient; Cor: 0.89; $R2=0.79$; $p<0.001$). As result of the comparison of ecosystem model indicators in estuaries, differences in the ecosystem structure from the low latitude zones (tropical estuaries) to the high latitude zones (temperate system) were noticed. The structure of temperate and sub-tropical estuaries is based on high flows of detritus and export, while tropical systems have high biomass, respiration and consumption rates. Higher values of System Omnivory Index (SOI) and Overhead (SO) were observed in the tropical and subtropical estuaries, denoting a more complex food chain. Globally, none of the estuarine models were classified as fully mature ecosystems, although the tropical ecosystems were considered more mature than the subtropical and temperate ecosystems. This study is an important contribution to the trophic modeling of estuaries, which may also help the knowledge of the role of key ecosystem processes in SIR.

Persistent Organic Pollutant (POP) levels and profiles in top predator fish from the Western Indian Ocean in relation to their trophic ecology

Authors: Catherine Munschy, Bely N., Héas-Moisan K., Olivier N., Pollono C., Hollanda S., Bodin N.

Presenter: **Catherine Munschy**

Tuna and billfish are large predatory fish of ecological and economic importance in offshore waters and open oceans. As top predators and long-range migratory species, they are prone to exposure to various toxic contaminants such as, persistent organic pollutants (POPs). POPs are toxic compounds widely distributed over the globe and represent a threat to both ecosystems and human health.

In this study, the contamination of three tropical tuna species, namely bigeye (Thunnus obesus, BET), skipjack (Katsuwonus pelamis, SKJ) and yellowfin (T. albacares, YFT) tunas, and the billfish swordfish (Xiphias gladius, SWO) by selected POPs was investigated in individuals collected from the Western Indian Ocean (WIO) in 2012-2015. The investigated zones included the Seychelles, the Somalian coast, the Chagos archipelago and the Mozambique Channel. Although the WIO is remote from major sources of anthropogenic organic contaminants, POPs are known to travel long distances, bioaccumulate and biomagnify along food chains, hence potentially impacting top predator exposure to these toxicants. Three pollutant families covering industrial, domestic and agricultural usages were investigated, including legacy compounds listed in the Stockholm Convention such as polychlorinated biphenyls (PCBs), organochlorinated pesticides (OCPs), and emerging compounds such as perfluoroalkyl substances (PFASs). The contamination levels and profiles in fish muscle were examined together with biological parameters (fish length and sex) and ecological tracers (carbon and nitrogen stable isotopes, total fat and polyunsaturated fatty acids).

In all species, POP levels revealed low contamination levels in comparison to those found in the same species collected from other locations worldwide. Tropical tunas, and among them SKJ, showed lower POP concentrations than SWO. A predominance of OCPs (and among them DDTs) over PCBs was revealed in all species, reflecting contemporary use of this insecticide for various purposes by several countries in the Southern Hemisphere. Among the studied PFASs, long-chain perfluorocarboxylic acids (PFCAs), which are more bioaccumulable than short-chain PFCAs, were found to be predominant over PFOS. POP accumulation

was examined according to the various studied species and their geographical distribution, revealing differences between species in relation to their trophic ecology. To our knowledge, the data presented here are among the first obtained for POPs in top predator fish from the WIO.

Mercury isotopes as a tool to investigate the spatial origin of Arctic seabird contamination

Authors: Marina Renedo-Elizalde, David Amouroux, Céline Albert, Paco Bustamante and Jérôme Fort

Presenter: **Marina Renedo-Elizalde**

As a consequence of their high position in marine trophic webs, seabirds are considered as effective bioindicators of marine contamination since they integrate biomagnifying pollutants, such as mercury (Hg), via food intake. Despite no direct Hg inputs in the Arctic region, Arctic top predators are among the most exposed organisms to Hg, which is bioaccumulated as its highly toxic organometallic form methylmercury (MeHg). Specific foraging habitats and migratory movements of Arctic seabirds have shown to determine their exposure to distinct environmental MeHg sources in marine ecosystems. Here, we focused on little auks (Alle alle), a zooplanktivourous seabird species, which are particularly interesting for Hg isotopic studies in the Arctic Ocean since they reflect MeHg accumulation in a short food web that is strongly dependent on sea ice abundance and seawater temperature. Besides, this migratory seabird species presents two feather moult during their annual cycle: a first “nuptial” moult when they only replace head feathers, and a second body feather moult at the end of their breeding period. Due to different Hg integration times between types of feather, we can study Hg contamination during both non-breeding (head feathers) and breeding seasons (body feathers) in a same individual. Previous studies in little auks already showed significantly higher Hg concentrations in head feathers, suggesting a higher exposure to Hg during their non-breeding period outside the Arctic. The measurement of Hg isotopic mass dependent (MDF, δ202Hg) and independent (MIF, Δ199Hg) fractionation has become an essential tool in identifying sources of Hg and quantifying its reactivity within the different compartments of the environment. To better understand the spatial differences of Hg exposure in migratory seabirds, we investigated Hg isotopes in head and body feathers of four distant colonies of little auks from the Arctic Ocean presenting specific wintering areas. Hg isotopic signatures obtained in both types of feather clearly separated little auks populations geographically, permitting the identification of the distinct ecosystems corresponding both to the breeding and the migration areas. Although slight differences on δ202Hg values were observed between the two types of feather at the individual level, Δ199Hg values were significantly higher for body feathers than for head feathers in all the individuals independently of the colony (0.36‰ on average). Since Hg MIF is mainly affected by Hg photochemistry and is preserved up to the food web, it is used as a proxy of Hg sources. Therefore, differences in Δ199Hg values between types of feather may be the result of different Hg photochemical extent related to seasonal variability (summer vs winter) and/or geographically different biogeochemical characteristics (Arctic Ocean vs wintery areas). This study highlights the utility of Hg isotopes to help elucidate the Hg exposure of migratory seabirds during their whole annual cycle, both during their breeding and non-breeding period, and then open a new horizon for exploring Hg dynamics in large zones of the marine environment.

Ingestion of microplastics by zooplankton and fish from the Yellow Sea

Authors: Xiaoxia Sun, Qingjie LI, Tao LIU, Junhua LIANG, Mingliang ZHU

Presenter: **Xiaoxia Sun**

Microplastics in the ocean is the plastic fragments less than 5 mm in diameter, which entered into the ocean through a variety of ways. In the past 60 years, the global plastic production increased by 560 times, and the accumulation of microplastics in the marine environment is increasing. The potential risks of microplastics to marine ecosystems caused widespread concern.However, the data on the in situ ingestion of microplastics by natural zooplankton and fish are very rare. In this research, the ingestion of microplastics by different natural zooplankton and fish groups was studied in the Yellow Sea. The microplastics were detected in zooplankton and fish sampled from almost all stations, with the fibrous microplastics accounting for the largest proportion. The average length of the microplasticsin zooplankton and fish was 259μmand 1 mm, respectively. The accumulation of microplastics in zooplankton and fish varied with taxa. The accumulation of microplastics was affected by the size, abundance, feeding habit, and environmental microplastics pollution.

Modeling 137Cs contamination of marine food-webs following Fukushima accident: from zooplankton to tunas.

Authors: Inna Senina, Patrick Lehodey, Vincent Rossi, Yutaka Tateda

Presenter: **Inna Senina**

We present a modelling approach that allows tracing the propagation of long-living radioactive isotope 137Cs through the oceanic food web. This work was undertaken in the framework of AMORAD project funded by the French National Research Agency after the Fukushima Daiichi Nuclear Power Plant accident. The approach consists in coupling existing ecosystem model (SEAPODYM-LMTL) with Thomann's radioecological equation describing dynamics of radionuclide concentration in marine biota. SEAPODYM-LMTL simulates the dynamics of functional groups of zooplankton and micronekton, i.e. organisms of the lower- and mid-trophic levels of the pelagic food web. These dynamics are governed by ocean circulation and a relationship between the temperature and the time of development from oceanic primary production to zooplankton or micronekton biomass. Calibrating 137Cs uptake and elimination rates and using simulated four-dimensional 137Cs concentrations in sea water over the north Pacific Ocean, we were able to quantify the radionuclide concentrations in lower- and mid-trophic organisms. The results of modelling were validated using published data collected after the Fukushima accident. These outputs were then used to compute contamination risk indicators for three tuna species in the north Pacific Ocean: skipjack, yellowfin and bigeye. The indicators are based on tuna habitats estimated within population dynamics modelling with help of maximal likelihood estimation method. Amongst the three species, skipjack seems to be the most exposed to contaminated habitat, both in terms of temporal and spatial overlap of favourable feeding grounds with highest concentrations of 137Cs. Bigeye tuna that were caught in the Kuroshio region in late 2011 were as well at risk of contamination. Almost no impact of radiocesium was estimated for yellowfin. An operational version of SEAPODYM model is currently running providing real-time and 10-days forecast outputs. This operational model configuration coupled with radioecological models can be used as a tool in the post-accident scenario to produce contamination maps for zooplankton and micronekton communities and to provide the indicators of risk of contamination for the exploited top predator species.

Spatial aspects of the Baltic fish dioxin risk formation: Social-ecological system analysis

Authors: Lauri Ronkainen, Jouni Tuomisto, Päivi Haapasaari, Annukka Lehikoinen

Presenter: **Annukka Lehikoinen**

Dioxins have been a nuisance to the Baltic Sea ecosystem for a couple of decades. Even though the concentrations in the environment and biota have continuously decreased, they still pose a multilevel social-ecological risk. Originating from industrial and other anthropogenic and natural burning processes, these compounds accumulate to lipids and biomagnify in food chains ending up to humans who consume fish. This paper presents a knowledge synthesis to compare the emergence of dioxin risk in different parts of the Baltic Sea. We studied the dioxin flux in the Baltic Sea food webs focusing especially on Baltic herring (Clupea harengus membras) and salmon (Salmo salar) which are important commercial species with high lipid concentration and have prominent role in the food web dynamics. A systematic literature search was conducted to explore how different elements under the categories of 1) anthropogenic dioxin pollution, 2) ambient environmental conditions, 3) food webs, 4) dioxin concentrations in fish, and 5) human exposure from fish, vary spatially within the Baltic Sea. Grouped under these five indicators, total of 21 elements were recorded and basin-wise risk profiles compiled by synthesizing heterogeneous evidence from 47 relevant articles, reports, and theses, the data varying from In situ monitoring data to experimental, as well as modelled information. Arising from the areal differences in dioxin pollution and environmental conditions affecting the ecology and biology, these elements vary spatially, affecting how the final exposure risk to human builds up in different basins. For example, in the Northern Baltic, Gulf of Bothnia (GoB), where dioxin concentrations in herring are the highest, the exposure of the key risk group, women in fertile age, is lower than in the Baltic Proper. When it comes to salmon, PCDD/F concentration is the highest in the Gulf of Finland, while the exposure of the key risk group is highest in the GoB. This study highlights the importance of spatial social-ecological understanding when assessing the area-specific dioxin risk, which may potentially also affect the locally optimal management strategies.

The Distribution and Morphology of Microplastics in Coastal Soils Adjacent to the Bohai Sea, the Yellow Sea and South China Sea

Authors: Qian Zhou, Haibo Zhang, Chuancheng Fu, Yuan Li, Chen Tu, Lianyhen Li, Yongming Luo

Presenter: **Qian Zhou**

Microplastics (< 5 mm) are considered to be emerging pollutants of global concern. Investigations on microplastics pollution in coastal and marine environments have increased recently but knowledge gaps still exist regarding microplastics in coastal beach soils with high-intensity human activities. In the present study the sampling sites along the coastline in Shandong province, east China, adjacent to both the Bohai Sea and the Yellow Sea coastlines and in Guangxi province adjacent to South China Sea under different land use patterns. Microplastics were separated from the soil samples using a continuous flow and floating separation apparatus. The shape type, size, abundance, spatial distribution, polymer composition and surface morphology of the microplastics were identified by a range of advanced microscopic and micro-analytical methods. The analytical results show that different shape types, namely foams, pellets, fragments, flakes, fibers, films and sponges, were present in the beach soils. The polymer composition of the microplastics included polyethylene, polypropylene, polystyrene, polyether urethane, rayon, acrylic and a polymer blend of both polyethylene and polypropylene. Microplastics abundance varied greatly among the soils, ranging from 1.3 to 14712.5 N kg^{-1} (dry weight) as influenced by land use types, such as mariculture, tourism, port construction and wetland. Some of the microplastics from the coastal environment with

different biogeographic climatic zones had different degrees of surface weathering based on surface morphology and infrared spectrum, possibly due to physical friction, photochemical oxidation and/or animal attack. The weathered surfaces of microplastics might act as a high-capacity carrier with adhering microorganisms and chemicals. Further studies are required on the weathering processes, sorption capacity and transport of microplastics under coastal conditions.
Keywords: Microplastics; Coastal soils; Shape types; Abundance; Spatial distribution; Surface morphology; Biogeographic climatic zone

Are jellyfish winners of Ocean Acidification?

Authors: Carsten Spisla, J. Taucher, L.T. Bach, K. Lohbeck, S. Lischka, M. Sswat, S. Alvarez-Fernandez, I. Dörner, S. Ismar, N. Aberle-Malzahn, U. Riebesell

Presenter: **Carsten Spisla**

Anthropogenic CO_2 emissions cause a drop in seawater pH and shift the inorganic carbon speciation. Collectively, these changes are summarized under the term ocean acidification (OA). In this context it is commonly stated that Hydrozoans - due to their high environmental tolerance - could benefit from ongoing ocean change. However, research of OA effects on Hydrozoans, and especially Hydromedusae, in complex natural communities remains scarce. Because Hydrozoans can be serious competitors to other top predators like fish, changes in their abundances can have significant consequence for marine food webs and ecosystem services. To investigate how Hydrozoans react to OA, we enclosed a natural zooplankton community in the Raunefjord, Norway, in 8 pelagic mesocosms with 60 m^3 volume each, for 55 days. Subsequently four of them were exposed to pCO_2 levels of ≈2200 µatm, while the other four served as controls. Over the course of the experiment the dominant Hydrozoan species Aglantha digitale, Obelia geniculata, and Sarsia tubolosa, responded similarly to ocean acidification. During the first post-bloom phase they were significantly more abundant under high pCO_2 conditions, while in the second post-bloom phase abundances where higher in the control mesocosms. This development is accompanied by strong OA effects on the non-gelatinous mesozooplankton community. Our results indicate that Hydrozoans, which were the dominant top predators in the food web enclosed in our mesocosms, did not only exert a top-down control on the pelagic community, but were affected themselves by indirect OA effects transmitted via the food web. In conclusion, OA effects on Hydrozoans strongly depend on the prevailing food web structure. Our findings therefore do not support the generalized concept of Hydrozoans principally benefiting from ocean acidification.

Is there enough data to perform robust spatial and temporal analyses of mercury levels in commercial tuna at a global scale?

Authors: Anaïs Médieu, David Point, Nathalie Bodin, Aurore Receveur, Patrick Houssard, Valérie Allain, John Logan, Heidi Pethybridge, Bridget Ferris, Takaaki Itai, Olivier Gauthier, Anne Lorrain

Presenter: **Anaïs Médieu**

Located at the top of marine food webs, tuna are known to bioaccumulate large amounts of monomethylmercury (MMHg), sometimes exceeding food safety guidelines (1 $mg.kg^{-1}$ fresh tissue). Mercury concentrations in tuna are highly variable between oceans and species and are mainly determined

by complex interactions between size (age), trophic ecology, assimilation efficiencies, foraging depth, and likely, in situ concentrations of methylmercury. We present a global tuna Hg database combining existing published Hg data with thousands of newly analyzed white muscle tissue samples of four tuna species (skipjack, yellowfin, bigeye and albacore) from different ocean basins (Pacific, Atlantic and Indian). This database was built through both international collaborations within the CLIOTOP IMBeR program and literature review.
This compilation illustrates that while many local studies are available, few inter-regional comparisons or global scale studies exist. Furthermore, biological data, in particular size and trophic position, necessary to conduct robust analyses of mercury variations are often lacking in the literature. In this context, spatial and temporal analyses were performed for ocean basins with sufficient data on tuna mercury concentrations, sizes and stable isotope values. When possible, generalized additive models were used to identify key processes governing the spatial variability of mercury in tuna and we show that size and depth of foraging are two of the main factors explaining those variations. This study highlights the importance of global analyses to understand broad patterns and trends in the distribution of mercury in marine top predators and the need to have access to complementary biological and environmental factors in the mercury community.
Keywords: Global mercury, trophic position, modeling, literature review, skipjack tuna, yellowfin tuna, bigeye tuna, albacore tuna

Regional patterns in mercury and selenium concentrations of swordfish in the Indian Ocean

Authors: Nathalie BODIN, Stephanie HOLLANDA, Rona ALBERT, Natifa PILLAY, Carine CHURLAUD, Evgeny ROMANOV, Wendy WEST, Paco BUSTAMANTE

Presenter: **Nathalie Bodin**

As long lived top predator in marine pelagic ecosystems, billfish such as swordfish bioaccumulate high levels of mercury (Hg) with reported concentrations higher than in their fellows, tuna and tuna-like species, and exceeding from time to time the recommended safety limits. Billfish are thus among the more appropriate bioindicator species for monitoring and understanding broad spatial gradients of Hg contamination in the world’s oceans. Although occurrence of Hg in predatory fish from temperate regions is well documented, data are still missing in tropical areas in particular in the Indian Ocean where they are the main targets of commercial and recreational fisheries and constitute high income and protein source for many regional countries. Here, we studied Hg levels alongside selenium (Se), an essential trace mineral known to confer protective benefits on Hg toxicity, in the muscle of 243 swordfish collected from different bioregions of the Indian Ocean, i.e. Bay of Bengal, Western Tropical Indian Ocean, South Sub-tropical Indian Ocean, and Mozambique Channel and South East Coast of South Africa. Spatial variations in metal concentrations were modelled taking into account variations in fish size and trophic markers inferred from isotopic ($\delta 15N$ and $\delta 13C$) data. The main factor that explained Hg concentration was the geographic origin of the swordfish. Our results also highlighted the potential of Hg, Se and stable isotopes all together for discriminating swordfish metapopulation structure in the Indian Ocean. Finally, the calculation of the selenium-mercury molar ratio and the selenium health benefit value revealed low risk for consumers with swordfish consumption even when Hg concentrations exceeded the recommended health thresholds.

Ecological trade-off between the intake of essential and toxic components in the great white shark

Authors: Gaël Le Croizier, Margaux Mathieu-Resuge, Antoine Bideau, Gador Muntaner , Marc Aquino Baleytó, Mauricio Hoyos-Padilla,James Ketchum, Fabienne Le Grand, Rudolph Corvaisier, Jean-Marie Munaron, François le Loch, Edouard Kraffe, Gauthier Schaal, Anne Lorrai

Presenter: **Gaël Le Croizier**

The collapse of apex marine predator populations including sharks represents a particularly alarming situation, causing large-scale cascading effects which finally impairs the global structure and function of marine ecosystems. Following centuries of anthropogenic mercury (Hg) use and emission, Hg has created a scenario of global environmental concerns and sharks are among the most contaminated marine organisms by this highly neurotoxic element. Essential fatty acids (EFA) originate from primary producers and are poorly synthesized by marine predators. Among EFA, omega 3 such as EPA and DHA are required for the development and functionality of the brain, vision and nervous system. The great white shark Carcharodon carcharias is known to feed on a large panel of prey such as marine mammals, large pelagic fish and cephalopods. Recent studies have revealed a high level of individual specialization in terms of foraging behavior, with sharks consuming prey that differ in their concentrations of EFA and Hg. In this context, the present study aims to determine if this inter-individual variability in foraging behavior influences the trophic intake of nutrients and contaminants for this endangered species, by focusing on EFA and Hg which have antagonistic effects. For this purpose, stable isotope analyses (SIA, i.e. bulk δ13C and δ15N), fatty acid composition, total Hg concentration and compound-specific stable isotope analyses (CSIA, i.e. δ13C values of EFA) were determined in skin tissues from 30 white sharks from the Northeast Pacific. The results showed a strong link between EFA source and EFA intake for this population, with sharks foraging on pelagic prey getting more EFA. On the other hand, the consumption of pelagic organisms appeared to lead to a greater Hg contamination. This study revealed the ecological trade-off between the intake of essential and toxic components as well as individual trophic strategies that may lead to different abilities to face the decline of shark populations.

Fish contamination and trophodynamic in three French subregions

Authors: Aourell Mauffret, Nathalie Wessel, Tiphaine Chouvelon, Pierre Cresson, Daniela Bănaru, Paco Bustamante, Jérôme Baudrier, Benoit Mialet, Lynda Saibi-Yedjer, Jérome Spitz, Marc Bouchoucha, Tiphaine Mille, François Le Loc'h, Mireille Harmelin Vivien

Presenter: **Aourell Mauffret**

Fish contamination (dioxins, PCB, Cd, Hg and Pb) was assessed in 2014/2015/2017 within the Marine Strategy Framework Directive (MSFD) coordinated program, through the optimization of French fisheries surveys in three different marine systems: the Eastern English Channel (EEC), the Bay of Biscay (BoB), and the Western Mediterranean (Med). Our objectives were to 1) assess MSFD good environmental status (GES) regarding environmental (D8) and human (D9) health, 2) compare fish contamination between the three French marine subregions, and 3) assess the contribution of trophodynamic (D4) to explain or drive fish contamination. Contaminant concentrations were higher than sanitary thresholds in some large individuals of mackerel sampled in the EEC (PCB, dioxins and dioxin-like compounds), dogfish from the BoB (Cd), and mullet, dogfish, hake and redfish in Med (Hg). PCB concentrations, especially CB118, were also higher than environmental thresholds in all the three subregions. For several contaminants, levels were higher in Med and EEC than in BoB, likely reflecting subregion differences in terms of 1) exposure to continental

contamination and 2) system characteristics (e.g. geochemical background, hydrology, primary production, size/age relationship). Trophodynamic, here defined by fish diets, trophic levels and main food sources sustaining species (i.e. benthic, pelagic, mixed), as well as individual characteristics (e.g. lipid content), contributed to explain differences in contamination patterns between species. By its spatial extent, the number of considered species and the variety of analyzed contaminants, this study is expected to provide key elements for understanding contaminant transfer in marine food webs. It will also enable the optimization of further monitoring programs by proposing relevant criteria for monitored species selection and associated parameters to be assessed to support a relevant interpretation of fish contamination.

PAH sediment toxicity assessment in Adriatic Sea

Authors: Jelena Mandic, Nevenka Bihari, Grozdan Kuspilic, Jacek Tronczynski

Presenter: **Jelena Mandic**

Polycyclic aromatic hydrocarbons (PAH) were investigated in the bottom sediments on 25 locations in the coastal area of Adriatic Sea. Total PAH concentrations ranged from 14,98 to 23970,92 µg kg^{-1}. The highest PAH levels were determined in sediments from the Sibenik Bay and the lowest PAH levels were determined in sediment near Island of Pag. Unsubstituted, parent PAHs predominated in sediments from the Sibenik Bay and the Coastal area, while methyl-substituted PAHs were dominant in sediments of the Kastela Bay. In order to estimate the possible toxicological significance of PAH concentrations, Sediment Quality Assessment was done according to three different guidelines: Canadian Sediment Quality Guidelines, North America Sediment Quality Guidelines and OSPAR commission quality Guidelines. According to all three applied criteria, high environmental risk was calculated for each station in Sibenik Bay; for the station in vicinity of the Industrial port of Split and for the two stations in Coastal zone. Low environmental risk was calculated for the remote areas such as Island of Pag, whereas moderate environmental risk was calculated for the majority of stations in Kastela Bay and Coastal area. Sediment extracts were further analysed for acute toxicity using the Microtox® bioassay. Obtained results show disagreement between sediment toxicity calculated upon total PAH levels in sediment and experimentally obtained sediment toxicity. Sediment extracts with low PAH levels were highly toxic indicating that only concentrations of PAH were not accurate indicators of sediment toxicity.

Food Insecurity and Children Malnutrition in Coastal Area of Central Java that was affected by Climate Change

Authors: Diana Nur Afifah, Hartanti Sandi Wijayanti, Vivilia Niken Hastuti, Denny Nugroho Sugianto

Presenter: **Diana Nur Afifah**

Climate change has negative impacts on all aspects of food security, including malnutrition, especially people in coastal area. Demak is a coastal area in Central Java that has many problems related with climate change. Demak consists of three types of area: dry, flooding, and tidal flooding area.
Objective : To identify food insecurity and children malnutrition in Demak, based on three types of area.
Method : A cross sectional study was conducted to 210 children aged 2-5 years old in three types of area with each of them 70 subjects were selected by simple random sampling. Data was collected with interview technique followed by anthropometric measurements by door to door survey. Height was measured by

stadiometer and weight was measured using calibrated digital weight-scale. To assess the nutritional status of children, Z-score of weight for age, height for age, and weight for height was calculated using WHO growth reference standards separated for boys and girls. Degree of food security was obtained using Household Food Security Survey Module (HFSSM) Questionnaire. Data were analyzed using Annova and Kruskal Wallis test.
Results : The mean of children food security score in dry area, flooding area, and tidal flooding area were 1.11±1.73, 0.30±0.85 and 0.98±0.95 respectively, while the mean of household food security score were 3.98±4.58, 1.50±2.79 and 2.27±2.37 respectively. The dry area was the most food insecure area compared to others. There was a significant difference of child and household security score between three types of area (p=0.001 and p=0.002). The prevalence of underweight and wasting was highest in dry area, while prevalence of stunting was highest in flooding area. There was a significant difference on weight for age and weight for height Z-score between three types of area with p value p=0.001 and p=0.026 respectively.
Conclusion : There were significant differences in degree of food insecurity and children nutritional status between three types of area in Demak.
Keyword : Climate change, food insecurity, stunting, coastal area

Physiological status and reproductive strategy of fish in a tropical estuary in face of climate fluctuation

Authors: Mahammed Moniruzzaman

Presenter: **Mahammed Moniruzzaman**

Most of the estuaries throughout the world are experiencing escalated variability of temperature, salinity and other abiotic factors. This fluctuating environment is affecting the present distribution and diversity of tropical fishes. However in absence of proper ecological indication it is hard to predict where fish distribution and diversity may be heading in near future. Alteration in temperature, pH, dissolved oxygen and salinity are influencing respiration rates, metabolic status and reproductive strategy of commercially exploited fishes. Chronic reproductive stress under plausible scenarios of escalated variability of physical factors was tested to predict future distribution of fish species. Indian Sundarbans are one of the most important mangrove estuaries in the world. Sundarban is experiencing wide salt shifts driven by stochastic events and climate changes. 25.2% increases in salinity were noted in this estuary in last ten years. Thereby it is likely that estuarine fishes are experiencing eco-physiological stresses some of which severely affecting the reproductive efficiency and production rate. Therefore, the final consequence of these stressors may have chronic effect on their abundance and distribution in longer terms. Salinity, temperature and dissolved oxygen variability of Sundarban estuaries have reached to an unprecedented level in last few years. Such climatic stress is correlated with crucial physiological output and reproductive performance in most of the fish. Therefore, we are trying to predict the consequences of change in temperature, salinity and/or dissolve oxygen on the abundance of estuarine fish on the basis of their physiological and reproductive status.

Ocean acidification affects survival of herring larvae via food web alteration

Authors: Michael Sswat, Catriona Clemmesen, Lennart T. Bach, Fredrik Jutfelt, Maria Algueró-Muñiz, Carsten Spisla, Martina Stiasny, Jan Taucher, Ulf Riebesell

Presenter: **Michael Sswat**

Future changes of the ocean, such as warming, acidification and anoxia were shown to directly affect a wide range of marine organisms. Since marine organisms interact in complex communities, each direct effect may in turn influence other species indirectly via the food web.
Here, the combined direct and indirect effects of ocean acidification were assessed in two mesocosm studies. Pelagic communities up to fish larvae were enclosed for several weeks and manipulated with CO_2 concentrations projected within the next hundred years.
The first experiment was performed in the Gullmarsfjord, Sweden. From January to June 2013, five of ten mesocosms were set to CO_2 levels of ~760 µatm pCO_2, while the other five served as untreated controls. In this study, an enhancement of primary production under elevated CO_2 was mirrored by an increase in zooplankton abundance, which served as prey organisms for the herring larvae. After six weeks, herring larvae survival was significantly higher in the elevated CO_2 mesocosms.
The second mesocosm experiment was performed from May to July 2015 in the Raunefjorden, Norway. Here, four of eight mesocosms served as untreated control, while the other four were set to CO_2 levels of ~2200 µatm pCO_2. This study confirmed the higher herring larvae survival at elevated CO_2, although overall survival rates were much lower than in the previous study. This time, however, no CO_2-induced enhancement of primary and secondary production was observed. Possible explanations for the higher herring larvae survival under elevated CO_2 in this experiment could be lower competition and predation by gelatinous zooplankton.
Results of herring larval survival from both studies will be discussed in the context of food web effects of ocean acidification and will be used as "food for thought" to highlight knowledge gaps regarding species interactions in ocean acidification research.

Mass balanced model to assess the trophic web in a tropical estuary, Northeastern Brazil and the flows of biomass of estuarine ecosystems

Authors: Valdimere Ferreira, Alex Souza Lira, Carlos Henrique Figueiredo Lacerda, Flávia Lucena-Frédou, Thierry Frédou, Frédéric Ménard, Ronaldo Angelini, François Le Loc'h

Presenter: **Alex Lira**

Trophic web is a network of complex interactions of species and energy links between them and the ecosystem. These interactions can be simplified into trophodynamic models, such as the Ecopath (EP) and Ecotroph (ET). In this study, EP and ET models were developed for the estuary of Santa Cruz Channel (SCC), Northeastern Brazil, aiming at evaluating the particular role of functional groups on the ecosystem, also investigating the flows of energy and biomass that supports the food chain. The relationship between the trophic level estimated by EP and nitrogen stable isotope (δ15N) values of some functional groups of the SCC were tested. Also, a meta-analysis of the trophic functioning in tropical estuarine ecosystems was conducted using 17 ET models. The SCC model presented 32 functional groups (3 primary producers, 5 invertebrates, 22 fish and 1 detritus). The pedigree index (0.44) indicated an acceptable accuracy of input parameters. High ecotrophic efficiency of invertebrates (worms, gastropod and shrimp), *Lutjanus* spp. and *Gobionellus oceanicus* showed that these groups are highly consumed or exported in the SCC. Most of the fish biomass dominates in low trophic levels and the primary consumers were the main sources of detritus flow. The predators feed predominantly on prey of the few trophic levels, mainly benthonic groups,

indicating a low Omnivore index (0.16). The key species were snook *Centropomus* spp., jack *Caranx* spp. and barracuda *Sphyraena* spp. The System overhead (67.54 %) suggested an intermediate-to-high level of resilience of the ecosystem. The low Finn's cycling index (2.71) values for SCC was similar to the observed in other tropical systems considered immature. The trophic level estimated by EP and the δ15N in the SCC were highly correlated (R=0.77). The ET model showed high biomass and strong catch in low trophic levels of tropical estuaries. The SCC is considered a system with high level of energy and an immature ecosystem with high potential for adaptation and resilience capacity. The EP and ET models can be considered as effective tools to better understand the trophic functioning of estuarine ecosystems.

SESSION 10: FROM GENES TO MARINE ECOSYSTEM FUNCTIONING: NEW METHODS AND MODELS FOR INTEGRATING BIG DATA AND SMALL BUGS IN TRAIT-BASED APPROACHES

Trait-based network analysis: predator-prey trait matching and functional changes of the Barents Sea food web

Authors: Laurene Pecuchet, Primicerio, Blanchet, Husson, Jørgensen, Frainer et al.

Presenter: **Laurene Pecuchet**

The Barents Sea, a productive arcto-boreal ecosystem, is affected by climate change through, e.g. increasing water temperature and shrinking sea ice extent. These changes led to major restructuring in species biomass and distribution across trophic levels, documented notably by a northward shift of both boreal and arctic communities and an increasing dominance of boreal species in the historically arctic part. This rapid borealization might have profound consequences on the functioning and vulnerability of the Barents Sea ecosystem, as the boreal species share different functional traits and life-history strategies than there arctic counterparts. Indeed, it is increasingly recognized that it is not species identity, but their traits that determine biological interactions and the functioning of the ecosystems. The consequence of climate change and anthropogenic impacts on the spatio-temporal structure of marine food web, as well as their effects on ecosystem functioning, remains thus a central question which could benefit from using food web modelling and integrating trait-mediated interactions. In this study, we use an extensive food web with more than 2,000 documented feeding links to analyse which, and how well, traits can predict prey-predators interactions. Once the key traits regulating species interactions are identified, we extend the food web by predicting interactions among pairs of species as a result of their trait values. This extended trait-based food web is then used to investigate functional changes in the Barents Sea ecosystem as a result of environmental change. We document how the borealization, by bringing new traits in the system, affects the structural properties of the food web such as its motifs, connectance and modularity. We argue that merging the trait-based approach with ecological networks might give a better mechanistic understanding of the relationship between trait composition and ecosystem functioning in multi-trophic systems.

Food web modelling and network analysis quantify the role of various functional groups of Zooplankton in three contrasted Arctic marine ecosystems.

Authors: Saint-Béat Blanche, Darnis Gérald, Fortier Louis, Babin Marcel, Maps Frédéric

Presenter: **Blanche Saint-Béat**

Zooplankton is a key component of the Arctic marine ecosystems, acting as a crucial hub of energy and matter between microbial producers and higher trophic levels. The zooplanktonic community, dominated by copepods, is composed of species characterized by various functional traits. A functional trait is defined as a specific morphologic, physiologic or phenologic individual feature affecting its fitness through by influencing its growth, reproduction or survival. The representation of the biodiversity by their functional traits is increasingly used in ecosystem models because it is assumed that species sharing similar functional traits play similar roles in the ecosystem. However, the effect of a particular functional group on the ecosystem remains often poorly characterized. We aimed at determining the respective roles of various mesozooplanktonic functional groups on Arctic marine ecosystems functioning by combining food web modeling and network analysis. Linear inverse modeling estimates the values of all flows composing the food web, while network analysis determines the emergent properties of ecosystems based on the distribution of carbon through these flows. We studied three contrasted Arctic ecosystems i) Amundsen Gulf ii) western Baffin Bay and iii) Eastern Baffin Bay in order to determine whether a functional group plays the same role whatever the ecosystem considered and to quantify the impact of functional groups aggregation on the emerging properties of food webs. For each ecosystem, mesozooplanktonic community was aggregated according to the same criteria: the feeding mode (passive or active ambush, current feeding or cruise) and the feeding type (herbivore, omnivore or carnivore). We aim at providing renewed criteria to guide the aggregation of individual species and functional groups in marine ecosystem models.

Interactions of parasitic marine alveolates with diverse protist species in the Southern Ocean

Authors: Ingrid Sassenhagen, Solène Irion, Ludwig Jardillier, Urania Christaki

Presenter: **Ingrid Sassenhagen**

Parasites of protists have a large impact on microbial community composition, thus, affecting the carbon cycle during primary production, grazing, respiration and transfer to higher trophic levels. In particular, marine alveolates (MALV), which are closely related to dinoflagellates and might exclusively represent parasites, are very abundant in marine ecosystems, as determined by metabarcoding studies. Some well studied MALV species can terminate harmful algal blooms, while other taxa might infect grazers such as micro- and mesozoplankton. Nevertheless, information about most MALV species is very limited and their host range and specificity is currently unknown.

Microbial communities for this study were sampled around the Kerguelen Islands in the Southern Ocean during the French MOBYDICK cruise in February and March 2018. The spatially restricted natural iron fertilization on the plateau of the Kerguelen Islands results in a highly productive ecosystem characterized by intense algal blooms contrasting lower productivity in surrounding waters. Sequencing of plankton net samples, which concentrated large (>30µm) protist cells and excluded free-living parasite spores, from surface waters of contrasting stations revealed high abundance of unicellular grazers, large differences in diatom communities including short-term dominance of Corethron inerme and high fluctuations in MALV abundance. Network analyses revealed correlations of MALV taxa with various microbial community members, especially diatoms. Interactions with diatoms were further supported by sequencing of >100 individually isolated plankton cells enabling direct identification of associated taxa. Fluorescence in-situ

hybridization of samples with probes specific for different MALV groups provided further information about parasite abundance and prevalence of infections. Selective parasitic infection of primary producers such as diatoms by MALV would release organic carbon into the environment, which subsequently becomes available for remineralization in the microbial loop and could ultimately result in decreased efficiency of the biological carbon pump.

Modeling optimal strategies, competition and seasonal succession within unicellular plankton using a mechanistic trait-based approach

Authors: Mathilde Cadier, Agnethe Nøhr Hansen, Ken H. Andersen, Andre W. Visser

Presenter: **Mathilde Cadier**

The trait-based approach is an emerging field of ecology which proves to be very well appropriate when studying plankton ecosystem. Indeed, ecologically relevant traits rather than taxonomic affiliation define ecosystem functions, and community composition is driven by the relationship between the organisms' features and the biotic and abiotic environment. In this talk, I will present a mechanistic model with two key functional traits of unicellular plankton: trophic strategy and vacuolation. The first trait describes the use of organic matter as a source of energy and carbon within mixotrophs to cope with inorganic nutrient limitation. The other trait describes gas vacuoles within the cell that expand the physical size relatively to cellular carbon content to face predation, reduce sinking and favor resource affinity. In terms of functional groups, the first trait represents flagellates and dinoflagellates with different investments in mixotrophy, and the second trait represents diatom with different vacuole size. The relative success (growth rate) and the outcome of the competition (relative biomass) between the two opposite strategies are assessed as a function of cell size for a set of environmental conditions and during a seasonal cycle.

An optimality-based cellular model in predicting response of nitrogen fixer Trichodesmium to ocean acidification

Authors: Ya-Wei Luo, Dalin Shi, Sven Kranz, Brian Hopkinson, Haizheng Hong, Rong Shen, Futing Zhang

Presenter: **Ya-Wei Luo**

The response of the prominent marine dinitrogen (N2)-fixing cyanobacteria Trichodesmium to ocean acidification (OA) is critical to understanding future oceanic biogeochemical cycles. Recent studies have reported conflicting findings on the effect of OA on growth and N2 fixation of Trichodesmium. Here, we quantitatively analyzed experimental data on how Trichodesmium reallocated intracellular iron and energy among key cellular processes in response to OA, and integrated the findings to construct an optimality-based cellular model. The model results indicate that Trichodesmium growth rate decreases under OA primarily due to reduced nitrogenase efficiency. The downregulation of the carbon dioxide (CO_2)-concentrating mechanism under OA has little impact on Trichodesmium, and the energy demand of anti-stress against OA has moderate negative effect. We predict that OA under the Representative Concentration Pathway (RCP) 8.5 could reduce global N2 fixation potential of Trichodesmium by 27% in this century, with the largest decrease in iron-limiting regions.

From theory to conservation priorities for the functioning and resilience of marine benthic systems across habitats: trait-based approach to monitoring data along 500 km of coastline

Authors: Aurélien Boyé, Éric Thiébaut, Jacques Grall, Pierre Legendre, Caroline Broudin, Céline Houbin, Vincent Le Garrec, Marion Maguer, Gabin Droual, Olivier Gauthier

Presenter: **Aurélien Boyé**

β diversity relationships with ecosystem functioning remain poorly documented. This impedes our capacity to predict how local community changes affect ecosystem functioning at scales relevant for conservation. Combining a trait-based approach to monitoring data covering a 7-year period and 500 km of coast, we evaluate the functional implications of on-going seafloor changes by characterizing the α and β diversities in different benthic habitats currently threatened by biotic homogenization. We describe the taxonomic and functional diversity of habitats associated with two different types of foundation species, intertidal seagrass and subtidal maerl beds, compared to bare sediment at similar tidal level and link the mechanisms underlying their α diversities to their repercussions at regional scale. Foundation species appear as a major factor governing community composition and locally promote taxonomic and functional α diversity, reinforcing the conservation value of biogenic habitats. However, our results reveal that these species act through different mechanisms and that the functional diversity of biogenic habitats is associated to different vulnerabilities whose implications for conservation are discussed. Maerl fine-scale heterogeneity promotes niche diversity and leads to high functional redundancy for the whole subtidal compartment at regional scale, providing insurance for seafloor functioning at long-term. In contrast, seagrass diversity is associated with redundancy for only a few functions because their functional diversity relies on transient species and mass effects. Maintaining the seascapes in which seagrass are embedded seems essential to ensure their long-term functioning. At regional scale, the locally poorer bare sediment harbored similar functional richness as biogenic habitats because of higher within-habitat β diversity, stressing a potential underrated conservation value for benthic ecosystem functioning. We show here that coupling trait-based approaches to monitoring data can help link broad-scale β-diversity to their underlying drivers, bringing local mechanistic understanding closer to the scales at which biodiversity loss and management actions occur.

Using species functional traits to explore the potential impacts of climate change on plankton functional diversity. The case of planktonic copepods in the Mediterranean Sea

Authors: Fabio Benedetti, Sakina-Dorothée Ayata, François Guilhaumon, Jean-Olivier Irisson, Fanny Adloff

Presenter: **Fabio Benedetti**

Functional diversity (FD) has emerged as an estimate to better quantify the impacts of changes in species composition and richness on ecosystem functioning. In this presentation, we show how quantitative and qualitative species-level functional traits can be used to define functional groups and estimate FD for plankton communities. The functional traits and the geographic distributions of 106 copepod species were used to estimate the FD of Mediterranean copepod assemblages for the 1965-1994 and 2069-2098 periods. Multiple environmental niche models were trained at the global scale to project the species habitat suitability in the future Mediterranean Sea and assess their sensitivity to climate change. Simultaneously, the species traits were used to compute a functional dendrogram from which functional groups were defined and FD was estimated through Faith's index. Null models were implemented to test if changes in

FD were significantly different from changes in species richness alone. All but three of the 106 species presented range contractions of varying intensity. A relatively low decrease of species richness (-7.42 on average) is predicted for 97% of the basin, with higher losses in the eastern regions. Changes in FD follow the same pattern and are often not different from those that can be expected from changes in richness. Relative sensitivity to climate change is not clustered in functional space and does not significantly vary across the seven copepod functional groups we defined. Consequently, the most and the least sensitive copepod species are functionally redundant. Such redundancy should buffer against the potential loss of ecosystem functions induced by climate change. However, the most negatively-impacted species share Atlantic biogeographic origins, so our results are in line with the hypothesis of the "tropicalization" of Mediterranean biological communities.

Relating taxonomic phytoplankton richness to cell size spectra in the ocean

Authors: Damiano Righetti, Meike Vogt, Nicolas Gruber, Niklaus E. Zimmermann

Presenter: **Damiano Righetti**

Understanding the role of biological trait diversity for carbon-climate dynamics globally means that we must consider photosynthetic members of the plankton—known as phytoplankton—as these organisms drive half of the Earth's primary production. Cell size– and taxonomic richness are two relevant aspects of plankton diversity, as they may both mediate primary productivity and ocean carbon export. One tenet is that temperature or kinetic energy fundamentally control global marine diversity patterns, since they are driving metabolic processes. Yet, the distribution, drivers, and annual dynamics of phytoplankton richness and size remain poorly determined in the ocean. Here, we use in situ records, spanning 536 phytoplankton species, and niche modeling to depict a global map of phytoplankton species richness. Results show that species richness scales positively with sea temperature over a large fraction of the ocean, yet certain temperate and high-latitude regimes appear governed by different drivers. Gathering data on cell size of individual species into the projected phytoplankton communities allows us to explore the spatial and seasonal pattern of cell size spectra. This serves to shed light on the possible patterns and drivers of macro-ecological diversity patterns of essential marine microbes.

Genomic Investigation of climate-change induced reshuffling of global plankton biogeography

Authors: Paul Frémont, Marion Gehlen, Mathieu Vrac, Olivier Jaillon

Presenter: **Paul Frémont**

Understanding and predicting the impact of global change on marine ecosystems is a major challenge of this century. Marine plankton, the base of the food web and actor of the ocean biogeochemical cycles is also a key player in tempering the effects of anthropogenic climate change. However our knowledge about biome-scale responses of plankton to global change is limited due to lack of ecosystem representative cultivated species. This study presents a quantification and analysis of possible climate change impacts on marine plankton based on trans-kingdom biogeographies at the metagenome scale. We analyzed present-day biogeographies from Tara Oceans data and global physical/biogeochemical climatologies based on niche modeling. We computed and compared biogeographies from mean historical conditions (2006-2015) and from projected future mean conditions (2090-2099; CMIP5 Earth system models). We found major expansions and poleward shifts of tropical communities at the expense of temperate ones. Results also

suggest a biogeographical decoupling between smaller and larger microbial organisms, potentially causing major community rearrangements. Finally, while temperature increase is predicted to be the main driver of reshuffling, it is not sufficient on its own to explain global changes. This work demonstrates the importance for joint biological surveys at the molecular level and physico-chemical sampling of the global ocean.

Selection and mixing of marine phytoplankton over a coastal tidal front

Authors: Pierre Ramond, Mathilde Cadier, Raffaele Siano, Colomban de Vargas, Laurent Memery, Thomas Gorgues, Marc Sourisseau

Presenter: **Marc Sourisseau**

Communities of marine photosynthetic organisms, i.e. phytoplankton, with various ecological traits are responsible for about 50% of the earth's primary production and shape global biogeochemical cycles. Their taxonomic and/or functional composition modulates these processes. The factors brought forward to explain phytoplankton's distribution and composition involve: advection and dispersion (e.g. water currents, mixing), selection processes by exclusive competition and resources availability (light, nutrients …), adaptation to environmental factors (e.g. temperature, salinity…) and biotic interactions (e.g. trophic or symbiotic). By coupling a theoretical model and in situ observations, we studied the selection processes influencing phytoplankton's diversity and composition in the Iroise Sea. Our work focused on the Ushant Tidal front. This physical process displays high primary production throughout summer but must be colonized by migration processes each year due to seasonality. A trait-based model was adapted to a hydrodynamic configuration of the Iroise Sea to study the phenotypic diversity patterns produced by competitive selection and migration. In situ DNA metabarcoding samples were used as a benchmark to test if other processes determined phytoplankton diversity in this environment. A hotspot of both phenotypic (model) and taxonomic diversity (metabarcoding) was highlighted close to the Ushant Tidal front. In both approaches this peak of diversity was mainly fueled with the advection of organisms from surrounding areas (i.e. ecotone), however, although less abundant, some organisms were found to survive only locally due to a decrease in competitive exclusion. Still, a significant difference was highlighted between the peaks of phenotypic and taxonomic diversity. The first one appeared on the west side of the front due to a local increase of the time for competitive exclusion, whereas taxonomic diversity was higher on the east side due to stronger migration processes. This result implies a decoupling between taxonomic and phenotypic diversity, with a higher phenotypic redundancy in the peak of taxonomic diversity.

From genes to functional traits in the global ocean : building de novo plankton functional types from environmental metagenomics data

Authors: Emile Faure, Arnaud Meng, Sakina-Dorothée Ayata, Lucie Bittner

Presenter: **Emile Faure**

One global challenge of the XXIst century is to understand and predict the impacts of anthropic climate change on ecosystem functioning. In the ocean, planktonic organisms play a crucial role in climate regulation, global biogeochemical cycles, and marine trophic networks. Models coupling physics and biogeochemistry are a widely used tool to quantify biogeochemical cycles through the simulation of planktonic ecosystems dynamics. But these models often rely on a biogeochemical view of marine plankton,

since they describe dynamics of functional groups historically described by marine biogeochemists (known as Plankton Functional Types, or PFT). These groups have been criticized for their lack of ecological justifications, potentially leading to an oversimplified representation of planktonic diversity in models. However, the lack of data-driven methodologies to determine and quantify the potential and realized functional traits of planktonic communities still prevent marine ecosystem modelers from implementing realistically diverse planktonic communities into models.
Here, we addressed this problem by building de novo plankton functional types from metagenomics data. More precisely, we used a set of 885 procaryotic metagenome-assembled genomes (MAGs) built from the Tara Oceans metagenomics data by a precedent study. For each of these MAGs, we detected and translated gene domains to protein sequences, and gathered the genes relative abundance in the Tara Oceans samples. A sequence similarity network was then built to create groups of homologous proteins that potentially participate to the same metabolic pathways. The functional annotations of these sets allowed to define groups of proteins linked to biogeochemical functions, e.g. photosynthesis or nitrogen fixation. We investigated the distribution of each of these sets across the global Ocean in perspective of the environmental conditions. This non-arbitrary and data-driven approach allows to quantify the relative abundances of groups of sequences assimilable to plankton functional types in any metagenomics sample. It will help modelers to define realistic sets of traits as input to their models, and offer them new ways to validate models outputs using sequence relative abundance.

The drivers of global community structure in open ocean eukaryotic plankton

Authors: Sommeria-Klein, Romain Watteaux, Daniele Iudicone, Chris Bowler, Hélène Morlon

Presenter: **Guilhem Sommeria-Klein**

Because microorganisms have high dispersal abilities and large population sizes compared to larger multicellular organisms, whether they exhibit biogeographic structure has been highly debated. The case of oceanic plankton is particularly striking since planktonic communities are subject to constant homogenizing forces from currents at the global scale. Describing plankton biogeography at a broad spatial and taxonomic scale, and disentangling the different factors driving this biogeography, has been limited by the huge diversity of planktonic organisms, the remoteness of their habitat, limitations in methodological approaches for analyzing big genetic data, and limitations in our ability to account for connectivity through currents. Here, we combine novel metabarcoding data from the Tara Ocean global survey that span the globe including the Arctic, powerful probabilistic mixed-membership models, and a global ocean circulation model to investigate the spatial community structure of eukaryotic plankton in the open ocean.
We show that eukaryotic plankton can, as a whole, be classified into 10 “community types”. These community types, identified by the Latent Dirichlet Allocation mixed-membership model, represent sets of Operational Taxonomic Units (OTUs) that tend to co-occur in local-scale communities. In turn, local-scale communities can be viewed as samples from the community types, drawn with varying proportions. We find that the 10 community types are geographically structured. Two of these community types correspond to the Artic plankton metacommunity, and share very few OTUs with the other community types. The 8 other community types are hardly ever found in the Arctic, and share a large number of OTUs, suggesting that their biogeographic structure is carried by a limited number of OTUs. In order to understand if and how eukaryotic plankton biogeography relates to their size and function, we split the plankton into 69 major groups, each characterized by its mean body size and its dominant function (parasite, phototroph, photohost, phagotroph, and metazoans). The number of community types identified for each group is quite variable, ranging from an imposed lower limit of 3 to 12. We find that the spatial community structure of most groups is well explained by a combination of environmental (i.e., abiotic and biotic) conditions and connectivity through currents. The relative importance of currents and environmental conditions depends on the taxonomic group considered, with large organisms (e.g. metazoans) comparatively more influenced by currents than smaller ones (e.g. phototrophs and phagotrophs). Within environmental factors, biotic

conditions are generally better predictors of community structure than abiotic ones.
These findings have important consequences for the predictive modeling of plankton communities at the global scale. This work also suggests that probabilistic modeling is a promising approach to infer patterns and processes form large metagenomics datasets.

From macro- to micro- evolutionary processes: how dispersal shapes gene flow and species diversification in coral reef fishes

Authors: Giulia Francesca Azzurra Donati, Albouy, C., Poirier, M., Debieu, M., Hagen, O., Leblond, J., Ibrahim, S., Zareer, I., Zyad, A., Govinden, R., Pagu, J., Claverie, T., Leprieur, F., Pellissier, L.

Presenter: **Giulia Donati**

Coral reefs as hotspots of biodiversity, have subsisted tens of thousands of years of natural change, but are threatened due to rapid anthropogenic climate change and overexploitation. To ensure the maintenance of ecosystem services provided by coral reefs for future generations, it is not only important to preserve its current biodiversity but also to ensure that the eco-evolutionary processes, which generate this biodiversity, keep functioning. Here, we explore macro- to micro- evolutionary processes shaping diversity in coral reef fishes. We expect that a set of functional traits determining gene flow among the populations within a given species, and thereby its population genetic structure, should corresponds to those related to diversification rates from phylogenies of fish clades. By means of phylogenetic-based approaches, we relate functional traits to diversification rates among 31 coral reef fish clades. Correspondingly, using double-digest Restriction site Associated DNA sequencing (ddRADseq), we examine whether genetic distinctiveness among populations of coral reef fish species is associated to the same functional traits as in the interspecific analyses. At the intraspecific level, we analyze 25 coral reef fish species sampled across four populations in the Western Indian Ocean (WIO), namely in the Maldives, the Seychelles, as well as in Mafia Island (Tanzania) and Mayotte Island (Comoros Archipelago). In the diversification analyses, we found that diversification rates were significantly associated traits related to dispersal ability, such as for example adult body size and home range mobility behavior. That is, we found highest diversification rates for clades with smallest-bodied species on average and containing a large proportion of species with narrow home range mobility behavior (e.g. Pomacentridae). Up to date this corresponded to the preliminary ddRADseq analysis for which we found evidence of population structuring in species characterized by the same combination of traits (e.g. Amphiprion akallopisos, Pomacentridae). Beyond advancing the fundamental knowledge of the processes that shaped current seascape genetic patterns in coral reef fishes, outcomes will provide valuable information for conservation management to support and improve Marine Protected Areas (MPAs) management plans in this region, especially upon directives concerning size and location of MPAs under climate change.

Exploring biogeographic patterns of marine planktonic cyanobacteria in coastal habitats- what can we infer from 'omics' based approach?

Authors: Punyasloke Bhadury, Tarkeshwar Singh

Presenter: **Punyasloke Bhadury**

The structure of marine planktonic cyanobacterial communities in coastal habitats can strongly influence rates and fluxes of coastal carbon cycling. Biogeographic patterns of marine planktonic cyanobacterial assemblages were elucidated from four coastal habitats namely, Baltic Sea (BL), Monterey Bay (MB), South China Sea (SCS) and Sundarbans (SB) based on deep phylogeny of 16S rRNA sequences generated using next generation sequencing and Sanger sequencing approaches. Based on 16S rRNA phylogeny, four major taxonomic orders of marine planktonic cyanobacteria were recovered in varying proportions with several novel 16S rRNA sequences in each of the four targeted habitats. Members of the order Synechococcales were dominant in all the habitats (−94% sequences) while the orders Chroococcales and Oscillatoriales were only detected in SB and SCS, respectively. In the phylogenetic tree, Synechococcus-like sequences showed overwhelming dominance in SB and they were found in three other habitats. Prochlorococcus-like sequences were found in sizeable number in MB and SCS but were absent in SB and coastal BL. Synechococcus-like sequences were represented by three major marine clusters (5.1, 5.2, and 5.3). Three novel clades as part of Synechococcus cluster were detected only in SB and one novel clade in BL. These clades could have potential functional significance in coastal carbon cycling. Interestingly, cultured based approaches also revealed a new species of Synechococcus, Synechococcus moorigangaii from SB which has the ability to grow across a range of salinity and metabolize different forms of nitrogen as well as fix di-nitrogen. This reflects the potential unexplored functional diversity of marine planktonic cyanobacteria in coastal habitats which have consequences for ecosystem functioning. Overall the study has revealed that majority of the marine planktonic cyanobacterial OTUs were found to be exclusive to each habitat, whereas some were shared by two or more habitats based on beta-diversity analysis.

Linking morphological characteristics of phytoplankton to functional traits from continuous imaging in Narragansett Bay, U.S.

Authors: Virginie Sonnet, Lionel Guidi, Coleen Mouw, Sakina-Dorothée Ayata

Presenter: **Virginie Sonnet**

Phytoplankton diversity plays a key role in the dynamics of marine ecosystems and global biogeochemical cycles, and in climate regulation. However, a huge part of this diversity remains poorly known, and its drivers poorly understood. This diversity can be taxonomic (e.g., at the species level), phylogenetic (e.g, evolution history) or functional (e.g., role played in the ecosystem). Here, we focus on the functional diversity, i.e. the part of the diversity due to the individual phenotypic characteristics (or traits) that influence the evolutionary success of organisms and the functioning of ecosystems regardless of their taxonomic classification. We use high-resolution plankton imagery generated by an Imaging FlowCytobot deployed in Narragansett Bay, United States, to detect the main morphological features of the local phytoplankton community. Our goal is to investigate the morphological diversity of the phytoplankton in Narragansett Bay, describe its seasonal variation, and identify its main environmental drivers. These morphological features are used to define functional types (or groups) and to estimate the functional diversity. A generic trait-based model of plankton communities is then developed including environmental factors. This study is a first step in linking phytoplankton functional traits with the hyperspectral absorption and attenuation signals also recorded at Narragansett Bay, moving towards the development of a new algorithms to process hyperspectral satellite data.

Session 11: Investigating and modelling linkages between biology and fleet behaviour in multi-species fisheries and ecosystems

FishSET: Methods and Models to Assess the Economic Impacts of Fisheries Management Actions and Environmental Change

Authors: Alan Haynie, Corinne Basin, Jordan Watson, Melanie Harsch, Y. Allen Chen

Presenter: **Alan Haynie**

There are large number of possible approaches to analyzing and modeling the impacts of environmental, stock, and management changes on fisheries. NOAA Fisheries and partners have worked to develop the Spatial Economics Toolbox for Fisheries (FishSET) to provide better information to managers and the public about the economic tradeoffs among different uses of our marine resources.

Since the 1980s, economists have used discrete choice random utility models to assess the factors that influence fishers' spatial and participation choices to understand the trade-offs of fishing under different conditions. This knowledge can improve evaluations and predictions of how fishers respond to the creation of marine reserves, to changes in market conditions, to variations in target stock abundance, or to management actions such as the implementation of catch share programs. FishSET includes a suite of discrete choice models as well as a range of related data management and analytical tools. Additionally, the FishSET project has focused on developing other metrics to assess fishery performance. In many cases, metrics such as changes in location, trip length, revenue per day, and CPUE also provide meaningful insights into how behaviors have changed with variations in policy and environmental conditions.

For several years, the FishSET project has worked to make this type of modeling easier. FishSET has worked to standardize best practices and enable robust model development, execution, comparison, and interpretation. The first versions of the software were based in Matlab, but since 2018 the project has focused on developing R-based software that can be more freely utilized across fisheries. Here we discuss the current status of the FishSET project and pilot projects from multi-species fisheries around the U.S. We also discuss how FishSET enables models and indices of fisher behavior to be better integrated with ecosystem and stock assessment models.

The interaction between catch patterns, discard avoidance tools and fleet economics in Irish fisheries

Authors: Julia Calderwood, Dave Reid

Presenter: **Julia Calderwood**

As a result of the introduction of the Landing Obligation in European fisheries there is a need to equip industry with the tools and knowledge to avoid unwanted catches. Optimising fishing practices in terms of time and location fished have been acknowledged as being important in modulating catch composition. As a result a number of mapping methodologies have been and are currently being developed in European fisheries to identify where discards and catches of key choke species are concentrated. This information can then be used to better inform decision making on when and where to fish to avoid unwanted catches.

Whilst avoiding unwanted catches and choke species will be important under the Landing Obligation, to maximise fishing opportunities, the additional influence of market drivers on fishing behaviour cannot be ignored. Using a hotspot mapping tool, developed for Irish demersal fisheries, we further investigated whether unwanted catches could be avoided whilst allowing the fleet to target productive and profitable fishing grounds. Our results indicated that Below Minimum Conservation Reference Size (MCRS) fish could be avoided whilst targeting the more valuable above MCRS species. For choke species scenarios the options to avoid unwanted fish whilst still targeting species with remaining quota, and fishing in profitable areas were minimal. Previous modelling has suggested that by utilising information from these hotspot maps catches of TAC species that are not quota restricted can be maximised prior to choke species quotas being exceeded. These modelling exercises had not, however, taken account of the potential influence of fleet economics on the outcomes. This information can, therefore, be added to such models to better understand the links between species distributions and catch patterns on future fleet behaviour.

Consequences of management measures on fishers’ behaviour and marine ecosystems: the example of the Eastern English Channel flatfish fisheries.

Authors: Raphaël Girardin, Elizabeth A. Fulton, Rebecca J. Gorton, Sigrid Lehuta, Marie Savina-Rolland, Olivier Thébaud, Morgane Travers, Youen Vermard, Paul Marchal

Presenter: **Raphaël Girardin**

Understanding the ecosystem reaction to management regulation is a key to achieve conservation and sustainability objectives. The implementation of such an ecosystem approach to fisheries (EAF) requires improved knowledge of ecosystem complexity. Over the past few decades, the development of ecosystem modelling contributed significantly to the improvement of our knowledge on ecosystem functioning in interaction with human activities, and it is now widely recognized used to evaluate management strategies. In our study, we coupled the ecosystem model Atlantis with various fishers’ behaviour models, and applied the coupled models to the Eastern English Channel (EEC) ecosystem and fisheries. The fishers’ behaviour models tested were a random utility model and several gravity models. Fishers' choice of métier and fishing area in those model were driven by a combinaison of various factors such as, tradition, expected revenue and species targeting. Once the models coupled, we evaluated the consequences of implementing a combination of area closures and effort reduction on the EEC ecosystem and on the French netters fleet targeting sole (Solea solea). We analysed both the modification of fishers’ behaviour and ecosystem functioning after 50 years of management constraint. The fishers' behaviour model selected was a simple gravity model including tradition and targeting as driver of metier and spatial effort allocation choices. Coefficient of the model derived from a meta-analysis of fishing fleet dynamics study using random utility models. We observed a noticeable benefit of the application of the combination of MPAs and effort reduction on the biomass of most commercial species, including sole and plaice (Pleuronectes platessa), and on the total value landed per unit effort. The response of the ecosystem varied across the metier and the species considered.

Eliciting spatial approaches to avoid unwanted catches in an EU Landing obligation context: A bio-economic evaluation in the Celtic Sea

Authors: Francois Bastardie, Höffle, H., Vigier, A., Nielsen, J.R., Farnsworth, K.D., Pedreschi D., Reid, D.

Presenter: **Francois Bastardie**

The full implementation of a landing obligation in EU waters from 1st of Jan 2019 associated with the TACs system in force in the northern EU waters may sometimes lead to a large quota underutilization, especially in the Celtic Sea, when the fishing is "choked" by the most restrictive quotas. If 'choking' is the result of decline in abundant commercial species, or of TACs lagging behind increasing fishing opportunities, there may be possibilities for the fishermen to avoid catching these species. We have developed a range of spatial fisheries models, integrating biological information with fisher decision-making dynamics. The models can simulate a range of possible management measures (both coercive and incentive) that would help such avoidance. We present the outcomes of the DISPLACE agent-based modelling platform for simulating bio-economic fisheries dynamics and clarifying options for sustainable and viable fisheries in the Celtic Sea. The Celtic Sea ecosystem consists of complex biological interactions among several fish species including commercially important species and unwanted by-catch species. This has encouraged us to integrate a size spectrum-modelling approach that accounts for potential predation effects among species when fishing pressure is displaced. The approach is specifically suited for evaluating whether the benefits of spatial plans and incentives compensate the potential biological costs of displacing fishing to the surroundings and possibly other stocks. The models generate an overview of short to medium-term impacts by aggregating the individual fishing operations, and at the same time detailing the spatiotemporal dimensions for particular fishing activities, harbor communities or national fleets. We found that computer simulations can support ecological-economical evaluations of spatial management strategies to elicit some viable paths when managing fisheries and for example avoiding quota underutilization and associated economic losses. We discuss the potential to facilitate nudging, incentivizing and/or self-government of the stakeholders. In the simulations, the fishers are provided with habitat credits and spatially varying tariff maps with which we can test in the model. The final model framework should ultimately anticipate the efficiency and effectiveness of the mitigation measures and the residual impacts on ecosystems at spatial and temporal scales relevant to fisheries interests and policy makers, in the Celtic Sea and beyond.
FB & RN were funded by EU FP7 ERA-net COFASP ECOAST Project (Grant Agreement No. 321553) and, together with KDF and DR, by PROBYFISH EASME/EMFF/2017/022 (The identification of measures to protect by-catch species in mixed-fisheries management plans). HH, AV, KDF, DP and DR were funded by the Science Foundation Ireland Investigators Program (Project: 'Creating the knowledge for precision fisheries management: spatially aware 'nudging' to achieve Maximum Sustainable Yield using real-time fisheries incentives')

Predicting the economic impacts of climate change requires understanding the link between environment and economic production

Authors: James Smith, Jonathan Sweeney

Presenter: **Jonathan Sweeney**

Predicting the economic impacts of climate change requires understanding the link between environment and economic production. In fisheries, economic production is determined both by fish population dynamics and the production decisions of fisherman. Although there is a growing literature on how climate change will impact fish populations, much less is known about how it will affect fishing behavior.

In this study, we use Hidden Markov Models (HMMs) to simulate fishing trips under alternative climate futures. We fit an HMM to VMS data from the California drift gillnet fishery and covariates from regional ocean models and species distribution models. Our work provides insight into how fisherman will respond to anticipated changes in climate and offers an important tool to simulate fishing effort under alternative climate scenarios.

The promises and limitations of integrating fishing styles analysis into fleet behaviour models

Authors: Amanda Schadeberg, Katell Hamon, Marloes Kraan, Jurgen Batsleer, Jan Jaap Poos

Presenter: **Amanda Schadeberg**

Demersal fisheries are difficult to manage due to the mixed and unpredictable nature of their catch. Fishers constantly have to adapt to comply with regulation, market conditions, and their environment. In this context the human dimension of fisheries management is difficult to study due to its dynamic and context-specific nature. One solution that attempts to balance parsimony with complexity, is the fishing styles approach (Boonstra & Hentati-Sundberg, 2016), which combines the traditional definition of fishing activities through quantitative analyses of logbook data with in-depth fisher interview data. Our goal was to segment the Dutch fleet into groups based on a combination of activity characteristics (i.e., what is happening at sea) and social factors (i.e., who the people doing this activity are, and what their motivations are). Groups of fishing practices are created in the quantitative phase based on the analysis of catch, trip, and vessel characteristics. Developments in the fleet activity can be observed over time, as some practices emerge and others become less prevalent. The qualitative phase of the research consists of interviews with fishers and experts about the motivations behind certain behaviours, with which we try to explain some of the non-rational elements of fishing activity at sea, such as family ties, connection to place, and business structure. The qualitative information also feeds back into the quantitative analysis to create more meaningful categories based on fishers' knowledge. With these results it is possible to identify some of the factors that drive fishers in the long and short term, as well as what makes one group of fishers more likely to engage in a certain behaviour than another. This presentation will discuss the promises of integrating the results of this research method into fleet behaviour models, as well as the limitations of the approach.

Empirical Fleet Behavior Models for Multispecies Rights-Based Fisheries

Authors: Matthew Reimer, Joshua Abbott, Alan Haynie

Presenter: **Alan Haynie**

The economics literature has a rich history of modeling the spatiotemporal behavior of fishers, which emerged with the growing use of spatial regulations in fisheries management and the recognition that the placement of gear over space and time is the primary short-run behavioral margin of fishermen. The dominant statistical method for modeling the spatiotemporal behavior of fishers is the random utility maximization (RUM) model, which assumes that individual fishers choose from a set of discrete fishing sites in order to maximize their expected utility, where the expected utility of selecting a fishing site is modeled (among other factors) as a function of expected revenue and the distance from a fisher's current location. Observed fishing location choices are then used to estimate how fishermen trade off the costs of traveling distance with expected revenue or to evaluate the welfare implications of spatial regulations. The prevailing RUM approach has been useful for examining the spatiotemporal behavior of fishermen in derby fisheries,

whereby fishermen act myopically to maximize contemporaneous expected utility. However, such an approach is not sufficient for prediction in fisheries with some form of catch-rights management structure because it does not incorporate dynamics associated with managing quota usage over a season. The dynamic nature of quota management is a fundamental element of fishing behavior, particularly in multispecies fisheries: fishermen must strive to balance their multispecies catch with their portfolio of quota, all the while considering the opportunity cost of using quota and the uncertain spatial and temporal distribution of species compositions later in the season. Failure to incorporate forward-looking behavior hinders prevailing models from predicting changes in welfare and the spatiotemporal distribution of fishing effort in response to fishery policy changes.
In this paper, we develop an empirical spatiotemporal model of fisher behavior in a multispecies fishery with tradable catch shares. The key innovation of our approach is the introduction of an annual lease-market for quota, which we model as a pure exchange economy with a rational expectations equilibrium. Fishers are assumed to be forward-looking and form expectations over future quota usage when considering contemporaneous quota supply and demand decisions. Our estimation strategy incorporates both dynamic and general equilibrium elements of catch-share fisheries through a nested fixed-point maximum likelihood procedure. We apply our methodology to the North Pacific multispecies groundfish fishery and evaluate the potential effects of non-rights-based policies, such as area closures and quota reductions. We demonstrate that our approach has superior predictive capabilities than standard models, particularly for out-of-sample predictions of the effects of policies that have not yet been implemented.
Given the prevalence of catch-share management programs in today's developed-world fisheries, adapting spatiotemporal models of fishing behavior to reflect prevailing institutional settings is long overdue.

Choice sets for fishery location choice models in the presence of fine-scalespatial heterogeneity: An application to the Pacific mutlispecies groundfish fishery

Authors: Robert Hicks, Daniel Holland, Peter Kuriyama, Kurt Schnier

Presenter: **Daniel Holland**

A central component of any discrete choice analysis is the selection of alternatives that determine a decision agent's choice set. Failure to properly specify choice sets will generate biased parameter estimates, inaccurate behavioral predictions, and erroneous estimates of policy relevant metrics (e.g., welfare effects of closed areas in fisheries). The development of more behaviorally realistic choice sets is integral to predicting agent behavior and informing public policy. In some contexts such as fisheries, discrete spatial choices are made repeatedly, and the decision-maker invests in the collection of fine-scale spatial information through time. Fine-scale targeting behavior may be particularly important for multispecies trawl fisheries where since small changes in location can strongly impact the species mix. We propose constructing choice sets by sampling from a fine-scale grid of location choices and compare this approach to a traditional conditional logit model with choices sets constructed of discrete fishing areas that aggregate many possible specific fishing locations. We present results from a Monte Carlo study that compares these modeling approaches in terms of parameter bias and prediction. We also compare results from an empirical application of the models to the multispecies Pacific Groundfish trawl fishery. We find considerable heterogeneity in the parameter estimates and support for our fine-scale choice set mode

Purse-seine fisheries modelling in a context of environmental and management challenges

Authors: Pierre Bourdaud, Lynne J. Shannon, Emma M. Lockerbie, Mathieu Genu, Yunne-Jai Shin, Astrid Jarre

Presenter: **Pierre Bourdaud**

Pelagic fisheries in Southern Benguela have suffered multiple shifts in their history, both environmentally- and human-induced. In the late 1990s / early 2000s, an Eastward shift was observed in several species, particularly sardine, which had severe repercussions for fishing industries, especially on the West coast. Recent research has concluded that both human and environmental drivers were involved, and current progress on the knowledge of sardine stock has helped determine that it should not be managed as a single stock, but rather as two interacting sub-stocks.

In an ecosystem driven by a high environmental variability, with pelagic fisheries managed by different targets and by-catch quotas, the implementation and efficiency of the new management OMP-18, which includes the two-components stock of sardine, represents a real challenge. This has been proven by the recent failure of spatial management considerations on the sardine stock. In this situation, a more complex representation of fishers in models is required to be able to predict future potential shifts in behaviors or critical ecological situations.

Using innovative coupling of a pre-existing multi-species trophic model OSMOSE with the fleet-dynamic individual-based model DSVM, different questions can be addressed. These include the impact of environmentally-driven factors, like different upwelling regimes, for fishers and the fish community, as well as aspects of management efficiency of the new OMP-18 on ecological and economic criteria at short- and medium-terms.

Such coupled modelling relies on a set of assumptions on fishers' behavior as individuals but also in its interaction in a network of actors. Therefore, uncertainty analysis of fishers' perception or the evolution of different psychological typologies of fishers must be explored to outline the current limits of such complex modelling approaches on prediction, but also draw the contours of future axes of research on fleet behavior modelling.

Evaluating how fisheries, environment and biological resources influence marine mammal fish depredation

Authors: Maria Ching Villanueva, Paul Tixier, Lyndsay Clavareau, Lavinia Suberg, Johanna Faure, Nicolas Gasco, Anaïs Janc, Gaétan Richard, Patrice Pruvost, Charlotte Chazeau, Clara Peron, Guy Duhamel, Bertrand Le Gallic, Sophie Gourguet and Christophe Guinet

Presenter: **Ching Villanueva**

Reports of direct and operational fisheries interactions with marine mammals increase globally and pose significant socio-ecological and economic viability threats. Close interactions of marine mammals with fisheries occur either as an active or passive behavior to depredate caught fish. In the Kerguelen and Crozet Economic Exclusive zones, some whales depredate mainly on Patagonian toothfish (Dissostichus eleginoides) caught using demersal longlines. Fish depredation by these large predators seems to have serious consequences for demersal longline fisheries, especially when they lose valuable catch and face other associated operational and regulatory challenges. Recent use of technological acoustic deterrent provided limited efficiency to reducing longline fisheries production loss. Thus, changes in some fishing strategies were quantified to evaluate their efficiencies in mitigating both bio-ecological and economic losses.

We observed that depredation is seasonal and influenced largely by fishery behaviors and prey abundance distribution. Spatial modeling analyses showed that Patagonian toothfish distribution influenced marine mammal occurrence. Despite this later observation, isotopic analyses seem to indicate that this fish species is not the primary targeted preys of depredating marine mammals. Several operational fishing strategy modifications were tested but only showed significant efficiencies when vessel-whale encounter is avoided. Ecosystem model analyses showed that this phenomenon impacts system structure and functioning which may weaken system viability and resilience to change while increasing challenges for future management.

Opening up the dead-end street of assuming constant métier-level catchabilities in mixed-fisheries models

Authors: Sarah B. M. Kraak

Presenter: **Sarah Kraak**

In mixed fisheries it is unlikely that all quotas are exhausted at the same time. Traditionally it is thought that when the first quota is filled, the fishery must stop fishing and underexploit the quotas for the other species or continue fishing for the other species while exceeding the quotas that are filled. The underlying cause is thought to be the “technical interaction”, where multiple species are captured during the same fishing operation. Technical interactions are, however, usually evaluated at the aggregation level of métier (= group of fishing operations targeting a specific assemblage of species, using a specific gear, during a specific period of the year and/or within a specific area). The problem then arises that at aggregated levels catches may be more mixed than at haul level. Therefore, aggregation implies or even promotes the view that fishers’ adaptation to quota mismatches is not feasible, whereas it may in actual fact be feasible at the fishing-operation level (e.g. by spatial avoidance). It may thus imply more stringent technical interaction than actually exists and it dramatizes the choke-species consequences, e.g., of a strict adherence to the EU landing obligation. If this view is held, less research effort may go into searching for the drivers of fisher behaviour resulting in the patterns found at the higher aggregated levels as well as for incentives to change their behaviour. Here I brainstorm about various approaches to better take account of the haul-level variability of species catchabilities in mixed-fisheries modelling, in order to reveal the possibly less stringent technical interactions and expose room for behavioural adaptation. For example, Fcube-like models could produce scenarios with minimized choking by searching in the x-dimensional space of métier catchabilities (where x is the number of species) bounded by, e.g., the ranges of the species catchabilities found in the recent years. Alternatively one could iteratively search for the minimum amount of catchability changes required to result in a scenario without choking, check whether these changes might be feasible, and, if not, search further until a feasible scenario is found with less choking. Subsequently it can be investigated what is needed to persuade fishers to make the necessary changes.

Projecting global fishing effort dynamics in the 21st century under climate change

Authors: Vicky Wing Yee Lam, William W.L. Cheung

Presenter: **Vicky Wing Yee Lam**

Previous studies assessing climate change impacts on marine fisheries focus on the impacts from changing ocean conditions on fish distribution, fish catch and the related human well-beings. However, these studies often use simple assumptions of fishing effort scenario without accounting for the effects of changing productivity of living marine resources, fisheries management measures, and the economics of fishing on fishers' behavior and fishing effort. Here, we develop and apply a holistic approach for projecting future impacts of climate change on global fisheries by linking a fishing effort dynamic model with the biological simulation model, Dynamic Bioclimate Envelope Model (DBEM). In each time-step (year or fishing season), spatial and temporal changes in fishing effort are predicted based on changes in catch and profitability of the exploited species while DBEM projects changes in species distribution and abundance under climate change and fishing effort. In the effort dynamic model, fishers are assumed to seek to maximize their profit given the constraints imposed by management measures e.g., harvest control rules, with the consideration of economic factors such as seafood price, operating cost of fishing, cost for purchasing a new vessel and the depreciation cost of the fishing vessels. We show that the effort dynamic model can broadly reproduce historical changes in fishing level. Projections of future catches with the consideration of effort dynamics can be substantially different from previous studies with simple fishing effort assumption. Thus, this study highlights the importance of projecting and applying plausible fishing scenarios in understanding climate change impacts on fisheries.

Seasonal variation and spatial distribution in the Norwegian Cod fishery

Authors: Tannaz Alizadeh Ashrafi, Arne Eide, Øystein Hermansen

Presenter: **Tannaz Alizadeh Ashrafi**

Everyone has heard about seasonality in fisheries. But what exactly do we know about seasonality in regulated fishery? This study empirically attempts to identify the presence of seasonality in Norwegian cod fishery, and if any detected, why it would happen and in what guise. We argue that to determine seasonality, geographical distinction need to be taken into account. In this regard, catch per unit effort (CPUE) as bio-economic ratio in major exploited areas is used to find the relationship between CPUE and measures of the degree of spatial and temporal concentration of fish stock and subsequently trawl fleet. The spatio-temporal data of 54 cod trawl vessels, with the total of 157 aggregated bi-weekly tows is used to investigate whether cod harvest is a spatio-seasonal process. The frequency-domain analysis of the CPUE provides clear evidences that spawning grounds off the west coast of Norway exhibits seasonality. We further show the importance of economic considerations such as sales price of fish in explaining trawlers' decisions about selecting or substituting cod. An understanding of the origin of CPUE variability and its spatio-temporal distribution to minimize the adverse consequences of heavy trawling during specific time and region is necessary for sustainable fisheries.

Exploring area-based fisheries management in multi-species oceanic fisheries

Authors: Guillermo Ortuno Crespo, Daniel C. Dunn & Patrick N. Halpin

Presenter: **Guillermo Ortuno Crespo**

The spatial expansion of commercial fisheries into ever more remote high seas waters entailed novel impacts on oceanic biological communities, which extend beyond the target taxonomic groups in these fisheries. Over the last few decades, the structure of the pelagic ecosystem in the North Pacific Ocean basin has changed due to the top-down pressure of commercial fisheries. Different forms of area-based fisheries management can be used to plan the amount of overlap between human activities, such as fishing, and target and non-target biodiversity, even in dynamic environments. However, these management measures are rarely used in areas beyond national jurisdiction.

In this study we explore the spatial ecology of 20 species of target and non-target pelagic predators caught by the Hawai'i-based longline fishery by fitting species distribution models using the logbook data and a suite of spatially-referenced oceanographic covariates. These models not only help us understand the individual habitat preferences of these species but how they may be overlapping in space and time throughout the North Pacific Ocean. We then use the taxa-specific monthly probability distribution surfaces of these pelagic species in conjunction with longline fleet dynamics information for the main fishing nations in the region (derived from Automatic Identification System data) to gain a better understanding of the distribution of areas of high probability of catch and bycatch.

By applying concepts that were originally developed to explore the ecological niches of terrestrial and marine species, we aim to better understand the fundamental niche of pelagic fish and longline fishing fleets in oceanic waters and to shed light on the factors shaping their distributions at large scales, which opens new avenues for predictive forecasting and management of future spatial patterns of global longline fishing effort and concomitant stresses oceanic biodiversity.

Factors affecting distribution of the Atlantic surfclam (Spisula solidissima), a continental shelf biomass dominant, during a period of climate change

Authors: Eileen E. Hofmann, Eric N. Powell, John M. Klinck, Daphne Munroe, Roger Mann, Dale B. Haidvogel, Diego Narváez, Xinzhong Zhang, Kelsey Kuykendall

Presenter: **Eileen Hofmann**

The Atlantic surfclam (Spisula solidissima) is a dominant member of the biological community of the Middle Atlantic Bight continental shelf and a commercially harvested species. Climate warming is affecting the biology and distribution of this species, which provides an opportunity to investigate the processes and conditions that are restructuring this fishery and the implications for ecological and socio-economic systems. The Management Strategy Evaluation (MSE), which is a system of linked models, developed for the surfclam fishery is an attempt to provide a comprehensive mechanistic description of the surfclam's response to climate change and understand the cascade of effects initiated by changes in oceanographic conditions. The environmental changes lead to modifications in the distribution of the fishing fleet and the fishing behavior of individual fishing boats, which in turn have social and economic implications. This presentation provides an overview of the components of the surfclam MSE, an analysis of fishing fleet behavior under varying environmental conditions, and implications for management and policy. The lessons learned from the surfclam MSE provide a basis for applying similar approaches to other ecologically important species that are also commercially exploitable resources.

Change in behavior and effort redistribution after implementation of Large Scale Marine Protected Areas

Authors: Juan Carlos Villaseñor-Derbez, John Lynham

Presenter: **Juan Carlos Villaseñor-Derbez**

The number of Large-scale Marine Protected Areas (LSMPAs) has significantly increased over the last years. Fishing effort is effectively eliminated within these protected areas upon implementation. The benefits of reducing fishing mortality within the bounded regions have been largely studied, but little empirical work has evaluated what happens to the effort after an MPA is created. The economic and ecological implications of displacing fishing effort as well as the differential responses under different institutional settings are not yet fully understood. We use identification of fishing activity via Automatic Identification Systems (AIS) and causal inference techniques to provide the first analyses of behavioral changes and spatial redistribution of tuna purse seiners due to the implementation of Large Scale Marine Protected Areas that operate under different institutional settings. Our work provides three main findings: 1) aggregate fishing effort remains relatively unaffected when effort is not caped; 2) Vessels that fished inside the protected area before its implementation redistribute to adjacent waters, but responses are idiosyncratic; and 3) We observe a crowding effect outside the LSMPA over the first years after implementation. Our results not only provide an impact evaluation of the effect of LSMPAs on fishing activity but provide insights into vessel redistribution dynamics. As countries continue to implement LSMPAs to reach the stated 10% target of ocean protection, managers should consider how existing institutions interact with the creation of an MPA. While LSMPAs can provide a wide range of benefits, their implementation must be accompanied with traditional fisheries management to maximize their effectiveness.

Is the local fishing effort adapted to the changing fish resources? Confronting LPUE at 0.05-degree resolution in the ICES area and satellite-derived ocean productivity available to fish.

Authors: Gibin M, Druon J-N, Vasilakopoulos P, Mannini A, Pinto C

Presenter: **Jean-Noël Druon**

The difficult balance between fishing effort and available resource needs to be found to reach sustainability. This balance is complex because it primarily depends on highly variable spatial and temporal processes, such as prey availability, recruitment, fish and vessel movements, all depending on climatic conditions. We propose here to compare the landings per unit effort (LPUE) estimated from VMS (Vessel Monitoring System) and logbooks data (ICES Working Group on Spatial Fisheries Data - WGSFD) with an estimate of the ocean productivity available to fish to evaluate regional and temporal discrepancies of the suitable fishing capacity across the North-East Atlantic area. The resolution of fisheries data is at 0.05-degree and annual from 2009 to 2016. Only mobile bottom gears (bottom otter, demersal seine and beam trawl) were selected excluding dredges for which the shell weight of mollusks would have likely induced a bias in the overall biomass estimate. Official sources of fishing effort the European Fleet operating in European Waters collected under the remit of the Data Collection Framework are made available at a coarse resolution that is incapable to capture local variations. The satellite-derived Ocean Productivity index for Fish (OPFish) represents the potential production of high tropic level communities (fish). The OPFish uses the daily detection of productive oceanic features from ocean colour satellite sensors at 0.0417-degree resolution as a proxy for food availability to fish populations. These productive features, such as eddies or gyres, were shown to attract fish and top predators (Druon et al. 2017, 2016, 2015, 2012) as they are active long enough (from weeks to months) to allow the development of mesozooplankton populations (Druon et al. 2019).

The results show that moderate spatial shift of fishing effort (up to ±10%) shall lead to substantial local changes in landings (up to ±50%) and LPUE (up to ±100%). A spatial index of productivity useful for fish such as OPFish, for which a link was shown (although likely weakened by over-fishing), shall be used to improve the local balance between local resource and fishing effort.

The effect of desiccation events and habitat complexity on the spatial distribution and temporal stability of species in the rocky intertidal shore of Israel

Authors: Chen Rabi, Gil Rilov, Tamar lotan

Presenter: **Chen Rabi**

The current anthropogenic climate change effects global biodiversity in both terrestrial and marine ecosystems. One of the major expressions of climate change is the increase in the frequency and intensity of extreme climate events. The Middle East is one of the areas that is strongly influenced by the increase of climate change related extreme climate events. On land, these events include an increase in heatwaves and droughts, and in the marine environment, extreme events can include strong storms or heatwaves, such as the El Nino events, that cause mass coral mortalities. Recently, a new phenomenon was described: prolonged desiccation events (PDEs) in the rocky intertidal zone of the Israeli Mediterranean coast. These events can cause massive bleaching of algae and mortality in sessile and mobile invertebrates. Climate re-analysis showed that the synoptic systems that produce these PDEs have increased in frequency in the past four decades. The multiple abiotic stress factors intertidal communities are experiencing, therefore, relate not only to air temperature but also to solar radiation, desiccation, and wind. The effect on individual organisms in the intertidal zone is also strongly related to the fine-scale 3D structure of the habitat that can create multiple microhabitats with highly variable conditions. Microhabitats can either facilitate abiotic stress in ‘hotspots” or offer refugia from extreme abiotic conditions, potentially allowing the persistence of a population during severe weather. In order to understand the fate of organisms and communities in the face of climate change, and specifically during extreme events, there is a need to conduct long-term monitoring of the state of the community at multiple scales, from the fine-scale to the regional scale. In addition, tracking organisms’ behavior during extreme conditions, and testing their LT-50 under warming and desiccation conditions in the lab will help to estimate the vulnerability and adaptation strategies of organisms to extreme stress. In the current project, I investigate the links between habitat topography and the response of the rocky intertidal community to different types of PDEs (durations, intensities and in relation to season) as well as assess the vulnerability of key organisms to such stress, in order to make projections on the fate of the ecosystem under increasing extreme events. This study will provide insights into the vulnerability and potential stability of the intertidal community under climate change.

SESSION 12: LESSONS FROM THE EXTREME EVENTS OF THE EARLY 21ST CENTURY FOR THE FUTURE OCEANS

Double, triple, and quadruple whammies: Compound extremes in ocean biogeochemistry

Authors: Nicolas Gruber, Flora C. J. Desmet, Thomas Frölicher, Luke Gregor, Urs Hofmann, Eike E. Köhn, Matthias Münnich, und Meike Vogt

Presenter: **Nicolas Gruber**

Extremes in sea-surface temperature, aka marine heat waves, have received considerable attention in the last few years. However, we know very little about the characteristics of corresponding extremes in ocean biogeochemistry, especially those associated with deoxygenation, nutrient stress, and ocean acidification. Of particular concern are the compound events, i.e., those where more than one of these stressors are concurrently or consecutively outside the norm. Here we investigate such events from the global to the regional scale, focusing on the eastern tropical and subtropical Pacific, as this represents a region of high variability and naturally occurring low pH and oxygen concentrations, and as such is very prone to an intensification of these stressors. To this end, we are combining analyses of in-situ and remote observations with model output from regional high-resolution models and define extremes using a combination of relative (temperature, nutrient stress) and absolute (oxygen and saturation state with respect to aragonite) thresholds. Singular events, i.e., those that are extreme with respect to only one variable are identified using a simple peak over threshold method, while we employ multi-variate methods, such as kernel density estimation for identifying compound events. Preliminary results suggest a strong interannual variability in the occurrence of compound events, largely owing to the dominant influence of El Niño/Southern Oscillation in altering the baseline upon which individual ocean or atmospheric weather driven extremes can occur. We also tend to find relatively few triple whammies, i.e., where all stressors are extreme. In contrast, double whammies, i.e., where oxygen and the saturation are low, are rather common, largely due to the tight coupling between these two conditions through the respiration of organic carbon.

Primary drivers of marine heatwaves in the North Atlantic

Authors: Robert W. Schlegel, Youyu Lu, Xianmin Hu, Eric C. J. Oliver

Presenter: **Robert Schlegel**

As the world warms it comes as little surprise that the frequency and intensity of marine heatwaves (MHWs) is known to be increasing as well. Of particular interest to us is what are the physical drivers most commonly responsible for/associated with MHWs and how may we better seek to accurately associate drivers to them given the inherent variability and long-term trends in seawater temperature data. We have narrowed the scope of this study to focus specifically on MHWs that have been classified as either severe or extreme. Using a three-dimensional model, the relationships between MHWs and a suite of environmental variables were determined within pre-defined regions in the North Atlantic Ocean. Self-organizing maps (SOMs) were then used to determine the broader patterns in both the atmosphere and ocean most commonly present during MHWs. From the direct relationships and common patterns observed it was then possible to determine which environmental conditions were most closely associated with MHWs and how these associations varied spatially. The strongest relationships and patterns were then tested against MHWs observed in remotely sensed and reanalysis products to test the inter-product reliability of the results. The

most effective conditions for the prediction of MHWs across datasets were then taken as the primary drivers of MHWs. The implications for the relationships between these drivers and important MHW metrics, as well as how they vary spatially, are discussed here in the context of their potential trends into the near future.

Surface and sub-surface marine heatwaves on the Kerguelen Plateau and their possible impact on the Patagonian Toothfish fishery

Authors: Stuart Corney, Zimeng Su, Gabrielle Pilo Semolina, Mao Mori, Nicole Hill and Neil Holbrook

Presenter: **Stuart Corney**

The Kerguelen Plateau is a large submarine plateau (approximately 2200 km from north to south) that forms a significant obstacle to the flow of the Antarctic Circumpolar Current in the southern Indian Ocean. The plateau is home to a significant Patagonian toothfish fishery, worth over USD50 million a year in the Australian sector alone, as well as being home to significant populations of seals, seabirds and whales. These populations are supported by the increased primary production that is consistently observed in the eddy-field caused by the interruption of the ACC as it moves around the plateau.

In 2016, the Australian longline fishery on the Kerguelen Plateau experienced lower than average catch rates for most of the season between April and November, especially in the early part of the season where the rate was about 50% of the 2011-2015 mean. Longline catch rates were again low at the start of the 2017 fishing seasons, but then rapidly recovered to a large degree by June. A preliminary investigation concluded that the declining catch rates were unlikely to be caused by a decline in fish stock biomass, but instead could have been related to a change in fish catchability driven by fish behaviour and environmental factors.

This presentation will discuss the results of an investigation into the frequency, intensity and depth of marine heatwaves on and around the plateau. The investigation indicates that the full-depth temperature on the plateau has been increasing over the past 20 years and that this has made heatwaves more likely. The drivers of heatwaves will be discussed, including the impact of the recent El Nino (that led to a significant marine heatwave in the Tasman Sea), but also how changes in water masses, such as Circumpolar Deep Water, are likely to influence the region. Finally, some initial results on how changes in water temperature are likely to impact upon a large, long-lived, benthic species such as Patagonian toothfish will be discussed.

The giant jellyfish blooms in the East Asian Marginal Seas: drivers, impacts, and countermeasures for fisheries sustainability

Authors: Shin-ichi Uye

Presenter: **Shin-ichi Uye**

The East Asian Marginal Seas (EAMS, i.e. Bohai, Yellow, East China and Japan Seas), which encompass less than 1% of the total global marine area but provide more than 10% of the world fisheries catch, have seen recurrent blooms of the giant jellyfish Nemopilema nomurai in recent decades, particularly in the 2000s, and concomitant declines of fish catch. Population outbreaks of jellyfish affect fisheries directly by becoming a nuisance in net-based fisheries (monetary loss in Japanese set-net fisheries in 2005: ca. 230

million Euro), and indirectly by diverting zooplankton food from fish in addition to consuming eggs and larvae of commercially important fishes. Because of its bipartite life cycle, causes for the increase in medusa blooms are primarily attributed to asexual reproduction of benthic polyps, which have been greatly enhanced in coastal waters of the EAMS due to human-perturbation (e.g., global warming, increased eutrophication, marine construction, loss of biodiversity). In the face of increasing jellyfish populations, fisheries have to develop adaptive management strategies, such as forecasting outbreaks and developing countermeasures once the blooms occur. At present, forecasting year-to-year bloom intensity is possible by monitoring juvenile medusae from ships of opportunity in Chinese waters, the seeding and nursery ground of this species, enabling Japanese fishermen to prepare countermeasures 1–3 months prior to the arrival of medusae in Japanese coastal waters. As countermeasures, Japanese fishermen have introduced various types of jellyfish exclusion devices in their fishing nets. For long-term fisheries sustainability in the EAMS, building a strong regional partnership in coastal environmental and fisheries management among affected countries (China, Japan, and Korea) is urgently needed.

Amplification and shift of seasonal extremes in ocean acidity during the 21st century

Authors: James C. Orr, Lester Kwiatkowski

Presenter: **Lester Kwiatkowski**

Unlike extreme marine warming events, future extremes in ocean acidification may be more cyclic and occur on both shorter and longer time scales (diurnal and seasonal) because that variability is altered along with the annual-mean trend as ocean chemistry responds dramatically to increasing atmospheric CO2. The amplitude of the seasonal cycle of surface-ocean free acidity [H+] is projected to increase by 81 ± 16% during the 21st century under the RCP8.5 scenario based on our recent comparison of nine CMIP5 Earth System Models despite minor changes in their seasonal cycles of sea surface temperature and salinity. The annual cycles of other ocean acidification variables are also altered but exhibit smaller changes in amplitude. For instance, the annual cycle of surface-ocean pH is attenuated by 16 ± 7%, a counter-intuitive result when compared with the change in amplitude in free acidity, which is larger and of opposite sign. This contrast exists because a change in pH actually represents a relative change in [H+], i.e., ΔpH is proportional to Δ[H+] / [H+], and the increase in the numerator (the seasonal amplitude of [H+]) is less than the increase in the denominator (the annual mean [H+]). The projected enhancement of the seasonal amplitude of ocean acidity could well exacerbate future impacts on marine organisms, relative to the case of considering no change in seasonality. At lower latitudes, marine organisms would be exposed to relatively higher acidity in the summer and lower acidity in winter; in the higher latitudes, it would be the opposite. This CMIP5 analysis is now being extended to the latest generation of Earth System Models, as the CMIP6 model output becomes available. Our analysis further assesses shifts in seasonal phasing and decomposes uncertainties into internal variability, model uncertainty, and scenario uncertainty, applied for the first time to projected changes in the seasonal cycle, not changes in the annual mean.

Ocean Acidity Extremes Altered by Variability Changes

Authors: Friedrich Anton Burger, Thomas L. Frölicher, Jasmin G. John

Presenter: **Friedrich Anton Burger**

The uptake of anthropogenic CO_2 by the ocean reduces the increase in atmospheric CO_2, but causes ocean acidification, i.e. a decrease in both pH and calcium carbonate saturation. On top of this secular change, recent studies suggest that the seasonal cycle in ocean acidity will strongly change over the 21st century because of the nonlinearity in carbonate chemistry of the ocean seawater. An increase in variability potentially leads to more frequent and intense short-term ocean acidification extreme events.

Here, we use daily output from global warming simulations with a comprehensive fully coupled Earth-System model (GFDL-ESM2M) to quantify the impact of changes in daily, seasonal and interannual variability in ocean acidity on changes in different extreme event characteristics. We show that an increase in the variability of ocean acidity leads to a strong increase in the occurrence of extreme events and to large changes in their characteristics. The number of days with extreme conditions for surface waters more than doubles by the end of the 21st century compared to present day under the RCP4.5 scenario. At the same time, the duration and maximal intensity of individual events increase by about 50%. At subsurface, where events tend to be longer lasting and more intense, similar trends in duration and intensity are simulated, but the model projects a six-fold increase in the number of extreme event days. The volume extent of individual events in the upper 200m of the water column triples over the 21st century. In addition, we show that changes in seasonality are the dominant drivers of changes in extreme events at the surface, whereas changes in interannual and daily variability are of similar importance at 200m depth. An increase in variability and extreme events in ocean acidity under future global warming will probably increase the risk of severe and detrimental impacts on marine organisms, especially on those that are adapted to a more stable environment.

Role of ocean deoxygenation and warming in the declines of fisheries resources in the Eastern Tropical Pacific

Authors: Tayler Clarke, Colette C.C. Wabnitz, Sandra Striegel, Thomas Frölicher, Gabriel Reygondeau, Fresia Villalobos Rojas, Ingo Wehrtmann, William W.L. Cheung

Presenter: **Tayler Clarke**

Oxygen minimum zones in the Eastern Tropical Pacific have expanded in the past 50 years and are projected to continue expanding and warming in the 21st century under ongoing climate change. Ocean deoxygenation and warming can affect the physiological performance of marine ectotherms, such as fish and invertebrates, by reducing oxygen supply, while increasing demand. These physiological effects can reduce individual growth rate, body size, reproductive capacities as well as survivorship and consequently result in population-level decreases in abundance and shifts in species distribution. Here, we test the hypothesis that ocean deoxygenation and warming contribute to shifts in marine species composition along an oxygen minimum zone in the Eastern Tropical Pacific, from the Gulf of California to the Humboldt Current System. Specifically, we expect that higher ocean temperature would increase the dominance of warm-water associated species, while expanding oxygen minimum zones may drive deeper water species (associated with cooler waters) into shallower, warmer waters resulting in greater overlap with fishing grounds. ENSO events may provide insights into how climate change may impact marine communities and fisheries in the future. Two separate datasets were used: (1) a four-year fishery independent shrimp bottom-trawl survey (2008-2011) that sampled the demersal community along the Pacific coast of Costa Rica from a wide range of temperatures and oxygen concentrations across warm and cold ENSO phases; (2) reconstructed catch time series from 1950 to 2007 for the Eastern Tropical Pacific (Pacific Exclusive Economic Zones from Mexico to Peru) at the species level by the Sea Around Us (www.seaaroundus.org). We calculate the mean temperature of the catch (average temperature preferences of exploited species weighted by catches) to detect the effect of warming on species composition. Also, we derive a metabolic index (the ratio of oxygen supply to resting demand) of the community across sampled temperature and oxygen ranges to indicate the potential physiological stress associated to ocean deoxygenation and warming. We test the effects of temperature and oxygen on the metabolic index and mean temperature of catches for each of the two datasets using generalized additive mixed models. Our results highlight the importance of ocean deoxygenation on marine fisheries resources in the Eastern Tropical Pacific region. These insights will help inform adaptation and management measures to ensure effective conservation and continued sustainable use of marine resources for dependent communities.

Severe hypoxia off the Changjiang Estuary in summer 2016 associated with El Niño

Authors: Xiao Ma, Feng Zhou, Fei Chai, Daji Huang, Jianfang Chen, Bin Wang, Xiaobo Ni, Jiliang Xuan, Dingyong Zeng

Presenter: **Xiao Ma**

Massive bodies of low-oxygen bottom waters are found in coastal areas worldwide, which are “dead-zones” for marine life. A severe bottom hypoxia event was observed in the Changjiang Estuary in summer 2016, with the hypoxic zone as large as 23,100 km^2 and the minimum oxygen concentration unprecedentedly low (0.06 mg/l). The oxygen depletion was bulk-estimated at 2.32 million tons, forming an extensive fan-shaped hypoxia area to the north of the Changjiang’s mouth. The severe hypoxia was found to be resulted from enhanced primary production and persistent strong stratification, which was associated with the strongest El Niño event on record, indicated by larger amount of riverine freshwater input and higher sea surface

temperature in the Changjiang Estuary, than those in normal years. Moreover, the weak wind field was also favorable for sustaining strong stratification. Historical hypoxia events and related hydrographic conditions are also compared in this study. It is likely that El Niño phenomenon alone is not a prerequisite for hypoxia event in the Changjiang Estuary. However, a lot of evidence provided in this study suggests that El Niño did enhance the severe dissolved oxygen depletion and induced a bottom hypoxia situation in summer 2016.

Attribution of recent marine heatwaves to anthropogenic climate change

Authors: Charlotte Laufkötter, Thomas Frölicher

Presenter: **Charlotte Laufkötter**

Recent marine heatwaves have caused increasing concern because of their devastating effects on marine ecosystems. Observations indicate that marine heatwaves have become more frequent, intense, larger and longer lasting over the last few decades, and climate models suggest that these changes are amplified under continued global warming. However, little is known about the extent to which anthropogenic climate change affected the likelihood of the occurrence and magnitude of recent prominent marine heatwave events.

Here we use sea surface satellite and climate model data to quantify the human influence on the occurrence of individual recent marine heatwaves. We first detect marine heatwaves during the satellite era from 1982 to 2016 and rank them according to their intensity, duration and spatial extent. We then select the largest and warmest heatwaves and calculate the fraction of risk that can be attributed to anthropogenic climate change. To this end we compare the probabilities of extreme events in temperature projections of a suite of CMIP5 Earth system models with and without anthropogenic forcing. We analyze and discuss the statistical uncertainties associated with the attribution process. Climate models suggest that climate change substantially increased the risk of occurrence of most recent prominent marine heatwaves, both in terms of their duration as well as their intensity. However, for several heatwaves there is a high uncertainty associated with the attribution statement.

Phytoplankton responses to the 2014–2016 warming anomaly in the Northeast Subarctic Pacific Ocean

Authors: Angelica Pena, Nina Nemcek and Marie Robert

Presenter: **Angelica Pena**

Significant changes in the abundance and composition of phytoplankton were observed along Line P in the northeast subarctic Pacific as a result of a rapid warming of surface waters in 2014-2015. This feature, labelled “the blob”, reached ~4°C above normal and restricted winter ocean-surface nutrient renewal due to increased stratification. As a result, nitrate depletion in summer extended farther offshore than in the last three decades. Within this nitrate-depleted region there was unusually low phytoplankton biomass and a dramatic increase in the dominance of cyanobacteria. Farther offshore, in the iron-limited region, phytoplankton biomass and annual net community production decreased after the first year of the warming but then phytoplankton biomass increased and production returned to the “pre-blob” value. Our results show that phytoplankton in oceanic waters of the northeast subarctic Pacific can respond to widespread changes in ocean conditions by dramatically altering their assemblage composition with the potential to impact the entire food web. Thus, our results offer insight into the likely impacts of future global warming on phytoplankton abundance and assemblage composition in the northeast subarctic Pacific

Doliolid blooms in the southeastern Gulf of Alaska as a result of the recent heat wave of 2014-2016

Authors: Alexei Pinchuk, Sonia Batten, Wesley Strasburger

Presenter: **Alexei Pinchuk**

The eastern North Pacific experienced a prolonged heat wave in 2014-2016 manifested by high sea near-surface temperature anomalies in the south-central Gulf of Alaska (termed the “warm blob”). The event provided a natural experiment on the response of southern Gulf of Alaska ecosystem to a dramatic change in sea temperature. Spatial and temporal variability in zooplankton communities following the culmination of the heat wave was investigated as a part of the US NOAA Eastern Gulf of Alaska Ecosystem Assessment program in 2016-2017. Here, for the first time, we report consistent observations of doliolid (Dolioletta tritonis) swarms observed beyond the shelf break (>3,000 m depth) during both years, with maximal density up to 4,000 ind. m-3 recorded in August 2016. Few doliolids were found on the shelf, apparently being advected from the offshore. The long-term Continous Plankton Recorder data indicated that doliolid blooms in the south-central Gulf of Alaska may have occurred in the past two decades during El-Nino events. Coincidentally, doliolids prevailed in the diets of juvenile sablefish collected along the eastern coast of Gulf of Alaska during 1997-1998 El Nino. Thus, we speculate that warming trends may increase the importance of doliolids in the Gulf of Alaska pelagic food web.

Impact of an extreme storm and flood episode on the biogeochemical balance in an exploited coastal lagoon (Thau, south of France): approach by coupled hydrodynamic-biogeochemical modelling.

Authors: Remi Caillibotte, Yann Leredde, Rémi Pagès, Claude Estournel, Caroline Ulses, Patrick Marsaleix, Francesca Vidussi, Eric Fouilland, Christian Salles, Sébastien Mas, Behzad Mostajir

Presenter: **Remi Caillibotte**

Global climate change seems to affect extreme events, both in intensity and frequency, particularly in the northwestern Mediterranean area (e.g. Michaelides, 2018). Furthermore, flood episodes generally provide an additional input of available nutrients for biological production (e.g. Chu et al., 2008). Within the SO REC-Thau (Service of Observation and Research in Coastal Environment of Thau) of the OSU OREME, authors find themselves here on a project of hydro-biogeochemical numerical modelling complementary of their activities of observations. Illustrated on the period of the RESTHAU campaign (November 2008), the aim is to assess the impacts of storms and floods episodes on microbial food web and biochemical cycles.

The coupled model Symphonie-Eco3m (Auger et al., 2011) was implemented on an unusual computing grid encompassing the Thau lagoon, the canals, the foreshore and open sea to the offshore zone. The hydrodynamic model (e.g. Leredde et al., 2013; Michaud et al., 2013) was coupled to the Eco3m-S model based on mechanistic formulations of biological processes. The model uses 35 variables and reproduces a complex planktonic ecosystem with several primary producers and several consumers. The biochemical cycles of the biogenic elements (C, N, P, Si) are managed by the model.

Owing to fields data (Fouilland et al., 2012), the November 2008 storm period was investigated. The first results showed no increase in phytoplankton biomass during and after the storm in the study site in spite of a nutrient enrichment. Results also showed that light and temperature during this event were not limiting factors for phytoplankton, but rather hydrodynamics could influence their biomass. Moreover, the extreme event largely affected biogeochemical balances of the Thau lagoon. The role of predation by oyster (more than 10 000 tonnes in the lagoon) is also investigated with the addition of a new compartment to the biogeochemical model.

Ocean acidification extreme events in the California Current System

Authors: Flora Desmet, Nicolas Gruber, Meike Vogt, Matthias Münnich

Presenter: **Flora Desmet**

In addition to a long-term decrease in surface ocean pH, a prominent consequence of ocean acidification in the California Current System (CCS) is the substantial shoaling of the aragonite saturation horizon over the last few decades. This trend has likely been accelerated in recent years owing to a trend toward stronger upwelling. While this saturation horizon remains in the CCS most of the time below 100 m, short-term ocean acidification extreme events can raise this horizon to very shallow depths, affecting calcifying organisms throughout nearly the entire water column. Here we use the high-resolution physical regional oceanic model ROMS coupled with a biogeochemical-ecosystem model (ROMS-BEC) to investigate the spatio-temporal distribution of such aragonite undersaturation ($\Omega arag < 1$) events in the CCS, as well as their duration, intensity and severity and the associated trends. We find that these extreme events occur most frequently close to the shore, due to strongest upwelling, and decrease in frequency and severity offshore. Our results suggest an increase of 3-5 % per decade of their intensity as well as a doubling of the probability of occurrence of events with a certain intensity from 1982 to 2015. We further investigate the drivers of variability of aragonite undersaturation extreme events for the present ocean. We find that surface ocean wind stress and the presence of mesoscale eddies and filaments play a major role in driving these extreme events. We validate our approach by comparing the model results to in situ data observations of the carbonate system, as well as satellite-based pCO_2, wind stress and eddy kinetic energy products.

Jellyfish blooms in coastal waters nearby thermal discharges of nuclear power plant

Authors: Chunjiang Guan, Yongjian Liu, Chuan Jia

Presenter: **Chunjiang Guan**

Hongyanhe Nuclear Power Station, which was constructed in 2007 and began to operate in 2013, is located in Liaodong Bay of Bohai Sea, China. In order to study the long-term effects of the thermal discharges on marine organisms, community structure and ocean ecosystem in coastal waters, long-term monitoring of marine organisms in the area with water outlet as the center and the radius of 4 km was carried out. In 2010, before the discharge of thermal waste water by the nuclear power plant, the maximum abundance of Aurelia aurita in this area, a common jellyfish species in the Bohai Sea, was recorded as 533 ind. /(net·h). Thereafter, the frequency of jellyfish bloom in this area has been increased. In 2014, jellyfish bloom of Aurelia aurita clogged the sea water intake and reduced the production efficiency of nuclear power plant. In 2015, the peak period of Aurelia aurita was recorded from late June to mid-August, with its maximum abundance reaching 12353 ind. /(net·h) on June 27. The average umbrella diameter and the average wet weight of Aurelia aurita was 14.7 cm and 170.0 g, respectively. In 2016, the peak period of Aurelia aurita was recorded from July to mid-August, with its maximum abundance reaching 16667 ind. /(net·h) on August 14. The average umbrella diameter and the average wet weight of Aurelia aurita was 17.9 cm and 360.0 g, respectively. In 2017, Aurelia aurita was recorded only in August, with its maximum abundance reaching 380 ind. /(net·h) on August 1. The average umbrella diameter and the average wet weight of Aurelia aurita was 17.7 cm and 262.7 g, respectively. In 2018, the peak period of Aurelia aurita was recorded from late June to mid-August, with its maximum abundance reaching 9188 ind. /(net·h) on August 6. The average umbrella diameter and the average wet weight of Aurelia aurita was 19.7 cm and 370.0 g, respectively. The average results in the past four years showed that maximum abundance of Aurelia aurita was about 18 times of that in 2010. Long-term monitoring and comparatively analysis of the structure and function of marine organisms, biological communities and ecosystems, before and after the operation of nuclear power plants, are crucial for rectangle the relationship between the marine ecosystem and the thermo water discharge. And it may be an ideal 'stress-tests' system for studying the impacts of climate change on marine ecosystems.

Diversity, biomass and size-structure of copepods in the coastal upwelling area off Humboldt Current System in the eastern South Pacific Ocean

Authors: Pamela Hidalgo, Ruben Escribano

Presenter: **Pamela Hidalgo Díaz**

Copepods are the most abundant organisms in the upwelling zone in the pelagic ecosystem and represent a key component in transport of the organic matter in the food webs in the Humboldt Current System (HCS). These organisms are considered as species model to evaluated their rapid responses derived of the global changes. In this aspect, observations and predictions indicate an increasing upwelling intensity over the last 20-30 years and consequently increasing and intensification of the oxygen minimum zones (OMZ). We analyzes the oceanographic database and zooplankton samples collect from upwelling area Coliumo bay (St-18; 36º 30' 46'' S; 73º 7' 38" W) off Chile. Diversity, biomass and size structure copepods were obtained. The dominants species were Acartia tonsa, *Centropages brachiatus, Calanus chilensis, Paracalanus* cf. *indicus, Oithona similis, Oncaea conifera, Corycaeus typicus* and *Calanoides patagoniensis*. Biomass and size-structure copepods were correlated. We observed an increasing in the upwelling index and elevation of the OZM. The copepods community shows changes in abundances, biomass and size spectrum associated with the oceanographic variability.

Oxygen variability and extremes in the eastern tropical South Pacific between 1979 and 2016

Authors: Eike E. Köhn, Matthias Münnich, Meike Vogt and Nicolas Gruber

Presenter: **Eike Eduard Köhn**

Over the last 50 years, observed marine dissolved oxygen has decreased by over 2%. The related long-term expansion and intensification of naturally occurring oxygen minimum zones (OMZs) might push large volumes of water to hypoxic or even suboxic conditions, thereby stressing ecosystems and possibly modulating climate-relevant biogeochemical processes. Present-day low oxygen extreme events can temporarily induce similar effects and are thus instructive for anticipating the future ocean state.
In this study we analyze the variability of oxygen concentrations in the OMZ of the eastern tropical South Pacific (ETSP) from 1979 to 2016 using hindcast simulations with the Regional Oceanic Modeling System coupled to the biogeochemical/ecosystem model BEC. The employed telescopic grid spans the entire Pacific basin with a substantial grid refinement towards the Peruvian coast, hence allowing for both, local and remote forcing of the oxygen variability in the ETSP, e.g. through coastally trapped waves.
We present results regarding the spatio-temporal variability of oxygen on sub-seasonal to inter-annual time scales, its underlying drivers and the impact on biogeochemical processes. While the El Niño-Southern Oscillation (ENSO) has been shown to strongly affect oxygen-sensitive loss mechanisms of fixed nitrogen in the ETSP OMZ, the impact of mesoscale dynamics on denitrification and anammox but also on nitrogen fixation remains less clear. Motivated by this, we present model insights into the biogeochemistry of extremely low oxygen eddies, their long-term modulation (e.g. by ENSO) and their impact on the marine nitrogen budget.

Historical reconstruction of Brazilian reef landscapes using the memory of active users

Authors: Maria Iohara Quirino Amador, Priscila Macedo Lopes, Guilherme Ortigara Longo

Presenter: **Maria Iohara Quirino Amador**

Reefs are sensitive ecosystems affected both by global changes (global warming and ocean acidification) and local processes (e.g., fishing and eutrophication). It is common to assume that a coral reef is healthier (or worse off) than another just based on current references which is a biased assumption known as the shifting baseline syndrome, common for when there is no or little past information on ecosystems and species. The few records on recent states of coral reefs give us insights into how these ecosystems are rapidly changing, and suggest that the longer we need to go back in time to detect when specific changes happened, the more we need to rely on the memory of active users, due to the lack of past scientific information. This is especially important for developing countries, where marine research is relatively new.
We assessed changes in the seascape of Brazilian reefs by interviewing key stakeholders that make different uses of these ecosystems, namely fishers, divers and researchers. Most stakeholders observed a decline of important reef builders (corals), both in number of colonies (particularly Siderastrea stellate), and colony size (e.g., the hydrocoral Millepora alcicornis). They also perceived a general decrease in the number and size of reef fish throughout the coast and the increase of sea urchin, which they consider a negative process. There is a common perception among the stakeholders that local processes, such as fishing and marine debris, have a stronger effect on Brazilian reefs than global processes such as warming and acidification. Not all perceptions are negative though, as the interviewees also believe that sea turtle populations have recovered and increased across the Brazilian coast. By tapping into users memories, we aim to recover part of the past of Brazilian reefs to understand current changes and predict future ones in these reef ecosystems, building a solid knowledge base to support reef conservation.

Session 13: Linking microbial activity and the cycling of dissolved organic matter using –omics approaches

Lifting the Lid: the microbial ecosystem under the Ross Ice Shelf

Authors: Federico Baltar, Clara Martinez, Daniele De Corte, Christian Ohneiser, Christian Hulbe, Craig Stevens, Blair Thomson, Zihao Zhao, Christian Greening, Ramiro Logares, Ramunas Stepanauskas, Gerhard J. Herndl, Sergio E. Morales

Presenter: **Federico Baltar**

The ocean under the Ross Ice Shelf (RIS) in Antarctica is one of the least explored environments on Earth. This remote marine environment, in total darkness under hundreds of meters of ice, touched only by passive moving deep ocean currents, is as unexplored as Mars. Microbes are the engines that drive biogeochemical cycles and the microbes under Antarctica's ice sheets may play a crucial role in releasing nutrients to the Southern Ocean. Thus, better knowledge of the roles that these microbes play in the transformation of organic matter will lead to a better understanding of the processes that control energy flow in the Southern Ocean, as well as the cycling of compounds that influence climate change. Still, we do not know which microbes live below the RIS, let alone what functions they perform. The only study in which the seawater under the RIS was studied (at the J9 borehole in 1977/78), revealed the presence of microbes together with a rich community of invertebrates and fish far from the open ocean. However, the technology required to investigate microbial diversity was not available at that time. 40 years later, we drilled through ca. 400 meters of ice shelf to reveal, for the first time, the actual structure and function of the RIS ocean microbial ecosystem. We combined rate measurements with amplicon sequencing to determine the abundance, heterotrophic activity, community composition and diversity of microbes under the RIS, together with -omics (metagenomic, metatranscriptomics and metaproteomics) and single amplified genomes (SAGs) to obtain a full analysis of their metabolic potential and actual gene expression and protein production. Collectively, our results "lifted the lid" on the RIS to reveal an active and diverse microbial ecosystem, dominated by chemolithoautotrophy and capable of obtaining their energy from a wide range of different organic and inorganic sources.

Increase in secretory enzyme capability is a genomic adaptation of dark ocean prokaryotes

Authors: Zihao Zhao, Federico Baltar, Gerhard J. Herndl

Presenter: **Zihao Zhao**

Microbes are the engines driving marine biogeochemical cycles since they have the majority of genes encoding the enzymes involved biochemical transformations. Two key groups of enzymes are the peptidases and the carbohydrate-active enzymes (CAZymes) either occurring extracellularly or located in the cytoplasma. Despite the importance of EEA in the carbon cycling, little is known about the functional diversity of these ectoenzymes. Here we conducted a global analysis on the abundance, the diversity, the functional classification and the phylogenetic affiliation of genes encoding CAZYmes and peptidase using 345 metagenomes from samples collected from surface to the bathypelagic waters,. The analyses were performed for the total and secretory pools of enzymes. The abundance, percentage and the diversity of gene encoding secretory enzymes increased from the epipelagic to the bathypelagic waters. While the phylogenetic composition of the prokaryotic community was depth-stratified, there was substantial

functional redundancy in secretory enzyme composition. Thus, we propose that the capacity to secrete enzymes might benefit prokaryotes thriving in the dark ocean where substrate concentrations are low.

Microbial utilization of organic matter in the Southern Ocean as revealed by metaproteomics

Authors: Debeljak Pavla, Barbara Bayer, Ingrid Obernosterer, Gerhard J. Herndl

Presenter: **Pavla Debeljak**

The availability of dissolved organic matter constrains heterotrophic microbial activity in surface waters of the Southern Ocean, characterized by generally low concentrations of organic carbon. In the region southeast of Kerguelen Island, the island mass effect leads to elevated iron concentration in otherwise HNLC waters. Thus, it represents an attractive site to study locally occurring spring phytoplankton blooms and the response of heterotrophic microorganisms to the release of phytoplankton-derived organic matter. To obtain insight into the types of organic substrates used by the microbial communities, we collected samples at sites with contrasting organic matter supply for metaproteomics analysis during the Southern Ocean and Climate cruise (SOCLIM, Oct 2016). First results indicate the presence of proteins associated with bacterial groups that have previously not been described in the area. Furthermore, differences between the metaproteomes obtained from HNLC waters and iron-replete waters were partially explained by temperature and dissolved organic carbon concentration, as revealed by multivariate constrained ordination analysis. Comparative proteomics of transporter proteins suggest that secondary active tripartite ATP-independent periplasmic transporters (TRAP) are more abundant in HNLC waters, while the ATP-dependent counterparts, TonB-dependent transporters (TBDTs) are relatively more abundant in iron-replete waters. Further analysis on substrate binding proteins will give insight into specific carbon compounds potentially taken up by microbial communities, contributing to our understanding of substrate preferences and organic matter remineralization dynamics in bloom-influenced and non-bloom influenced sites.

Seasonal changes in free-living and attached prokaryotic communities in the Southern Ocean

Authors: Yan Liu, Stéphane Blain, Olivier Crispi, Ingrid Obernosterer

Presenter: **Ingrid Obernosterer**

Marine autotrophic and heterotrophic microbes are tightly coupled through the production and remineralization of dissolved organic matter (DOM). In surface waters of the Southern Ocean, diatoms are major contributors to spring phytoplankton blooms and previous short-term observations have demonstrated that the production of bioavailable diatom-derived DOM markedly affects prokaryotic activity and community composition. Due to its distance from land, access to the Southern Ocean remains challenging, therefore limiting our understanding of the seasonal dynamics of microbes. We present here results of prokaryotic community composition from samples collected at 5-12 days interval by a remote autonomous sampler deployed from the end of October to the end of February in the surface mixed layer (40m) off Kerguelen Island. Illumina sequencing of the 16S gene revealed pronounced seasonal patterns of the free-living and the particle-attached prokaryotic communities. We will discuss these findings in relation to changes in environmental factors and the succession of diatom assemblages.

Linking microbial diversity (Bacteria and Archaea) and chemodiversity of dissolved organic matter in the major water masses of the north Atlantic

Authors: Marta M Varela, Tamara Rodríguez-Ramos, Helena Osterholz, Thorsten Dittmar, Xosé-Antón Álvarez-Salgado and Mar Nieto-Cid

Presenter: **Marta Varela**

Interactions between microbial communities and dissolved organic matter (DOM) include microbial uptake, transformation and release, affecting the molecular composition of the heterogeneous DOM pool. Conversely, DOM composition can select for specific microbial taxa. Here, we explore the diversity of microbial (both Bacteria and Archaea) communities (Illumina tag sequencing of 16S rRNA genes) and the chemodiversity of dissolved organic molecules (Fourier-transform ion cyclotron resonance mass spectrometry, FT-ICR-MS). Sampling was conducted in the Eastern North Atlantic Ocean off the Galician coast (43ºN, 9º-15ºW) from 100 m to >5000 m, thereby encompassing a wide variety of water masses with contrasting origins and different aging. Eastern North Atlantic Central Water (ENACW) displayed lower values of AOU (35.3-77.1 µmol/kg) than those measured in the Mediterranean Water (MW, 98.8 µmol/kg) and the underlying North East Atlantic Deep Water (NEADW, 95.7 µmol/kg) and the Lower Deep Water (LDW, 107.2 µmol/kg). FT-ICR-MS average molecular composition of Solid Phase Extracted (SPE) DOM samples was $C_{871}H_{1087}O_{415}N_{18}S_{2}P_{1}$, with a mean molecular mass of 432.1 Da. Highly unsaturated molecular formulae were the most abundant (90.1%) followed by unsaturated (5.1%) and aromatic molecular formulae (3.0%). Potential peptides, carbohydrates and polycyclic aromatics accounted, each, for less than 1% of the total composition. There was no significant relationship between the FT-ICR-MS elemental composition and molecular mass with depth or AOU values, except for the H/C ratio, which correlated negatively with AOU. Highly unsaturated molecular formulae correlated significantly and positively with AOU whereas unsaturated aliphatics and potential peptides also correlated significantly, but negatively, with AOU. Accordingly, the relative abundance of some bacterial phylotypes (such as Acidobacteria, SAR202 and Chlamydiales) increased their relative contribution to community composition with depth or AOU, while some others (such as Acidimicrobiia, Bacteroidia and some Verrucomicrobia) showed the opposite trend. Thaumarchaeota was the dominant archaeal group and tended to increase in relative abundance with depth or AOU. Applying ecologic diversity metrics to relative abundances of both, organic compounds and microbial operational taxonomic units, we found that microbial (both Bacteria and Archaea) diversity and richness were negatively correlated to DOM diversity and richness, respectively, and also negatively correlated to the organic carbon concentration. Besides, our results demonstrate that this trend is linked to the water mass aging, which speeds biosphere taxonomic diversity but reduces the chemodiversity. DOM diversity decreasing along the AOU gradient would likely reflect the persistence of the most refractory molecules, as result of the organic refractory compounds produced as subproduct of the microbial carbon pump. We further speculate that the observed increase in DOM homogenization with water mass aging can be associated to the functional diversity of microbial communities. We are currently analyzing functional diversity (i.e. genes encoding enzymes involved in organic matter degradation) by using the metagenomic technique

Temperature dependence of prokaryotic inorganic carbon assimilation in the dark ocean

Authors: Roberta L. Hansman, Pavla Debeljak, Beat Gasser, Gerhard J. Herndl

Presenter: **Roberta Hansman**

Chemoautotrophy, determined through the uptake of inorganic carbon, has recently been identified as a significant metabolic pathway of prokaryotes in the meso- and bathypelagic ocean that is comparable in magnitude to heterotrophic prokaryotic metabolism. While some studies have implicated the oxidation of ammonia by members of Thaumarchaeota as fuelling dissolved inorganic carbon (DIC) assimilation, the extent and potential of chemoautotrophy and its contribution to the carbon cycle in the dark ocean has not been fully identified and quantified, particularly with respect to changing global climate and ocean conditions. Seawater collected in the meso- and bathypelagic Atlantic and Pacific Oceans and incubated at 20°C exhibited DIC fixation rates, as measured through 14C-labeled bicarbonate uptake, up to 500 times greater than organisms at in situ temperature. When combined with temporal experimental measurements from the DYFAMED (Dynamics of atmospheric fluxes in the Mediterranean Sea) time-series site in the northwestern Mediterranean Sea, the Q10 temperature coefficient of inorganic carbon uptake in the deep ocean is 25 (n = 360, r2 = 0.66). This value is significantly greater than the more typical Q10 of 2.6 (n = 412, r2 = 0.26) for prokaryotic heterotrophic production as calculated from 3H-leucine incorporation from the same regions. While much remains to be determined regarding this process, including more precise identification of the organisms involved and confirmation of the energy source(s) used to fuel this presumed chemoautotrophic carbon fixation, the apparent temperature sensitivity of DIC assimilation in the dark ocean has implications for microbially mediated carbon turnover and the marine carbon cycle under future climate and ocean warming scenarios.

Evidence for pulsed exportation in the water column of the northwestern Mediterranean Sea

Authors: Michel Denis, Dominique Lefèvre, Melilotus Thyssen, Gérald Grégori

Presenter: **Michel Denis**

Peaks of respiratory activity were observed over many years below 500 m depth in the north-western Mediterranean Sea. The first day-night vertical profiles of respiratory activity were interpreted as pulsed mineralisation which was supposed to be periodic. In line with these observations and others, a special cruise, DYNAPROC2, on board the RV Thalassa from September to October 2004. was dedicated to carbon production and exportation, and the control by heterotrophic organisms at short time scale. It took place in the NW Mediterranean Sea at a fixed station subject to weak horizontal advection currents. Up to 3 h interval CTD casts (0-150 m & 300-1150 m) were run over periods from 36 h to 5 days to address the short term variability of heterotrophic prokaryote (HP) vertical distribution determined by on board flow cytometry analysis of seawater samples as soon as collected and after single or double staining. HP respiratory activity was assessed in the mesopelagic layer after 23 dm^3 seawater filtration at each sampled depth. In the epipelagic layer, 3 HP groups were resolved with respect to their nucleic acid content (HNA1, HNA2, LNA) whereas only two (HNA, LNA) could be distinguished in the mesopelagic layer. The HP viability assessed according to the nucleic acid double staining (NADS) procedure, was close to 95% over the sampled water column and there was no accumulation of dead cells. The HP high abundance and variability in the epipelagic layer were essentially confined in the upper 80 m. In the mesopelagic layer, HP abundance around 500 m depth was about twice that of the background, likely sustained by excretions of mesozooplankton resting at this depth after their diel upward vertical migration. Peaks of HP abundance and respiration were observed further deep without any apparent periodicity. The dynamics of the HP abundance and respiration peaks is accounted for by involving the following mechanism : TEPs produced in the epipelagic layer generate aggregates that are colonised by HP and may also trap phytoplankton cells. Above a TEP concentration threshhold, similarly to the critical micellar concentration, auto-aggregation occurs with the formation of sinking aggregates loaded with HP detected by flow cytometry. This discrete sinking of HP loaded particles maintains a permanent pocket flush of surface organic matter (OM) and contributes to an automated limitation of OM accumulation at surface. This mechanism also provides a permanent seeding of deep waters with live HP and supplies deep water communities with fresh and labile OM. To our knowledge, this is the first in situ evidence of a mechanism whose potential existence was demonstrated in mesocosm experiments.

Exploring changes in bacterioplankton community structure in response to tannic acid, a major component of litterfall, in a mangrove ecosystem: a laboratory mesocosm approach

Authors: Anwesha Ghosh, Punyasloke Bhadury

Presenter: **Anwesha Ghosh**

Litterfall constitutes a major source of allochthonous matter for bacterioplankton communities in estuarine mangroves. Tannic acid, an abundant component of mangrove litterfall, leaches out and contributes substantially to DOC and DOM pools of the adjacent estuaries. About 50% of mangrove litterfall maybe degraded and channelized into the marine microbial loop. Estuarine conditions of Sundarbans, the world's largest contiguous mangrove, was mimicked in a laboratory mescocosm set-up using barrels to understand the influence of tannic acid on bacterioplankton communities. Estuarine water from a station, Stn3 of Sundarbans Biological Observatory Time Series (SBOTS) was enriched with tannic acid and the change in bacterioplankton community structure was analysed on the start (Day 0), intermediate (Day 7) and end (Day 15) of the experiment. Bacterioplankton community structure was elucidated by sequencing the V3-V4 region of 16S rRNA on an Illumina MiSeq platform. Concentration of tannic acid, gallic acid, trace elements, dissolved nutrients such as nitrate and ortho-phosphate along with hydrological parameters were determined on a daily basis. Degradation of tannic acid was tracked by decrease in concentration of tannic acid and generation of gallic acid, one of the final products of tannic acid degradation. Tannic acid was shown to significantly affect the concentration of dissolved nitrate and trace elements in the barrels. Proteobacteria was found to be the most dominant bacterial phylum in Control and tannic acid enriched barrels (Barrel 1 and 2) on Day 0. With the progression of experiment, the abundance of Proteobacteria decreased significantly in the Control barrel indicating the dependence of this phylum on steady flux of nutrients. The abundance of Proteobacteria in the tannic acid enriched barrels remained high indicating that members of Proteobacteria may be capable of using tannic acid as a source of carbon and nitrogen. Tannic acid appeared to inhibit other bacterioplankton phyla including Actinobacteria, Acidobacteria and Verrucomicrobia that existed in large abundance in the Control barrel on Day 15 but were absent in the tannic acid enriched barrels. At class level, Bacteroides was found to be present in highest abundance in the tannic acid enriched barrels. Bacteroides are capable of breaking down tannic acid using tannase as an enzyme. This experiment indicated that bacterioplankton communities of Sundarbans could harbour genes necessary for breakdown of complex components of litterfall and recycle them into the marine microbial loop. Breakdown of tannic acid could influence the marine nitrogen and carbon cycling by releasing DON and DOC respectively into the adjacent estuaries. An understanding of the breakdown of tannic acid and other components of mangrove litterfall and its influence on the resident biological communities of estuarine mangroves could be essential for our understanding of functioning of coastal ecosystems.

Metagenomics of a microbial community capable of surviving with low-density polyethylene as the sole carbon source

Authors: Maria Pinto, Gerhard J. Herndl

Presenter: **Maria Pinto**

Every year there are tons of plastics entering the oceans. Once in the ocean, plastics are rapidly colonized by a complex community of microorganisms. There is growing evidence that some of these microorganisms are capable of plastic biodegradation. We aimed at isolating communities capable of surviving in seawater with low density polyethylene as their sole carbon source. We collected two plastic pieces from the northern Adriatic Sea and transferred them to separate bottles with artificial seawater without any additional carbon source. After several transfers, sterile low-density polyethylene (PE) pieces were added to each of the incubations. After being colonized, these new PE pieces were also transferred to new artificial seawater every 30 to 50 days. After one and two years since the initial plastic was collected, DNA was extracted from the new PE pieces for metagenomics analysis. Amplicon sequencing of the 16S rRNA gene of the bacterial community colonizing the original plastic and the samples collected after one year incubation was performed. The 16s rRNA gene analysis revealed that after one year of incubation the bacterial community growing on the plastic pieces had greatly decreased in complexity and that the families Hyphomonadaceae, Rhodobacteraceae and Alcanivoracaceae were dominating the bacterial community making up to 75% of the total relative abundance of the entire prokaryotic community. Additionally, metagenomic analyses revealed that bacteria harbouring a diverse array of genes encoding hydrocarbon degrading enzymes were abundant in the bacterial community associated with the plastic associated biofilm. Thus, it appears that biofilms of plastics found in the ocean harbour bacteria potentially capable of hydrocarbon and plastic degradation.

Microbial Community Diversity and Phycotoxin Risk of Toxic Microalgae from China Coast

Authors: Renyan Liu, Yubo Liang

Presenter: **Renyan Liu**

The increasingly frequent of harmful algal bloom (HAB) have been aggravated the deterioration of the coastal ecological environment on the worldwide and caused huge losses to the aquatic economy in coastal countries. Some toxic microalgae can produce phycotoxins, which may cause poisoning or death to human beings, marine animals and even aquaculture organisms. These toxic microalgae can also poison the marine organisms coexisting in the same ecosystem. How do these poisons, especially to marine plankton and micro-organisms, affect the marine ecological structure, and what are the risks to the ecosystems? In the past, more attention was paid to the harm of phycotoxins in marine food to human. In this paper, 3 species of toxic dinoflagellates, Protoceratium reticulatum, Prorocentrum lima and Alexandrium minutum, which widely have distributed in the coastal waters of China, were studied by analyzing the 16S rDNA clone libraries using MiSeq high-throughput sequencing. The affecting of three species of toxic dinoflagellates on the bacterial community and their diversity have been studied. The results suggested that the diversity in the bacterial communities that were sensitive to toxic microalgae and phycotoxins upon exposure, that toxic algal bloom may play a role in structuring bacterial communities, and that the effects of phycotoxins were selecting for or against specific species. The possible ecological risk was also estimated by the species sensitivity evaluation method, and these results may lay the foundation for the in-depth study and evaluation of the harm and risk of harmful algal bloom to the marine ecosystem.

Key words: toxicity; toxic dinoflagellates; ecological risk; plankton; bacterial community

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Microbial enzymatic activities: critical methodological issues to understand organic matter cycling

Authors: Urvoy M, Creac'h L, Delmas D, Labry C, L'Helguen S

Presenter: **Marion Urvoy**

Heterotrophic bacterial activities are one of the main factor affecting organic matter (OM) processing in the ocean. Whether dissolved or cell-bound, bacterial enzymatic activities initiate the mineralization of OM through the hydrolysis of polymers into monomers that can be directly taken up for bacterial production, growth, and ultimately fuel the microbial loop. These activities deeply influence global biogeochemical cycles (C, N, P, micronutrients), and finally the fate of carbon in current and future ocean. The detailed composition of OM, obtained by recent advances in analytical methods, and the functional diversity of microbial communities, provided by omics approaches, need to be faced to actual degradation rates of OM provided by enzymatic activity data. However, in spite of a widespread utilization of enzymatic measurements in aquatic sciences, many methodological divergences can be found when investigating aquatic literature, which greatly affects velocity data and meaningful inter-study comparison. The differences rely on (1) incubation conditions (optimal, standardized pH and temperature, as in pure biochemical assays, or close to in situ conditions), (2) the use of single trace substrate concentration or a range of concentrations to determine kinetic parameters, and (3) the range of substrate concentrations actually used (nM to few µM in oligotrophic waters against µM to mM in coastal waters). The aim of this study is to evaluate how these methodological choices affect actual enzymatic degradation rates and prevent inter-study comparison. For the first time, we also address the potential occurrence of an Inner Filter Effect (IFE), a fluorimetric artefact that has never been taken into account in the context of aquatic studies, despite significantly affecting measured enzymatic activities. Finally, despite being extensively used, such assays are not as trivial as they appear and should be carried out cautiously. All these methodological issues need to be addressed in order to combine enzymatic measurements with more recent approaches to study the mineralization of organic matter.

Session 14: Long-term time series of ocean data to describe and better understand dynamics of coastal marine systems and drivers of change: integrated tools, methods, in situ observation systems, models and results

Carbonate system time-series in the coastal Arctic

Authors: Jean-Pierre Gattuso, Samir Alliouane, Jonathan Fin, Nicolas Metzl, Uwe Posner, Philipp Fischer

Presenter: **Jean-Pierre Gattuso**

Predictions of the impact of global and climate changes in the oceans requires time-series data to detect internal variability, build realistic scenarios as well as parametrize and validate models. The Arctic ocean is subject to high rates of ocean warming and acidification, which has critical implications for marine organisms, ecosystems, and ecosystem services. Yet, only few measurements of the carbonate system have been performed in the Arctic Ocean and they are spotty both in space and in time. Notably, there is no time-series station measuring the carbonate chemistry in this region, particularly in coastal waters. In its 2013 assessment, the Arctic Monitoring and Assessment Programme (AMAP) stated "It is of paramount importance that long-term, dedicated marine carbonate system observation programs are developed".
The Alfred Wegener Institute for Polar and Marine Research (AWI) together with the Helmholtz Centre for Coastal Research Geesthacht (HZG) and the French Polar Institute (IPEV) teamed up in 2015 to establish the first time-series of carbonate system parameters in the coastal Arctic (AWIPEV-CO_2). This station, located at Ny-Ålesund (Spitsbergen) at 12 m depth, benefits from a lot of ancillary data from the AWIPEV FerryBox (http://bit.ly/2Dzqjsg). The following parameters have progressively been added in the past three years: discrete total alkalinity and dissolved inorganic carbon (once a week), pCO_2 (every min), *in situ* and FerryBox pH (every min), and discrete spectrophotometric pH (once a month to calibrate the sensors). There are also attempts to get high frequency measurements of total alkalinity (every 90 min). Data are available in near-real-time (http://bit.ly/2DwByln).
This presentation will provide a broad overview of the challenges involved with Arctic time-series and will provide information on four key questions this data set could help answer: (1) What is the seasonal variability (there are very few winter data in the Arctic)?; (2) What is the rate of acidification in a high Arctic fjord ?; (3) What are the combined effects of changes in the carbonate chemistry, temperature and salinity on the calcium carbonate saturation state?; (4) What is the annual balance of air-sea-CO_2 fluxes?

High frequency observation of turbidity near the seafloor in Brittany (France)

Authors: Edith Le Borgne, Elodie Marches, Vincent Perier, Olivier Morio, Thierry Garlan, Andre Lusven, Valerie Cariou

Presenter: **Edith Le Borgne**

The ROEC project (high frequency observation system in coastal environment) is a regional project around Brittany (North-West of France) which aims to monitor the environmental state of coastal waters in this area. Different physical, hydrological and biogeochemical parameters have been measured for a long time period in order to assess natural or anthropic changes and variability. This project relies on technological innovations or existing systems supporting the development of benthic bottom-mounted measurement systems in order to observe turbidity near the sea floor. The objective was to acquire continuous turbidity measurements with a time step of 20 minutes. Seven measurement sites were defined considering their

ecological interest (environmental protection of benthic habitats) or the local anthropic activities conducted (e.g. fishing, aggregate extraction, port activity). After one year of mooring, the first results emphasize that : (1) high frequency observation over a long period of time is possible and relevant for research but includes some constraints such as nautical means, sensors' battery life, biofouling ; (2) the seven turbidity time-series underline a high variability of turbidity near the bottom with important outbursts of turbidity over different periods ; (3) the interpretation of the registered time series reveals a good agreement between some environmental factors (waves, river flows, currents velocity) and the increase in turbidity but several turbidity peaks still remain unexplained if we base on natural hydrodynamics forcings only.
Human activities might be the source of the observed increase in near-bottom turbidity but this requires further investigations. Yet, the lack of high resolution data (higher frequency and higher spatiotemporal scale) for anthropic forcing doesn't allow to clearly make the link with the increase in turbidity.
As a conclusion, the long-time series obtained provide a good opportunity to understand bottom sedimentary dynamics through the observation of suspended matters and the demonstration of the anthropic impact is now a real challenge. The outcomes of this study will also be used for calibrating the hydro-sedimentary models.

Acknowledgements
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Vertical average irradiance shapes winter phytoplankton biomasses in the Yellow Sea

Authors: Lei Lin, Yueqi Wang, Dongyan Liu

Presenter: **Lei Lin**

The horizontal distribution of the concentration of chlorophyll-a (Chl-a) in the well-mixed water of the Yellow Sea in winter is generally stable, as has been determined by years of observation. The cause of this pattern has, however, not been established. In this study, the spatial pattern of the Chl-a concentration in the Yellow Sea in winter was investigated through in situ observation in January 2016 and climatological data acquired by satellite between 2003 and 2016. The formation mechanism of the spatial pattern of the Chl-a concentration was examined, particularly with the purpose of quantifying the impact of light availability. This was accomplished through examination of the correlation between the vertical average irradiance Im and the Chl-a concentration. The in situ observation revealed consistency of the spatial pattern of the Chl-a concentration with previous observations, as well as very good vertical mixing of the water in winter. Principal component analysis of the in situ-observed Chl-a concentration and environmental factors suggested that Im significantly determined the Chl-a concentration distribution in winter. The satellite data also revealed a significant linear positive correlation ($r = 0.73$, $p < 0.0001$) between the climatological (2003–2016) distribution of the Chl-a concentration and Im in winter. A high Chl-a concentration (>1 mg/m^3) was generally found to occur in a region with a high light availability (Im > 50 µmol photons/m^2/s). The results of further analyses suggested the availability of sufficient nutrients in the Yellow Sea in winter, but very limited light. Owing to the light limitation and strong mixing, Im predominantly determined the Chl-a concentration distribution. Regions with high Chl-a concentrations were found to have both relatively low total suspended matter (TSM) concentrations and shallow water depths, which increase Im. The stable spatial patterns of the TSM and water depth (D) in winter generally determined the Im pattern, possibly explaining the stable spatial pattern of the Chl-a concentration. In the eastern coastal waters of Jiangsu and Shangdong, the observed high TSM (>5 mg/L) could limit light availability, resulting in low Chl-a concentrations (~0.5 mg/m^3). The noted Chl-a enhancement on the nearshore sides of the thermal fronts could also be attributed to the rapid reduction of the TSM toward the fronts.

Response of phytoplankton to climate-driven changes in a Mediterranean coastal area : results from 4 decades of observations

Authors: Anne Goffart, Pierre Lejeune, Francis Gohin, Sylvain Coudray

Presenter: **Anne Goffart**

In the Mediterranean coastal areas, most of the long-term studies of plankton dynamics concern highly urbanized areas, where long-term variability reflects the combined effects of climate and anthropogenic forcing. Here we use a unique long-term time series (1979-2017) performed at a fixed station in a well-preserved NW Mediterranean coastal area (Bay of Calvi, Corsica) to understand how climate variation drives changes in phytoplankton biomass and composition.
From a high-frequency data set, which combines environmental parameters, nutrients and HPLC pigments, we highlight the importance of winter conditions to determine the state of phytoplankton community structure in surface waters. We show high variability in total biomass and phytoplankton composition resulting from changes in winter intensity associated with both interannual and decadal fluctuations.
We identify four distinct periods. The 1980s (1979-1988), the 1990s (1989-1998) and the 2000s (1999-2013) are characterized by moderate, mild and highly variable winters, respectively. The last period (2014-) shows very mild winters and increasing winter water temperature, associated with decreasing trends in rainfall, nutrients, total phytoplankton biomass and diatom abundance. Moderate and severe winters are favorable for diatoms, which do not develop during mild winters, when nutrient replenishment is not sufficient to support their growth.
The two decades years (1998-2017) of SeaWiFS-derived and MODIS-derived chlorophyll a concentrations in the Western Corsican Current are consistent with in situ data from the Bay of Calvi. This suggests that changes observed in the Bay of Calvi reflect phenomena occurring at a larger scale, and that our data set can contribute to predict changes of Mediterranean phytoplankton dynamics under different climatic scenarios.

SOMLIT-Astan time-series: a morphogenetic approach to study the seasonal succession of the eukaryotic marine plankton communities in the coastal waters.

Authors: Mariarita Caracciolo, Fabienne Rigaut-Jalabert, Nicolas Henry, Frédéric Mahé, Laure Arsenieff, Anne-Claire Baudoux, Eric Thiébaut, Nathalie Simon.

Presenter: **Mariarita Caracciolo**

Seasonal species successions and associated biomass variations are hallmarks of plankton ecology. However, the mechanisms producing the sequence of plankton that occurs along a seasonal cycle have not been totally elucidated yet. This study aims at describing and understanding the taxonomic diversity and the seasonality of the marine plankton communities at the SOMLIT-Astan time-series station (Roscoff, Western English Channel). By combining both dataset consisting of (i) morphological taxa counts and (ii) reads of Operational Taxonomic Units (OTUs) from a metabarcoding analysis (V4 Illumina sequencing of the nuclear 18S rDNA), our results elucidate the recurrent seasonal patterns of plankton communities and help to identify the major OTUs and the dominant species. The morphological identification allows to recover the species abundance, while the molecular dataset enhances the analyses of plankton dynamics since it allows (i) improving taxonomic resolution and (ii) recovering more precise annual patterns. Our objectives are to understand the drivers of the succession and to determine how environmental forcing may modify the temporal dynamics of phytoplankton communities. Also the biotic interactions are analysed in order to rationalize all the processes that are involved in the succession.

Plug and play monitoring: developing novel solutions for marine observations using divers as citizen scientists

Authors: Celia Marlowe, Jan Kaiser, Kieran Hyder, Martin Sayer

Presenter: **Celia Marlowe**

Sea temperature has been defined as an essential ocean variable by the Global Ocean Observing System project; it is a vital component of climate and weather predictions. In-situ observations are essential for calibration and verification of satellite data and observations are taken from a variety of platforms, including permanent moorings, ships, buoys, drifters and floats. Larger temperature datasets are required, but there is currently a lack of information on seawater temperature below the surface especially for inshore and coastal areas. Coastal regions are particularly vulnerable to human pressures, often shallow, inaccessible, or difficult to monitor using conventional techniques, however, these areas are often the location for high levels of marine recreational activity, such as surfing, SCUBA diving and fishing. Citizen science offers the opportunity for an increased levels of data collection and community engagement, and utilising participants in marine recreational activities to gather sub-surface information could help fill the data gap.
In-shore satellite sea surface temperature data is affected by land mass, leading to reduction in accuracy. Any bias in recorded SST will affect global temperature estimates due to the proportion of ocean covering the earth's surface, so maximising available, accurate, in-situ data is key. Here, the potential is assessed for the use of SCUBA divers as a low-cost monitoring solution for physically relevant data from marine environments. The major barrier to uptake and usage of the data is understanding accuracy and precision of sensors. To assess this, various scenarios are simulated within recreational SCUBA depth limits in hyperbaric chamber-based trials, alongside in-ocean data collection; including identification of thermoclines. 26 dive computers (10 models across 7 brands) are assessed for accuracy and precision, and within and between model differences established. Data are compared with satellite sea surface temperature data and depth resolved models and the potential for developing algorithms to correct for error is explored.
With processing, dive computers could potentially provide a useful and novel tool with which to augment existing sea temperature monitoring systems at a global scale, especially in under-sampled or highly changeable coastal environments. Therefore, a broad scale SCUBA citizen science programme could contribute to both science and society, by feeding into model hindcasts, forming part of wider in-situ temperature datasets, providing a baseline for comparison with ecological datasets, and helping to inform policy.

Time series of zooplankton biomass to assess the ecological response of EBUS to climate change: the upwelling zone off central-southern Chile as a model

Authors: Ana B. Venegas, Carolina E. González, Rubén Escribano

Presenter: **Ana Belén Venegas**

Eastern Boundary Upwelling Systems (EBUS) are widely recognized as key regions of the world ocean in terms of biological production, biogeochemical processes and tele-connections with the global ocean, with strong implications for regional climate variation and socio-economical impact. How EBUS are responding to global warming has thus become a highly relevant issue for the scientific community, in particular in relation to their present and future productivity. In this context, the dynamics of plankton has been considered as a suitable indicator for ecosystem response to climate change, mostly because of their rapid reactions to environmental change. Zooplankton biomass (ZB) represents an ecological response of EBUS productivity. In the coastal upwelling zone of central/southern Chile a time series of zooplankton is available from 2002 to present at monthly intervals on a fixed station (ST18). Seasonal and interannual variation of ZB appears strongly correlated to upwelling intensity and to changes in vertical distribution of the oxygen-deficient subsurface layer (Oxygen Minimum Zone, OMZ). ZB shows seasonal and low-frequency cycles (>3 years) in the coastal zone and significantly responds to stratification and other upwelling-controlled variables. The relationship of ZB with OMZ depth reveals a highly significant optimal window (between 25 and 45 m) for greater levels of biomass. Our findings stress the need for monitoring simple, but biologically relevant variables as to assess ecosystem response to climate-oceanographic changing conditions. ZB is thus suggested as a suitable indicator of EBUS functioning under the impact of climate variability.

Spatio temporal co-variation of assemblages and environmental and fishing drivers in the Celtic Sea – 2000 to 2016.

Authors: Laurene Merillet, Sandrine Pavoine, Marianne Robert, Maud Mouchet, Dorothée Kopp

Presenter: **Marianne Robert**

The Celtic Sea is one of the major European fishing zone in terms of landings and is of great importance for French fisheries (in 2010-2012, landings ranged between 80 000 and 60 000 tons). This area faces various modifications of its environment, and shows some already visible effect of global warming with an increase of bottom temperature as well as modification of the main fishing effort in link with the implementation of the new European Common Fishery Policy. In the context of the Ecosystem Approach to Fisheries Management, an integrated assessment of the stability of this ecosystem facing these changes has to be conducted. More precisely, we focus on the macro bentho-demersal communities that are relatively diverse and composed of more than one hundred species.

Based on the yearly ground fish survey EVHOE, we carried out a spatio-temporal analysis of the dynamic of species assemblages in the Celtic Sea in link with environment (chlorophyll a and temperature) and fishing effort (bottom trawl, pelagic trawl) variables. Sediment and depth were also used to define species distribution. We ran an integrative statistical analysis (STATICO method) to detect the stable structure of the communities in link with environment and fishing effort. Species were grouped in six assemblages with similar environmental and fishing characteristics.

It appeared that this area has been relatively stable from 2000 to 2016. However, some variability is detectable and the time series can be fractioned in three periods. The period from 2000 to 2002 is characterized by a strong influence of bottom trawl in driving the dynamics of communities. From 2003 to 2007, pelagic trawl took over the driving role. Then from 2008 to 2016, we showed an increased importance of chlorophyll a and temperature. Overall, chlorophyll a, temperature and depth are more important structuring the relationship between species and environment than bottom and pelagic trawl. Theses variations lead to a displacement of the assemblage gathering species affine with cold temperature toward a colder area in 2011 and 2012 (warm years). Another example is the displacement of species probably sensitive to bottom trawl effort toward deeper area, less trawled, in 2001-2002, which are years characterized by high values of bottom trawl effort

Overall, this analysis provide an overview of the dynamics of the communities in the Celtic Sea, allowing to characterize the main trend of this ecosystem stability but also environmental variations affecting some assemblages that have to be monitored carefully.

An ecological time series of oyster growth and survival: data curation and analysis of 24 years of monitoring along the French coast

Authors: Julien Normand, Laurent Dubroca, Elodie Fleury

Presenter: **Julien Normand**

As global change becomes a major concern, the need to contextualize discrete observations to highlight long-term evolutions also becomes more relevant. In response to this challenge, Marine Historical Ecology (MHE) has recently emerged as a new discipline within the marine sciences, dedicated to studying the relationship between long-term evolution of marine ecosystems and temporal variations of external predictors such as meteorological parameters, or descriptors of human activities. In recent years, therefore, considerable effort has been devoted to study long-term time series on fisheries and environmental data. This approach has increased our knowledge about natural variability and functioning of marine environments and has helped us to characterize breaking points and baseline shifts in these systems.
However, MHE studies were rarely planned when data acquisition has begun, and some information about the critical components of ecosystem functioning, although helpful, could be missing without turning back. In particular, very few long-term datasets on mollusk bivalves have been released, although these species are cultivated worldwide, could account for a large part of the biomass and also act as ecosystem engineers. From an ecological point of view, oysters also have the advantage to exhibit great phenotypic plasticity in response to environmental variability and to be sessile, making them perfect sentinels of the environment. In this context, we have compiled dataset from three monitoring networks of oyster production coordinated by IFREMER, named REMORA, RESCO, and ECOSCOPA. These networks have monitored growth and mortalities rates for spat and adult Crassostrea gigas oysters reared in 13 locations along the French coastline during the 1993-2017 period. We modeled the evolution of mean individual weights and mortality rates as a function of time to cope with changes in data frequency acquisition during annual monitoring campaigns. We have thus produced standardized indicators associated with a detailed metadata file, in order to share them in an open data depository.
Oyster growth and survival appeared indeed very variable across years and sites. Annual variations explain a significant part of spatial mortality variations and site x year matrices depicted waves of mortalities coinciding with the massive-virus-associated-epizooty that hit spat oyster until 2008. On the contrary, adult oyster growth appeared to be more driven by site-specific environmental conditions. As a first approach to investigate the causal determinants of these variations, we used classification methods to rely on them with seasonal changes of phytoplankton and hydrological parameters, considering another restricted dataset (only nine years and 11 localizations) issued from the Ifremer-REPHY-hydrobiological monitoring network. This approach revealed unexpected relationships between environmental parameters and oyster traits variations, which strongly encouraged further explorations with a broader dataset of environmental descriptors.

Monitoring coastal ecosystems over decades: the SOMLIT Network

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Presenter: **Nicolas Savoye**

The water column of coastal systems shares interfaces with adjacent compartments (land, atmosphere and sediment) and consequently is under the influence of highly dynamic physical (e.g. hydrodynamics, sink/resuspension, mixing), (biogeo)chemical (e.g. nutrient uptake and remineralisation) and biological (e.g.

primary or secondary production) processes, which in turn impact their physical, (biogeo)chemical and biological characteristics. These processes exhibit high seasonal and spatial variability in these systems and are subject to long-term changes due to climate change and anthropogenic activities. Both short-term and long-term variabilities are reflected by the above-mentioned characteristics.
In order to understand the seasonal variability, together with the long-term changes and their environmental drivers within the coastal systems, long-term time series of sub-monthly resolution are needed. The French Coastal Monitoring Network SOMLIT (Service d'Observation en Milieu LITtoral; INSU/CNRS; http://somlit.epoc.u-bordeaux1.fr/fr/) performs such time series within eight ecosystems since the late 90's and more recently within four additional ones. These ecosystems are distributed over the whole littoral of the continental France. Surface water is sampled every two weeks for 16 parameters (temperature, salinity and pH, concentration of dissolved oxygen, nutrients, suspended particulate matter, chlorophyll a and particulate organic carbon and nitrogen (POC and PN, respectively), and more recently stable isotopes of POC and PN and pico- and nano-plankton).
The objectives, the scientific strategy and the overall functioning of the Somlit Network will be presented. Then, three snapshot overviews of some main findings will be reported: 1) the studied coastal systems are highly sensitivity to the climate variability and to the climate change; 2) decadal change in nutrient concentration varies over space and is driven by different forcings depending on the studied ecosystem; 3) the origin and composition of the particulate organic matter vary over space along land-ocean and trophic-status (oligotrophic versus eutrophic regime of the ecosystem) gradients.

Response of a planktonic biomass spectrum to variability at scales from inter-annual, seasonal to that of an extreme storm event

Authors: Angus Atkinson, Martin Lilley, Claire Widdicombe, Andrea McEvoy, Glen Tarran, Elaine Fileman, Paul Somerfield, Tim Smyth

Presenter: **Angus Atkinson**

Given the role of body size as a "master trait", size based models are being used increasingly to understand the functioning of diverse and complex aquatic assemblages. However, the paucity of high resolution time series with both size- and taxonomically based analyses has hindered our understanding of the whole system's response to variability at scales ranging from inter-annual to that of extreme weather events. We examined 275 time-points collected at weekly resolution over 6 years at station L4 in the Western English Channel. Despite order of magnitude variability in the mean biomass of key functional groups across years, the total planktonic biomass (from pico-eukaryotes to fish larvae) varied only twofold, with slopes of their normalised biomass size spectra (NBSS) being statistically indistinguishable. This reflected a strong "anchoring" effect by pico-and nanoplankton, with the much more variable larger taxa being replaceable according to size. The NBSS slopes were consistently steeper than -1, suggesting highly inefficient trophic transfer within the pelagic, likely due to export to the benthos. Conversely, a shallowing of the slope in spring related to imports of meroplankton from the benthos. In addition to the stability of the biomass and size spectra, they showed remarkable robustness to the largest storms experienced by the southwest UK for 60 years. These storms, during winter 2013/2014, had profound effects on seabed integrity and water clarity. While the slope of the NBSS steepened and total plankton biomass were reduced over this period, they rapidly recoiled to normal, emphasising the resilience as well as the stability in a strongly size-structured planktonic system.

Decadal dynamics of benthic communities at the regional scale

Authors: Aurélien Boyé, Jacques Grall, Éric Thiébaut, Pierre Legendre, Caroline Broudin, Céline Houbin, Vincent Le Garrec, Marion Maguer, Gabin Droual, Olivier Gauthier

Presenter: **Aurélien Boyé**

Understanding what drives communities to exhibit different temporal dynamics and apprehending the consequences at broad spatial scales of heterogeneous responses of communities is a key challenge to predict and mitigate future biodiversity changes. Here, we address the role of foundation species in mediating the response of benthic communities to changes in abiotic conditions and assess how they affect the temporal dynamics of their associated communities at a regional scale. For this purpose, we explored the imprints of recent environmental changes on the temporal trajectories of 42 benthic communities over 9 years in two biogenic habitats, intertidal seagrass and subtidal maerl beds (calcifying red algae) and in bare sediment at similar tidal level across 35 locations differing in their local environmental conditions. Benthic communities exhibited similar predictable variation in relation to the environment in biogenic and bare habitats, suggesting that biogenic habitats may not buffer changes in mean environmental conditions. However, biogenic habitats promoted the temporal stability of communities compared to bare sediment by dampening the effect of extreme events. In particular, while regional diversity patterns of intertidal communities changed more quickly than subtidal ones, seagrass meadows mitigated this variability and maintained stable spatial β diversity through time. Overall, our results confirm the crucial role of biogenic habitats in mitigating future biodiversity changes of benthic communities but highlight that the ecological processes involved differ according to the foundation species and tidal level. Lastly, despite temporal variation of communities and occurrence of extreme events over the 9 years, spatial β diversity remain remarkably preserved, highlighting that only a long-term perspective can fully reveal the extent of biodiversity changes and provide appropriate baselines. In this perspective, our work presents an application of innovative statistical analysis for the study of community temporal trajectory that may help revealing sites that have been recently diverging from the mean regional trend, even before that these changes become conspicuous in the spatial β diversity of communities.

Temporal variations of the relative abundance of Acoupa weakfish-Cynoscion acoupa, (Lacepède, 1801) in the region of the influence of the plume of the Amazon River and its relations with oceanographic parameters estimated by remote sensors.

Authors: Jeandria Negreiro Freire, Eduardo Tavares Paes

Presenter: **Jeandria Freire**

The North Continental Shelf of Brazil (NCSB) is characterized mainly by the presence of the discharge of the Amazon River, which interacts with the oceanic waters, establishing a sub-superficial plume of water composed of lower salinity and great proportions along almost all the South American east coast, introducing a high load of dissolved organic carbon and nutrients. This region, due to its unique characteristics, presents one of the greatest biological and fishing productivity along the Brazilian coast. Among the fishing resources exploited in the NCSB, there is an important specie Cynoscion acoupa (Lacepède, 1801), which is exploited mainly by the handcrafted gillnet fleet at NCSB. This work aims to analyze the temporal variations of the relative abundance of Cynoscion acoupa over a period of 12 years (1996-2007). Furthermore, its tendency, cycles and its possible relations with the variability of SST anomalies (SSTA) in the NCSB, estimated by remote sensors. The monthly remote sensing data from the SST were estimated by the AVHRRs sensor from January (1993) to December (2007). The data used to

calculate the Capture per Unit of Effort – CPUE were collected by Brazilian government agencies. The CPUE had a positive growth trend in the period. On the other hand, the analysis of wavelets detected periodicities associated to the peaks of higher energy centered in cycles of 2 and 4 years, approximately. The main temporal variations of the first EOF (Empirical Orthogonal functions) of SSTA data also occurred with higher energy peaks in cycles of 22.6 months (2 years) and 45 months (4 years) well marked according to the wavelet analysis. Correlation maps between the series of CPUE and SSTAs pixel by pixel revealed significant correlation fields in lag of 31 months, 48 months and in lag of 51 months. The result suggests that SSTA spatial and temporal variations may be influencing the life cycle of Cynoscion acoupa, so that it is possible to formulate the hypothesis that juveniles and sub adults of C. acoupa, after passing through a breeding period in the mangroves of the west coasts of NCSB, are transported by the North Brazilian Current (NBC) to the region of the plume of the Amazon in the east coast of NCSB where the gill fleet acts on the adult population. Based on preexisting studies, it was possible to estimate the population growth parameters for the C. acoupa, besides it establishes that 65% of C. acoupa commercial catch during the years of 2002 and 2003 was composed of 5 to 6 years old specimens. The field of correlation with lag of 48 months, which the specimens would have from 1 to 2 years old (juveniles), would be being transported by influence of the NBC that approaches the coast near the Bay of São Marcos in extreme west of NCSB. There are empirical evidences that the mangroves region in the North Brazilian Coast contemplates the principal breeder to the most important commercial species of NCSB.

Time series of organic matter and nutrients in the north-eastern Adriatic Sea (gulf of Trieste)

Authors: Michele Giani, Federica Relitti, Lidia Urbini, Marina Kralj, Matteo Bazzaro, Cinzia Fabbro, Cinzia De Vittor

Presenter: **Michele Giani**

In the northern Adriatic Sea the warming of seawaters and the variations in the discharges of river-borne nutrients are causing variations in the trend of dissolved and particulate organic matter and of nutrients. A nineteen years' time series was analysed, from January 1999 to December 2017, in the Long-Term Ecological Research site C1 (bottom depth 17.5 m), where a long term ecological monitoring started since 1970. This site is located in the shallow Gulf of Trieste (maximum depth 25 m), which is the northeasternmost edge of the Adriatic Sea. The Gulf is strongly affected by the highly variable riverine discharges (Isonzo River on the northwestern coast) controlling salinity and inorganic nutrients supply. Higher riverine inputs generally characterize late spring and autumn while drought periods occur in winter and summer. The system is influenced also by the oligotrophic intrusions from the southeastern area through the Eastern Adriatic Current (EAC) that shows high interannual variability.
Depth profiles of salinity and temperature were determined using Conductivity-Temperature-Depth/Pressure probes and discrete water samples were collected monthly with 5-L Niskin bottles at four depths (0.5, 5, 10, 15 m) in order to measure dissolved organic carbon (DOC), particulate organic carbon (POC), chlorophyll a and nutrients (nitrates, phosphates and silicates).
The study area seems affected by increasing riverine discharges in the period investigated, as shown by the negative linear trend of salinity ($p < 0.001$) both in surface and deep waters. As a consequence of the higher riverine inputs, a significant increase in nitrates and silicates surface concentrations was observed ($p < 0.01$ and $p < 0.001$, respectively). On the contrary, a decrease of phosphate concentration ($p < 0.001$) in the investigated period was detected, in agreement with the oligotrophication trend already observed in the gulf of Trieste and in the open northern Adriatic Sea. Similarly to nitrates and silicates, DOC concentration seems to be affected by the increase of freshwater ($p < 0.001$).
In accordance with the global warming trend, seawater temperature in the gulf of Trieste has been increasing since 1986 ($p < 0.001$). This condition might enhance the stratification of water column, resulting in a higher DOC accumulation, as indicated by the positive correlation between temperature and DOC (p <

0.001).
Regarding the particulate fraction of organic matter, a decreasing trend has been observed in POC concentration ($p < 0.001$) during the last two decades. Since freshwater inputs are increasing in the period investigated, the decrease in POC might be mostly related to changes in planktonic communities rather than in terrestrial inputs as suggested by the positive linear correlation found between POC and chlorophyll a ($p < 0.001$).

Long-term evolution of the Northern France coastal zone and relationship with historical sea-level changes

Authors: Latapy Alexa, Arnaud Héquette, Amandine Nicolle, Nicolas Pouvreau, Nicolas Weber

Presenter: **Alexa Latapy**

Changes in sea-level at local or regional scales may differ significantly from global sea-level change due to a number of factors. Previous studies revealed local variability in long-term series of sea-level measurements that can go back several centuries in some areas. Along the Northern coast of France, however, changes in sea-level are only known for the last few decades. Nevertheless, water level measurements were carried out in the region since the early 19th century and tidal records, usually in the form of tidal charts, were stored in the French Hydrographic Service (Shom) archives. At the same time that these tidal measurements were conducted (mostly in the harbours of Boulogne-sur-Mer, Calais and Dunkirk), hydrographic surveys were made for mapping the seabed of the coastal zone where tidal sand banks are common, forming linear shore-parallel or slightly oblique massive sand bodies. Digitization of these historical records and analysis of the water level time-series was undertaken in the course of this study, enabling to reconstruct past sea-level changes and assess changes in sand bank morphology and position. Our analyses of bathymetry changes shows significant morphological variations across the shoreface since the 19th century, which are largely due to sand bank mobility. Alongshore migration and elongation of sand banks can be related to tidal asymmetry directed to the East-North-East. Shore-perpendicular movement can be related to the action of storm waves that can be responsible for onshore-directed sediment transport. One of the objective of this study is to attempt to relate the observed changes in coastal and nearshore morphology with possible changes in hydrodynamic processes. A simulation of tidal circulation based on historical tidal records time-series and of wave propagation over bathymetry grids based on historical bathymetric soundings will enable to compare coastal hydrodynamics during distinct time periods and assess their possible effects on nearshore morphology change. This could lead to a better understanding of the long-term mechanisms responsible for coastal zone evolution.

Extreme event occurrence linked with natural and anthropogenic climate variations in coastal waters of western Europe and their impact on the marine ecosystem

Authors: Maximilian Unterberger, Guillaume Charria, Peggy Rimmelin-Maury, Eric Goberville, Nicolas Barrier, Emilie Grossteffan, Michel Repecaud, Loïc Quemener, Sébastien Theetten, Paul Tréguer

Presenter: **Maximilian Unterberger**

Coastal waters of western Europe and their associated marine ecosystems are under the influence of contrasted hydro-meteorological dynamics, that are highly sensitive to natural and anthropogenic climate variations at a global scale. These dynamic oceanic regions experience a variety of extreme events (e.g. freshening events due to river discharge) which remain challenging to assess and furthermore to predict in terms of temporal and spatial scales.

In this study, the physical and chemical dynamics in the Bay of Brest were investigated to obtain a better understanding and predictability of the influences of teleconnections, such as large-scale weather regime variability and climate change, on local extreme events. We analyzed long-term high- frequency in situ observations recorded from the year of 2000 onwards, focusing on the winter period (December to March) for extreme event characterization. We ran numerical simulations over the same period of the observations to investigate and understand the dynamics in the Bay of Brest and their temporal occurrence. Furthermore, we directly compared these numerical simulations with our observations to analyze the involved ocean processes in the considered region.

Observations suggest that the temporal distribution of local extreme precipitation patterns linked with terrestrial watershed saturation capacities during the pre-event period appears to be the main driver for triggering freshening events. Within this study, the interannual occurrence of extreme events and the role of the different oceanic and atmospheric processes (e.g. tides) are explored in detail.

Keywords

Extreme events, coastal environment, climate variability, high frequency in situ sampling, model emulation

Assessment of a long-term, multi-site and high frequency monitoring of a tidal estuary after 15 years

Authors: Sabine Schmidt, Hervé Derriennic, Pascal Lebleu, Isabel Jalon-Rojas, Mario Lepage

Presenter: **Sabine Schmidt**

With its 625 km^2, the Gironde-Garonne-Dordogne estuarine system in the South-West France is one of the largest European estuaries in terms of surface area (625 km^2) and annual mean discharges (1000 m^3 s^{-1}). A prerequisite to predict the evolution of turbidity and dissolved oxygen in waters of the Gironde estuary under climatic and anthropic pressures (global change, population rise of Bordeaux metropolis, land use) is to understand the factors controlling their variability over a wide range of temporal and spatial scales. Since 2004, a real-time high frequency monitoring system (MAGEST network) records temperature, salinity, turbidity and dissolved oxygen to establish a reference database. First, we will present the 15-year time record of these parameters to discuss the merits and drawbacks of high-frequency monitoring. It reduces uncertainties in concentrations from semi-diurnal to inter-annual timescales and shows reliable inter-annual variability in relation with the local hydrology and climatology. However, we demonstrate that interpretations from fixed stations must also be considered with a special care, and additional samplings, like longitudinal survey, are required to correctly interpret dissolved oxygen or turbidity variability. Secondly, we illustrate how the combination of spectral methods (Singular Spectrum Analyses, Lomb-Scargle

periodograms and Wavelet Transform) provides new ways for analyzing multi-year, high-frequency datasets. Frequencies, but also the relative contributions, of the main environmental factors affecting turbidity in the Gironde estuary were thus identified: river flow regime and variability, tidal range/cycles, and turbulence. On the seasonal time scale, the relative influence of forcings is almost constant in the lower estuary, dominated by tidal frequencies (60% and 30% for tidal cycles and tidal range, respectively); in the upper reaches, it is variable depending on hydrological regime, even if tidal frequencies are responsible for up 50% of turbidity variance.
Based on different data treatments (spectral methods, statistics) applied to the multi-year MAGEST record, we demonstrate the global changes and its local impacts are expected to promote a more persistent turbidity maximum zone and a permanent summer hypoxia in the urban tidal Garonne River, a sub-estuary fluvial section of the Gironde estuary, in the next decades.

Multiscale methods for characterizing and predicting long-term marine time series

Authors: Francois Schmitt

Presenter: **Francois Schmitt**

We consider here two types of time series recorded at fixed points (Eulerian sampling) : (i) high frequency data recorded at e.g. 30 minutes resolution, during several years, and (ii) lower frequency data recorded e.g. every week during 20 years or more. These data sets are complex, they span time scales from 3 to 5 decades wide; they may have missing data or irregular sampling time and can be non-stationary. Adequate statistical methods must be used to characterize such time series.
For example their fluctuations are usually non Gaussian, so that classical time series tools assuming gaussianity cannot be applied. They may have long-range memory so that simple forecasting models such as ARMA cannot be used.
We illustrate this on high frequency data (MAREL and others), on low frequency data (SOMLIT and others). We estimate power spectra, autocorrelation functions, probability density functions (pdf) of data and of their increments. We identify scaling ranges, heavy tailed pdfs, periodic components versus multiscale intermittencies. Finally, the long-range properties are exploited to propose a prediction model.

The influence of global and local drivers on the long-term seasonality and variability of the nutrients in the French marine coastal ocean: the case study of the Arcachon Lagoon.

Authors: Arnaud Lheureux, Nicolas Savoye, Yolanda Del Amo, Dominique Soudant, Eric Goberville, Isabelle Auby, Line Bourasseau, Marie-Ange Cordier, Laurence Costes, Sophie Ferreira, Antoine Nowaczyk, Michel Parra, Florence D'Amico, Florian Ganthy, Laure Gouriou,

Presenter: **Arnaud Lheureux**

Coastal marine ecosystems, which play a crucial role in the biogeochemical and ecological functioning of the earth system, are highly sensitive to the combined effects of climate variability and human activities. Such impacts are not restricted to the biological compartments but extend to the whole ecosystem. Because nutrients are among the main limiting factors of phytoplankton growth, even subtle changes in

their dynamics may therefore induce pronounced modifications at the ecosystem scale. However, it remains challenging to assess the spatial and temporal scales at which climate influence operates on coastal ecosystems, especially in a climate change context.
Here, by focusing on the Arcachon Bay, a small (180 km^2) semi-enclosed lagoon located along the south-western coasts of France, we investigated (1) the long-term and seasonal changes in nitrate, phosphate and silicate concentrations and nutrient ratios, (2) spatial changes in the hydrological features of the lagoon and (3) the relationship between the nutrients evolution and the climatic and anthropogenic drivers including their global and local components.
Long-term (from 10 to 30 years) time series, originated from two monitoring programs (SOMLIT and ARCHYD) that encompass 11 sampling stations (located within the subtidal 40 km^2 of the lagoon), was used to describe exhaustively this ecosystem, from the most outer sites close to the Bay aperture, and therefore mainly influenced by oceanic conditions, to the most inner sites close to the streams flowing into the bay, directly under the influence of continental inputs. In addition, the geomorphological characteristics of this shallow system (average depth of 4.6m and a maximum of 20m in the main channels), together with a meso- to macro-tidal regime induce vertical inputs of nutrients.
Dynamic Linear Models (DLMs) performed on nutrient concentrations and the use of seasonal indices allowed us to detect and characterise both seasonal cycles and long-term trends in nutrients, but also abrupt changes. By applying multivariate analyses combined with a correlative approach, we quantified how global (i.e. large-scale hydro-climatic indices that occur in the Northern Atlantic Ocean (AMO, NHT, NAO, EAP, AO)), regional (i.e. changes in SST, SLP, atmospheric circulation), local (i.e. meteorology and riverine nutrients concentrations and flows) forcings contributed to the spatio-temporal modifications in nutrients over the last 30 years in the Arcachon Bay. Moreover, the physical (temperature, salinity, suspended matter) and biological (phytoplankton biomass) ecosystem variables were considered to complete the overview.

Integrated time-series analyses to support ecosystem assessment.

Authors: Benjamin Planque, Saskia Otto

Presenter: **Benjamin Planque**

Integrated time-series analyses are commonly used by Integrated Ecosystem Assessment groups as a way to summarize changes that have occurred in recent decades in ecosystems and highlight the possible connections between physical, biological, and human components. We review a number of the methods currently in use and highlight some of their strengths and weaknesses. Since this field is rapidly developing, it is demanding to evaluate the performance of the many novel methods that are regularly suggested. For this purpose, we present an evaluation procedure of current and future integrated time-series analyses based on numerical simulations. We describe how numerical simulation protocols and algorithms can be used to generate few contrasted ecosystem datasets and how to use these datasets to evaluate the performance of integrated time-series analyses. This evaluation protocol is expected to empower Integrated Ecosystem Assessment groups in selecting and applying integrated time-series analyses that can provide robust interpretations of ecosystem time-series.

Climate variability and change: Response of a coastal ocean ecosystem

Authors: Francisco Chavez

Presenter: **Francisco Chavez**

Monterey Bay and contiguous waters of the California Current System have been observed repeatedly since 1929 and more intensively since 1989 with ships, moorings and autonomous vehicles. Seasonal, interannual and multidecadal variations are linked to local weather and large-scale climate ocean-atmosphere dynamics. In the springtime when the northeast Pacific subtropical high pressure system strengthens, coastal upwelling fertilizes the surface layers driving a dramatic increase in biological productivity. Upwelling weakens into the fall bringing oceanic water coastward, and winter storms routinely interrupt upwelling and deepen the mixed layer. Every 3 to 8 years, the interannual El Niño impacts the region with varying intensity. El Niño most strongly impacts California during the low productivity winter season, obscuring biological impact. The multidecadal Pacific Decadal Oscillation is evident in the time series as several decades of relatively cool conditions after the strong 1997-98 El Niño. Two recently identified phenomena, the central Pacific El Niño Modoki and the North Pacific Gyre Oscillation, increased in amplitude and were first reported during this cold phase. Primary productivity in Monterey Bay increased during the cold phase at a rate of 3% per year. The shift to cool conditions marked the beginning of a monotonic decrease in subsurface oxygen, with a greater than 3% decrease per year in the 300-400m depth horizon. In spite of high variability anthropogenically-driven increases in sea surface pCO_2 and concomitant decreases in surface pH have been measured. There is no increasing trend in temperature at all observed depths from 1988 to the present; prior to recent warm years of 2014-16 trends showed cooling. A recompilation of temperature data back to 1929 indicates that average or cool years are not significantly different over the past century, but the recent record has warmer warm episodes leading to a trend of increasing temperature. The most recent warm episode from late 2013 to 2016, the included the Blob and an El Niño, led to an unprecedented long period of warmer than average temperatures reminiscent to one seen in the early 1940s. Our results highlight the value of long-term observations and the need to modernize these collections so that they are sustainable.

Recent changes in the ocean carbon pump in the South China Sea and implications for regional atmospheric CO_2 accumulation

Authors: Anthony Banyouko Ndah, Lalit Dagar, Kazimierz Becek

Presenter: **Anthony Banyouko Ndah**

The major biochemical and physical mechanisms that drive air-sea CO_2 flux in the South China Sea (SCS), and constitute important modulators of regional atmospheric CO_2 concentration, have been investigated. The objectives are two-fold: firstly, to ascertain the relative contribution and cumulative effects of primary production and phytoplankton functional communities (Diatom, Cyanobacteria, Chlorophyte, Coccolithophore), to the temporal patterns of air-sea CO_2 flux in the SCS, and CO_2 concentration in the regional atmosphere (biological carbon pump). Secondly, to uncover the cumulative factors that drive the physical carbon pump by examining the relationship and effects of temperature change, fresh water flux, upwelling, wind-speed, mixed layer depth and ocean currents and sea surface height anomalies (SSHA) on carbon dynamics. Multiple time series data-sets were analyzed (corresponding to the period 1998-2014) using mixed statistical methods. Primary production (using Chl-a and CDOM as a proxies) and phytoplankton were found to contribute approximately 50% of the variability of air-sea CO_2 uptake into the SCS, representing the biological carbon pump. However, the magnitude of CO_2 fixed seasonally and yearly, by biological processes in the sea explain only approximately 15% of the variability of regional atmospheric

CO_2 concentration. In contrast, CO_2 uptake declined by approximately 0.50 $mol^{-1}m^{-2}s^{-1}$ and 0.53 $mol^{-1}m^{-2}s^{-1}$ in response to a unit increase in SST and PAR respectively (99% confidence level), inducing an increase in atmospheric CO_2 concentration by approximately 0.03% ($p=0.04$). The cumulative changes in SST, PAR and SSS explain approximately 72% and 13% of the changes of air-sea CO_2 flux and atmospheric CO_2 concentration respectively. Out-gassing equally intensified due to El Nino events, identified as the strongest source of inter-annual growth rates of regional CO_2 outgassing forced by positive temperature anomalies. Changes in de-stratification/stratification mechanisms (MLD and freshwater input) and wind-speed and SSH induced a weak decline of atmospheric CO_2 concentration (-0.02% and -0.001%, and -0.002%, 0.014%, respectively) and an equally weak increase in air-sea CO_2 uptake, explaining about 45% of the variability of air-sea CO_2 flux, and 18% of the variability in regional atmospheric CO_2 concentration. Net outgassing and a positive contribution to atmospheric CO_2 concentration was found to be associated with Summer upwelling zones (Off Hanoi, Fujian and Guangdong), while winter upwelling off S.W Taiwan was a significant sink CO_2 sink, contributing to a weak decline of atmospheric CO_2 concentration equivalent to 0.000012%. In conclusion, the strength of the physical pump, particularly the strong warming experienced in the SCS since the 1970s is indisputably a major driver that has transformed the SCS into a net source of CO_2 to the regional atmosphere in recent decade, coupled with the relatively weak biological CO_2 sink. These results serve as a useful reference for future deterministic modeling of marine ecosystem responses to regional carbon system dynamics.

Emergence of novelty in the Anthropocene: the Baltic Sea case

Authors: Yosr Ammar, Thorsten Blenckner, Susa Niiranen, Walter Finsinger

Presenter: **Yosr Ammar**

Global changes have accelerated at unprecedented rates in the Anthropocene due to human activities. These changes have contributed to the increase of novelty in ecosystems. In fact, natural processes and anthropogenic drivers may affect ecosystem dynamics and species assemblages toward novel functions and associations. Here we study the emergence of novelty in biotic and abiotic dimensions, using long-term monitoring data covering over three decades from the Baltic Sea. We define novelty as the degree of dissimilarity of a system to its closest analog across time and space. Our results indicate that Baltic basins changing the most are not necessarily the most novel. We found that the degree of novelty in abiotic and biotic dimensions differs across the spatial and temporal scale and indicate different baseline trajectories. Novelty is greater in the phytoplankton level than higher trophic levels. In addition, Baltic basins follow different baseline trajectories over time and trophic levels. We will discuss how novelty affects abiotic and biotic dimensions in the context of ecosystem dynamics and how these results will furnish new insights on measuring novelty in marine ecosystems.

Multidisciplinary expertise of historical information for the characterization of water levels during storm and flooding events

Authors: Nathalie Giloy, "Historical Storms and Floodings" WG members

Presenter: **Yann Ferret**

Characterization of coastal water level reached during extreme events is a strong societal concern for a better coastal risk management. Historical archives related to storms and floodings are still not often considered whereas they could be used to improve statistics on extreme sea levels. In this context, the Working Group (WG) "Historical Storms and Floodings" has been created to perform a multidisciplinary expertise of historical information. This WG includes researchers, statisticians and historians from different entities (IRSN, Artelia, BRGM, Cerema, EDF, Shom and Université Populaire du Littoral Charentais).
As a starting point, the database called TEMPETES (the corresponding French word for storms) waspreviously created by the IRSN and has been provided to the WG members. This database aims at inventorying qualitative and quantitative information on storms and/or floodings that occurred on the English Channel and Atlantic coastlines. Currently, more than 1500 sources describing 750 events are outlined for the period from the 16th century up to now. By the way, this database is continuously enriched by new sources and events thanks to ongoing research projects and studies carried out by WG members.
The available information in the database describe these extreme events but do not provide any information on water levels. This information is an important variable of interest for the WG members but needs complementary data in order to put the events into their geo-historical context and to estimate water levels. These data can be found, for example, in archives and can be historic city maps, sketches, profiles of the flooded dikes, historical local press etc.
Storm sheets are elaborated by considering all the available information in the database, in order to characterize each storm individually. These storm sheets provide a synthesis of different reconstructed water levels (maximum water level, surges …) reached during one event for the different impacted cities and an illustration of the different sources used for the reconstructed levels. The elaboration of the storm sheets will be presented for two historical storms of the 19th and 20th century.
This multidisciplinary and innovative approach allows a better knowledge of extreme water levels on French coastlines throughout the integration of new data types and, especially, historical information. The access to this database is public and entities interested in these topics are highly encouraged to join the WG "Historical Storms and Floodings".

Large-scale distribution of tuna and billfish species in a warming ocean

Authors: Maite Erauskin-Extramiana, Haritz Arrizabalaga, Alistair Hobday, Anna Cabré, Leire Ibaibarriaga, Igor Arregi, Hilario Murua, Rui Coelho, Guillem Chust

Presenter: **Maite Erauskin-Extramiana**

Despite of the fishery relevance of tunas and billfishes, a global-scale study addressing historical trends and future climate change impacts for the most commercially valuable species has not been conducted. In this study, we investigate the effect of environment in worldwide distribution and abundance of six tuna species and the swordfish between 1958 and 2004 and estimate the expected changes under the climate change highest carbon dioxide emission scenario. For this purpose, we used a long-term time-series Japanese longline fishery dataset (47 years) and a two-step Generalized Additive Models (GAMs). The potential rate of tuna abundance changes in countries' Exclusive Economic Zones (EEZs) was estimated to assess the future impact for those countries. Over the historical period, suitable habitats shifted poleward for 20 out of 22 tuna stocks, based on their gravity centre and/or one of their distribution limits. On average, tuna

habitat distribution limits have shifted poleward 6.5 km per decade in the northern hemisphere and 5.5 km per decade in the southern hemisphere. Larger tuna distribution shifts and relative abundance changes are expected in the future, especially by the end-of-the-century (2080-2099). Abundance is expected to change in coastal countries' EEZ, mainly increasing in high latitudes and decreasing in tropical areas (except for skipjack and yellowfin). These results allow us to anticipate the potential effects of climate change in tuna populations and start taking the appropriate measures to diminish the impacts.
Fish distribution historical changes can, however, triggered by different factors such as food resources, niche tracking and fleet dynamics. Thus, we developed a conceptual framework to ascertain whether the changes in spatial distribution and abundance of the fishes are due to habitat conditions or environmental changes. We applied this approach to the six stocks of swordfish as a case study. In particular, we analyzed historical trends following the framework in i) fishing effort, ii) population and its abundance, iii) habitat, and iv) spatio-temporal reconstruction.

SESSION 15: MANAGING THE EFFECTS OF CHANGE ON SOUTHERN OCEAN ECOSYSTEMS: UNDERSTANDING, CHALLENGES, AND SOLUTIONS

Response of Antarctic krill to rapid regional warming over the last 90 years

Authors: Angus Atkinson, Simeon Hill, Evgeny A. Pakhomov, Volker Siegel, Christian Reiss, Valerie Loeb, Deborah Steinberg, Frances Perry, Katrin Schmidt, Geraint Tarling, Laura Gerrish, Sévrine F. Sailley

Presenter: **Angus Atkinson**

Productive, high latitude ecosystems comprise some of the fastest warming marine habitats on the planet. Stenothermal polar species might be sensitive to rising temperatures and loss of sea ice, but solid evidence is still scarce and conflicting. Long-term, temporal-spatial coverage is a key to understanding climate change responses, and Euphausia superba is one of the very few species with the necessary intensity of sampling, due to its role in commercially exploited food chains. Within the KRILLBASE project we have rescued and compiled all available net sampling data on krill spanning the period 1926-2016. KRILLBASE now comprises three databases, on abundance of the larval stages, on post-larval abundance and on post-larval length, sex and maturity stage. This has allowed a comprehensive analysis of long-term trends in abundance, distributional range and body size. We have identified a strong bottom-up control on krill population dynamics, with the Southern Annular Mode (SAM) influential in modulating recruitment across the SW Atlantic sector. We will discuss the implications of the ongoing trends that we are observing, include future projections and examine these in the context of future access to spawning grounds, linkages to the rest of the food web, biogeochemical cycling and fisheries management.

An integrated approach to test spatially-based population structure and life history connectivity of Antarctic silverfish (Pleuragramma antarctica) in the southern Weddell Sea

Authors: Jilda Alicia Caccavo, Julian R. Ashford, Svenja Ryan, Chiara Papetti, Michael Schröder, Lorenzo Zane

Presenter: **Jilda Caccavo**

The Antarctic silverfish (Pleuragramma antarctica) is a critically important forage species with a circumpolar distribution and is unique among notothenioid species for its wholly pelagic life cycle. Studies have provided mixed evidence of population structure in silverfish over regional and circumpolar scales. Microsatellite markers previously showed homogeneity in allele frequencies along the Antarctic Slope Front and the associated Antarctic Slope Front Current westward from the Ross Sea to the northern tip of the Antarctic Peninsula. Furthermore, spatially recurring length modes provided evidence for episodic connectivity. In this study, as part of a hydrographic survey of the Filchner Trough system in the southern Weddell Sea, otolith nucleus chemistry, which provides a record of environmental exposure during early life, was used to test between physical-biological hypotheses of silverfish population connectivity. Despite strong gene flow observed from Atka Bay to west of the Filchner Trough, significant population structuring was found using otolith chemistry, in the same samples as used for the previous genetic study. MgCa-1 and SrCa-1 differentiated large and small length modes, suggestive of disparate origins for the two size groups, and MgCa-1 showed significant contrasts between Atka Bay, Halley Bay and Filchner Trough. Self-recruitment shaped by circulation associated with the Filchner Trough, fluctuations in mixing between immigrant and locally-recruited fish, and feeding opportunities between inflowing Modified Warm Deep Water and outflowing Ice Shelf Water, help explain structuring revealed by otolith chemistry, length, abundance and biomass data, as well as gene flow along the continental slope. These results illustrate how comparisons between multi-disciplinary techniques based on integrated sampling designs that incorporate hydrography can enhance understanding of population structure and connectivity of species around the Southern Ocean.

Sound scattering in the Scotia Sea: Environmental drivers of mesopelagic species distribution and behaviour

Authors: Tracey Dornan, Sophie Fielding, Ryan A. Saunders and Martin J. Genner

Presenter: **Tracey Dornan**

As we move towards a holistic approach to monitoring and management of Southern Ocean ecosystems, it is imperative that we understand the environmental drivers of pelagic ecosystem community structure at the basin scale. Mesopelagic fish play a critical role in the Southern Ocean food web and biogeochemical cycling, and research has started to reveal distinct mesopelagic fish communities and trophic interactions in the Southern Ocean and Scotia Sea. However, much remains to be discovered about the environmental drivers of fish species distribution and vertical migration behaviour. We use six years of trans-basin acoustic backscatter as a proxy for mesopelagic fish biomass to elucidate the environmental drivers of fish distributions in the Scotia Sea. These relationships are key to forecasting species response to environmental change. Furthermore, we explore the extent to which diel vertical migration (DVM) behaviour is visible in acoustic backscatter, and the implications this has for modelling biogeochemical cycling and ecosystem dynamics.

The effect of regional environmental forcing on the similarities of two embayment's along the Western Antarctica Peninsula

Authors: Juan Höfer, Ricardo Giesecke, Emilio Alarcón, José Garcés-Vargas, Andrea Piñones, José Luis Iriarte, Humberto González

Presenter: **Juan Höfer**

During summer 2017 (January – February) we registered stratified coastal waters in Maxwell Bay (MB, South Shetland Islands) and in South Bay (SB, Palmer Archipelago), promoting the development of large phytoplankton blooms, which yielded high primary production (PP) rates (2.58 – 14.46 gC m^{-2} d^{-1}). On the contrary, during summer 2018 lower PP rates were estimated through the photic layer. Although SB only presented a slightly larger phytoplankton biomass compared to MB, the primary productions rates attained within SB (2.91 – 5.52 gC m^{-2} d^{-1}) were much higher than the ones yielded within MB (1.3 – 1.85 gC $m^{-2}d^{-1}$). From November 2016 to February 2017 the Southern Annular Mode (SAM) presented a strong negative phase, whereas from November 2017 to February 2018 the opposite happened (i.e. strong positive phase). Negative SAM during spring/summer reduces the number of windy days as well as wind speeds promoting stratification then enhancing phytoplankton growth (2017), whereas positive SAM increases wind speed and the frequency of windy days, then limiting phytoplankton growth (2018). However, this regional forcing seems to have a stronger effect on the northern Antarctic Peninsula (MB) than in southern coastal areas (SB), because positive SAM affected more the westerly winds (position and magnitude) towards the equator, thus reducing the similarities between both areas during SAM positive phases.

The spatial and temporal variations in mean total zooplankton abundance and average copepod community size of the Southern Ocean from the SO-CPR activities

Authors: Kunio T. Takahashi, John A. Kitchener, Karen V. Robinson, Graham W. Hosie, and SO-CPR Survey Team

Presenter: **Kunio Takahashi**

The Southern Ocean Continuous Plankton Recorder (SO-CPR) Survey commenced in 1991 with the purpose of mapping spatial and temporal variations in zooplankton pattern, and to make use of the sensitivity of plankton to environmental change as an early warning indicator of the health of the Southern Ocean ecosystem. The CPR can collect surface zooplankton continuously for 450 nautical miles during a single tow at normal ship speed. Therefore, it is ideal for sampling large areas quickly and mapping the distribution of the surface zooplankton community in relation to ocean environments over large ocean scales. We compared the total zooplankton abundance and average copepod community size between two regions of the Southern Ocean; the East Antarctic region from 60 to 160°E where there has been the highest density of CPR tows to date, and the Ross Sea region between New Zealand and the Ross Sea, 160°E to 150°W where CPR tows have been conducted regularly since 2006. The four predominant latitudinal zones Sab-Antarctic Zone (SAZ), Polar Frontal Zone (PFZ), Permanent Open Ocean Zone (POOZ), and Sea-Ice Zone (SIZ) were compared within the East Antarctic and Ross Sea regions. The Total Zooplankton Abundance is the sum of abundance of all zooplankton collected in a section (sample) of CPR silk expressed as numbers per cubic meter, each sample normally representing 5 nautical miles of tow which equates to ~1.5 m^3 of water filtered. The large inter-annual variation in zooplankton abundance in the Ross Sea region contrasts with the observed patterns in the East Antarctic region where there is less inter-annual variation in total zooplankton abundance. The Average Copepod Community Size (ACCS) metric was used to compare dominance in copepod species between regions. There was no significant trend in the ACCS in the Ross Sea

region during the sampling period. In the East Antarctic region, the ACCS metric showed a significant positive trend from 1991 to 2013, suggesting a shift towards larger copepod species. As with the study of long term changes in abundance above, sampling in the Ross Sea region between 160°E and 150°W is still relatively too short to make clear comment on trends, other than the Ross Sea region does not show the same patterns as the Eastern Antarctic region despite the PFZ and POOZ of the Ross Sea region being "downstream" of the Eastern Antarctic region in relation to the ACC. (*I would like not to deliver a lightning presentation.)

Theme 2 Seminar: Modelling and projecting ecological change: Progress and challenges in modelling the Southern Ocean ecosystem

Authors: Jess Melbourne-Thomas, Andrea Piñones, Rowan Trebilco, Juan Höfer, Andrew Constable, Eileen Hofmann, Nadine Johnston, Eugene Murphy, Stuart Corney

Presenter: **Stuart Corney**

Southern Ocean ecosystem models are central tools to facilitate enhanced understanding of ecosystem structure and function, inform regional and global ecosystem assessments, and support decision making for conservation and ecosystem-based management. During the last four decades there has been significant progress in the development of such models, including regional foodweb models for all major sectors of the Southern Ocean, and significant advances in modelling the lifecycle, trophic role and movement of Antarctic krill. In this seminar, we provide an overview of progress in these areas and highlight challenges for future development of Southern Ocean ecosystem models to support sustainable governance. These include: (i) better representation of alternative energy pathways in ecosystem models; (ii) developing full lifecycle models for Antarctic krill; (iii) downscaling and standardisation of environmental forcing for ecosystem projections; (iv) the development of end-to-end ecosystem models that integrate physical, chemical and biological processes across multiple species; and (v) better incorporation of models into assessment and decision-making processes. We suggest some potential options and pathways for addressing these challenges.

How good is good enough? Tools for the assessment of a physical ocean model to use as forcing of ocean ecosystem models

Authors: Stuart Corney, Dave Gwyther, Jess Melbourne-Thomas, Mao Mori, Sophie Bestley and Andrew Constable

Presenter: **Stuart Corney**

Ecosystems are comprised of interactions between biology and the physical environment and as such, modelling of an ecosystem requires an underlying representation of that physical system. That representation may be based on observations but is often provided by a dynamical physical model. Good skill at reproducing the environment is needed if the outputs of a physical model are to be used to generate scenarios for the ecosystem model.
While the use of an existing physical model in an end-to-end ecosystem model has the advantage of having already undergone a documentation and assessment process, this assessment most likely focused on the physics and may not have been focused on suitability for use as input into an ecosystem model. We present a circum-Antarctic realisation of the Regional Ocean Modelling System and assess its performance in the

Indian sector of the Southern Ocean at different scales that are ecologically relevant for this region. Specifically, we define a set of ecologically relevant criteria and assess the performance of the model against these criteria. We show that the model performs satisfactorily in its ability to simulate the location of fronts, eddy kinetic energy, particle transport and evolution of water properties within polynya, however needs improvement in the reproduction of mixed layer depth if it is to be used to drive an ecosystem model in this region. We propose that ecologically-relevant assessments such as we propose should be an essential step before using physical model output to drive ecosystem models.
As an example of how the model can be used as input into an ecosystem model we finish up with a method for transforming the gridded model into the polygon structure required as input for a Southern Ocean configuration of the Atlantis ecosystem model and demonstrate that this process maintains important properties such as seasonal cycle and transport of tracers across polygon boundaries.

Future constrains for phytoplankton growth in coastal Antarctic Waters: the effect of nutrient stoichiometry in icebergs under increasing glacier melting scenarios

Authors: Juan Höfer, Mark J. Hopwood, Emilio Alarcón, Humberto E. González

Presenter: **Juan Höfer**

The Southern Ocean (SO) has been described as a High Nutrients Low Chlorophyll (HNLC) area. Currently, low iron availability in the SO is causing the low productivity of Antarctic waters. Melt-water from glaciers and icebergs represents an important source of iron for Antarctic waters. During the summer of 2017, increased glacier melt-water outflow enhanced the stratification and productivity of coastal waters in the Western Antarctica Peninsula, promoting the formation of large phytoplankton blooms, which almost exhaust nitrogen in surface waters. The nitrogen and silica content of glacier melt-water is relatively low in relation to phosphorus and especially dissolved iron content (available for phytoplankton), when compared to the extended Redfield ratio (16:15:1:0.002; N:Si:P:Fe). Using this data along with the nutrient stoichiometry of seawater, we assessed which elements are going to be more limiting for phytoplankton growth under different freshening scenarios.

Distribution of CDW Intrusion Sites in Eastern Amundsen Sea and West Antarctic Peninsula Continental Shelves Revealed by Antarctic Seals

Authors: Klinck J.M., D. Costa, L. Hückstädt

Presenter: **John Klinck**

Warm, nutrient-rich Circumpolar Deep Water (CDW) moves onto Antarctic shelves through bathymetric depressions. CDW supports biological production through nutrient supply as well as heat flux which maintains shelf water temperatures between 1°C and 2°C. This study considers the distribution of CDW intrusion sites along the continental shelf in the eastern Amundsen Sea and the west side of the Antarctic Peninsula (WAP) (100°W to 60°W, 75°S to 60°S). Observations from Southern Elephant seals that were outfitted with tags that contained CDT sensors (www.meops.net) are available in this area from 2005-2010 and 2013-2015. Data are sufficiently frequent to characterize hydrographic conditions from late summer through winter for February 2007 to September 2010. Daily profiles of temperature and salinity are constructed by averaging all seal dive profiles in each region and the daily values at fixed depths are

smoothed with a 3-day and a 2-week weighted filter. Thermohaline changes from the surface to 150 m show seasonal mixed layer variability over the four years. Below the permanent pycnocline (200 m) temperature varies between 1.5° and 1.8°C with clear events representing intruding oceanic CDW (temperature of ~1.8°C). Analysis of the spatial distribution of seal dive locations shows a clear focus of foraging regions in areas with frequent intruding CDW that are linked to bathymetry. The distribution of CDW intrusion regions derived from the seal data are compared with those observed in the simulated circulation distributions. This comparison provides cross calibration for the seal-derived observations and numerical ocean circulation model.

Alternative energy pathways to alternative futures - a balanced food web model for Prydz Bay, East Antarctica

Authors: Stacey McCormack, Jessica Melbourne-Thomas, Rowan Trebilco, Andrew Constable, Julia Blanchard

Presenter: **Stacey McCormack**

Short, krill-dominated food chains are the focus of many existing food web models for the Southern Ocean, despite increasing recognition that such a simplistic view may not apply over many regions. With environmental change already causing region-specific alterations to Southern Ocean habitats, understanding the mechanisms which govern how Southern Ocean food webs are structured and function is a vital goal for developing conservation and sustainable management strategies. Ecosystem models offer a powerful tool for understanding how food webs are organised and for exploring alternative food web states and pathways for energy flow under scenarios of change. For areas where few ecosystem models exist, such as the Indian sector of the Southern Ocean, alternative energy pathways including those through mesopelagic fish and squid remain a key area of uncertainty in understanding the structure and functioning of these ecosystems.
We present the first food web model developed for Prydz Bay and the southern Kerguelen Plateau region aimed at exploring alternative energy pathways through mid-trophic levels. The model is implemented in the software Ecopath with Ecosim and its structure is informed by the Southern Ocean Dietary Database. We describe the process for building the model, including our unique documentation of the model parameterisation process using dedicated pages on the Southern Ocean Information Wiki (SOKI; http://soki.aq/), a dynamic environment where ecosystem models can be documented and peer-reviewed openly. We discuss the diverse assemblage of central energy pathways revealed by the model, with energy flow through mesopelagic fish and squid groups, as well as the well-characterised krill pathways, fundamental components of the Prydz Bay food web. Using simple scenarios of reductions in krill biomass under climate change, we explain how the system may reach a potential tipping point with the response of krill-reliant predators strongly dependent on their ability to switch to other prey sources. We conclude by discussing what these findings might suggest for the future vulnerability of food webs within East Antarctica and the implications for future modelling work in the region.

Modelling Southern Ocean primary productivity change with climatic change.

Authors: Elodie Salmon, Eileen E. Hofmann, Michael S. Dinniman, Walker Smith

Presenter: **Elodie Salmon**

Large blooms of the haptophyte Phaeocystis antarctica and diatoms in the Ross Sea are supported by dissolved iron supplied by sea ice melt and vertical entrainment of deeper iron-rich waters. The relative contribution of these iron sources and the effect of sea ice variability on the development and maintenance of these blooms is evaluated using a one-dimensional numerical model that includes the complexities of the P. antarctica life cycle, diatom growth, iron and irradiance controls, and the taxon's response to the changes in these variables. Simulations of current Ross sea ecosystem indicate that sea ice melt accounts for 20% of total iron inputs during low light conditions in late November-early December, which stimulates a P. antarctica bloom. As this iron source is depleted, advective inputs of dissolved iron (60% of total iron inputs) maintain the P. antarctica bloom through early January and support development of a diatom bloom in early to mid-January. In the absence of iron source from sea ice and sea ice cover during the growth season a diatom bloom forms in December whereas the P. antarctica bloom slowly starts its development in early December and then reaches its maximum a month later. Sensitivity studies show that surface input of dissolved iron from sea ice melt, a transient event early in the growing season, sets up the phytoplankton temporal progression and bloom magnitude, suggesting that the productivity of the Ross Sea system is vulnerable to changes in the extent and magnitude of sea ice. Primary productivity evolution with expected future ecological changes will also be presented.

Environmental and behavioural drivers of krill distribution at the South Orkney Islands – I. A large-scale perspective

Authors: Sally E Thorpe, Emma F Young, Angelika HH Renner, Eugene J Murphy

Presenter: **Sally Thorpe**

Antarctic krill is a key species in the marine ecosystem of the Southern Ocean. It is the major prey for multiple predators but is also the target of a commercial fishery. The potential for competition between predators and the fishery requires the development of risk management strategies for the fishery, underpinned by an understanding of krill movement and retention in target areas. This necessitates a deeper understanding of the key physical and behavioural drivers for krill distribution, and the sensitivity to climate variability and change.

Here we present results from a modelling project investigating the distribution of Antarctic krill at the South Orkney Islands. One of the main fishing grounds for krill, this region is also critical for determining the overall availability of krill downstream across the wider Scotia Sea. The project focuses on processes affecting krill distribution at two spatial scales: the large-scale flux of krill into the South Orkney region, described here, and small-scale transport and retention patterns on and around the South Orkney plateau, examined in an accompanying poster.

At the large-scale, we use the NEMO 1/12 degree ocean-sea ice model to drive an individual-based model (IBM), parameterised for krill, to investigate the influence of oceanographic and sea-ice variability on transport of krill into the South Orkney region from upstream regions, specifically the western Antarctic Peninsula and Weddell Sea. Aspects of krill behaviour (diel vertical migration, association with sea ice) are implemented in the IBM to examine the impact these traits may have on krill distribution at large scales. The model suggests that the primary influx to the South Orkney region is from the Weddell Sea, with only episodic transport from the western Antarctic Peninsula. The behaviour of krill under sea ice is particularly important in determining the pathways and timing of transport to the region, increasing the probability of influx from the western Antarctic Peninsula. Findings from this project are essential for implementation of a feedback management system for Antarctic krill, currently being developed under the auspices of the Commission for the Conservation of Antarctic Living Resources (CCAMLR).

Environmental and behavioural drivers of krill distribution at the South Orkney Islands – II. A regional perspective

Authors: Emma F Young, Sally E Thorpe, Angelika HH Renner, Eugene J Murphy

Presenter: **Sally Thorpe**

Antarctic krill is a key species in the marine ecosystem of the Southern Ocean. It is the major prey for multiple top predators such as whales and penguins, but is also the target of a commercial fishery. The potential for competition between predators and the fishery requires the development of risk management strategies for the fishery, underpinned by an understanding of krill movement and retention in target areas. This necessitates a deeper understanding of the key physical and behavioural drivers for krill distribution, and the sensitivity to climate variability and change.

Here we present results from a modelling project investigating the distribution of Antarctic krill at the South Orkney Islands. One of the main fishing grounds for krill, this region is also critical for determining the overall availability of krill downstream across the wider Scotia Sea. While the project also considers the large-scale flux of krill into the region, described in an accompanying poster, here we focus on the small-scale transport and retention patterns on and around the South Orkney plateau.

Using a state-of-the-art high-resolution ocean-sea ice model, coupled with an individual-based model (IBM) parameterised for krill, we investigate the influence of oceanographic variability on patterns of transport and retention, and the effect of krill behaviour, specifically diel vertical migration and sea-ice association, on these patterns. The model suggests that krill caught in the strong shelf-edge flows are transported rapidly anti-clockwise around the plateau towards the main fishing grounds to the north. On the plateau, where currents are weaker, retention is influenced by the strength and direction of local winds, with shorter retention times associated with stronger westerly winds. Such insights are essential for implementation of a feedback management system for Antarctic krill, which is currently being developed under the auspices of the Commission for the Conservation of Antarctic Living Resources (CCAMLR).

Implications of foodweb change for Southern Ocean fisheries, conservation and carbon export

Authors: Rowan Trebilco, Jess Melbourne-Thomas
Andrew Constable

Presenter: **Rowan Trebilco**

Southern Ocean food webs provide services with significantimmense global value including carbon sequestration, fisheries and the existence of iconic wildlife like penguins, seals and whales. These services are underpinned by different energetic pathways (food chains) such as those dominated by krill, fishes and squids, or salps. There is increasing appreciation that changing climate change is likely to have implications for the foundations of Southern Ocean food webs by affecting the structure of both primary producer communities and ice habitats. HoweverBut, the implications of these changes for wildlife populations, fisheries and carbon sequestration are unclear, as are the implications for policy and decision making.

BARRIER TO POLICY. Here, we present a simple analysis of Southern Ocean foodwebs using qualitative network modelling, and describe the consequences ecosystem services and the conservation of important Southern Ocean taxa. Counter to prevailing wisdom, our results suggest that increases in gelatinous zooplankton (salps) might not have negative consequences for ecosystem services and could potential enhance carbon export potential. Simulated unregulated increases in krill and toothfish fisheries affect predator groups and could also both reduce carbon export potential from Southern Ocean foodwebs. Improved quantitative understanding and modelling capability for energy pathways in Southern Ocean foodwebs will be important to develop robust management responses to climate change impacts

Improving the uncertain future of Antarctic krill: Estimating future Antarctic krill growth using CMIP5 projections

Authors: Devi Veytia, Stuart Corney, Sophie Bestley, So Kawaguchi, Klaus Meiners, and Eugene Murphy

Presenter: **Devi Veytia**

Antarctic krill (Euphausia superba) are considered the keystone species of the Southern Ocean food web, and much effort has been dedicated to developing a suite of krill growth models to predict responses to changes in environment (i.e. Hofmann and Lascara, 2000, Atkinson et al., 2006, Wiedenmann et al., 2008, Constable and Kawaguchi, 2017). These models have been developed and tuned to reproduce observed krill growth rates. Major changes are expected over the coming decades in Southern Ocean environments, which are likely to affect the growth rates of krill and hence their population dynamics. Information on potential future changes in krill growth rates will be valuable for informing management of the krill fishery as well as the conservation of Southern Ocean species reliant on krill as a prey source.

In a model study of circumpolar variation in krill growth Murphy et al. (Murphy et al., 2017, Figure S3) showed that growth rates vary throughout the Southern Ocean and are particularly sensitive to changes in food availability (see also Atkinson et al. (2006). This highlighted the importance of including food availability in generating projections of future changes in krill growth rates. Hill et al. (2013) developed preliminary projections of changes in krill habitat and productivity in the Scotia/Weddell Sea region, with assumptions of changes in food availability based on currently observed chlorophyll fields. These studies show that robust model projections of changes in food availability that can be used alongside the available physical projections are required to assess potential impacts of change in krill growth rates.

To generate projections of changes in food availability, in this study we assessed circumpolar seasonally-averaged projections for historical sea surface temperature and chlorophyll from all available CMIP5 Earth System Models (ESMs) against satellite observations. This gave us a suite of 9 ESMs with both variables available for historical and future conditions (RCP8.5). We assessed the seasonal temperature and chlorophyll concentration of each member of this ensemble against observed conditions for the historical period, identifying models that had low chlorophyll biases for further analyses. Historical and future projections from this model subset were input in an instantaneous growth rate model to generate circumpolar fields following Murphy et al (2017). Our findings show that krill growth rates derived from the historical outputs of our model subset do a reasonable job of replicating rates that are produced using observational data, and that the rates seen using our subset are significantly improved when compared to the complete ensemble of CMIP5 models with chlorophyll available. sThis finding improves confidence in future krill growth projections made with this subset. As dialogue between climate scientists and ecologists/biologists increases, we can expect improved representation of primary production in the Southern Ocean in future climate models, which will aid better predictions for the impacts of climate change upon this key species and Southern Ocean ecosystem processes more broadly.

Theme 3 seminar: Policy implications and decision-making for Southern Ocean ecosystems (with a focus on integrated understanding of natural and human systems interactions)

Authors: Rachel Cavanagh, Susie Grant, Keith Reid, Mecha Santos, George Watters

Presenter: **Rachel Cavanagh**

Climate change is expected to modify Southern Ocean ecosystem dynamics and associated ecosystem services, and existing conservation and management strategies must therefore be responsive to change. It is recognized that scientific advice and recommendations that specifically address climate change impacts are lacking but urgently needed. The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) is developing work to integrate climate change information into management decision-making, with the aim of providing mechanisms to prepare for, and build resilience to, the environmental impacts of a changing climate and the associated implications for the governance and management of the Southern Ocean and the conservation of Antarctic marine living resources. Enhancing ecosystem resilience is a priority, and information gaps on species and habitats at risk due to climate change, and the effects of climate change on marine living resources, remain to be addressed. Using the management of the Antarctic krill fishery and the designation and future management of marine protected areas as illustrative examples of some of the key challenges and potential responses and adaptations to change, this seminar intends to stimulate creative thinking and debate on how best to adapt existing measures for the conservation and management of Southern Ocean ecosystems such that they are future-proofed in a changing climate.

Marine Ecosystem Assessment for the Southern Ocean (MEASO)

Authors: Andrew Constable, Jess Melbourne-Thomas, Rowan Trebilco, Madeleine Brasier, Dan Costa, Huw Griffiths, Julian Gutt, Eileen Hofmann , Nadine Johnston, Eugene Murphy, Yan Ropert-Coudert, Oscar Schofield, Jan Strugnell, Anton van de Putte

Presenter: **Rowan Trebilco**

A first Marine Ecosystem Assessment for the Southern Ocean (MEASO) is under development. MEASO aims to provide a forward-looking assessment of what trends in Southern Ocean ecosystems are happening now and into the future, and what may need to be planned for, in terms of research and management. The aim is to have a quantitative assessment that enables managers to achieve consensus in adapting their management strategies to ecosystem change. MEASO officially began at an international conference held in Hobart in early April 2018 (http://www.measo2018.aq/). The conference provided an opportunity to share relevant science, enhance community input into the design and planning of the MEASO, and to develop a work plan. Since the conference, summaries of information available for a MEASO have been compiled in order to determine what can be used to assess status and trends within the Southern Ocean on regional and circumpolar scales (http://www.soki.aq/display/MEASO). This review includes a record of field programmes and ecological surveys, current Southern Ocean syntheses, model coverage and assessments. The types of biological data collected from the field programmes have also being summarised, based on an open, international survey of researchers. This paper will report on progress towards a MEASO in preparation for a workshop at the IMBeR Open Science Conference in 2019 to develop methods, including infographics, for reporting these types of assessments to policy makers.

Developing projections of the impacts of change in Southern Ocean ecosystems for the sustainable management of krill fisheries

Authors: Eugene J Murphy, Johnston, Nadine, Corney, Stuart, Reid Keith, Rachel Cavanagh, ICED-CCAMLR workshop participants and contributors

Presenter: **Eugene Murphy**

Climate change will alter the structure and functioning of Southern Ocean ecosystems, affect the ecosystem services they provide, and therefore require development of conservation and management strategies. Here we report the outcomes of collaborative studies between the Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) programme and CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) to consider the potential impacts of climate change on Antarctic krill in the Scotia Sea and Antarctic Peninsula region; the centre of the current krill fishery. Initial analyses suggest that under a high emissions scenario, future warming and loss of sea ice is expected to result in a reduction in the abundance and biomass of krill in northern areas of the Scotia Sea, with consequent southward shifts in the distribution of the various krill-dependent species. These changes are also likely to result in substantial changes to the structure of the food web, which may occur rapidly as particular biological thresholds are reached. However, lower emission scenarios suggest a reduced likelihood of major future climate-driven change in ocean and ice conditions and hence in large impacts on krill populations and the ecosystem. We recommend that uncertainty in both future climate-driven physical change and in the susceptibility of krill populations in Area 48 to change needs to be incorporated into projections in order to generate a range of feasible outcomes. Communicating such uncertainty, and hence risks associated with different management and conservation strategies, is crucial in the provision of advice to policy makers. We emphasize the importance of a joint and systematic approach between ICED and CCAMLR to improve scenarios and ecosystem models, and to develop quantified model projections of ecosystem change to inform conservation and management decisions.

Protected areas in the Southern Ocean: The last five years, the next five years and beyond

Authors: RM Roura, C. Christian

Presenter: **Ricardo Roura**

Marine Protected Areas (MPAs) are one of the solutions put in place to address some of the anthropogenic pressures affecting global oceans. In the Antarctic region, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) has been discussing the adoption of MPAs in the Southern Ocean since 2009. CCAMLR is an international commission tasked with the conservation of marine life in the Southern Ocean, in accordance to the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CAMLR Convention). Under CCAMLR Conservation Measure 91-04 General framework for the establishment of CCAMLR Marine Protected Areas (2011) MPAs aim to achieve a range of ecosystem protection, research and climate change objectives.

In IMBER's first Future Oceans conference in 2014 we summarized different conceptual and practical aspects of CCAMLR MPAs, including a "strategic thinking" analysis of CCAMLR's marine conservation initiatives, and the international campaign to raise public and political awareness about Southern Ocean protection. In the intervening years we have seen the adoption by CCAMLR of the Ross Sea MPA, but also a continued failure by CCAMLR to reach consensus on the adoption of other MPA proposals under discussion.

Decisions by CCAMLR are based on the best available science as assessed by its Scientific Committee.

However, decision-making on conservation issues is increasingly impacted by fishing, geopolitical and strategic considerations by individual Member states. Increasingly some CCAMLR members systematically deny consensus on most conservation matters, or allow consensus only after significantly weakening the original proposals. This underscores a drift away from conservation and towards marine living resource utilization as the basis of Southern Ocean governance under CCAMLR.
Based on our active participation as observers and stakeholders in these discussions, in this presentation we summarize developments over the past years and the current status of marine spatial protections in the Southern Ocean, and make recommendations for the way forward.

Ecological hotspots, physical drivers, and jurisdictional frameworks of the subantarctic Southern Ocean

Authors: Sara Sergi, M. O'Toole, A. Baudena, C. Cotté, C. Azarian, R. Guillaume, C. Bost, C. Guinet, H. Weimerskirch, M. A. Hindell, K. Delord, F. d'Ovidio

Presenter: **Sara Sergi**

Following intergovernmental commitments and recommendations to conserve vast areas of the global ocean (Aichi target 11; 2014 IUCN Work Park Congress), conservation policies are extending their boundaries from the coast to include ecological hotspots in the open ocean, where increasing commercial interests are also developing. In respect to coastal systems, managing and conservation of the open ocean faces two new challenges. Firstly, the challenge of setting conservation boundaries in a dynamical landscape, in which the biogeography and diversity of the pelagic region is mainly structured by dynamical features like fronts and current systems, and even finer scale features like eddies and filaments, whose position is not always fixed in space nor recurrent in time. Secondly, policies in the open ocean are framed by a complex jurisdictional system, in which multiple actors control the fate of this vast area.
Here we consider the subantarctic Southern Ocean (Indian sector) as an interesting case study in terms of these two challenges. This region is an ecological hotpost for its pelagic megafauna, at the moment under minimal direct anthropogenic stress. This region also accounts for important bio-resources, as the enormous abundances of myctophids, which support the marine top predators, and constitute at the same an important stock of protein not yet targeted by the commercial fishing. For these reasons, scientific support for future conservation and managing actions is urgently needed.
Our analysis aims:
(1) to identify the ecological hotspots and their physical drivers
(2) to evaluate the spatial relation between the ecological hotspots and the fragmented multi-jurisdictional framework.
Our analysis is based on the integration of ocean physical features derived by multi-satellite data, large database of top predators' tracking data as well as jurisdictional context. In terms of ecological functioning, we exploit the fact that biological production in this region is limited by a micro-nutrient – iron – whose sources are in large part known. Our approach therefore consists in tracking along the Antarctic Circumpolar Current the drifting water masses which have been originally in contact with iron sources. These water masses are expected to undergo massive phytoplanktonic blooms in springtime, and in the later seasons to aggregate the prey (including myctophids) for the megafauna species. The trajectories of the enriched water masses are derived from a Lagrangian model based on surface currents, over which we integrate species-specific information of prey accessibility (like the thermocline depth) which are known from the behaviour of top predators. The hotspots identified in this way are then mapped on the regional jurisdictions and the vulnerability of these habitats tested against scenarios of climate change.

Enhancing essential observing on Southern Ocean ecosystems: progress in SOOS and future developments

Authors: Andrew Constable, Seb Swart, Eileen Hofmann, Mike Williams, Louise Newman

Presenter: **TBD**

The Southern Ocean is disproportionately important in its effect on the Earth system, impacting climatic, biogeochemical and ecological systems, which makes recent observed changes to this system cause for global concern. The enhanced understanding and improvements in predictive skill needed for understanding and projecting future states of the Southern Ocean require sustained observations. Over the last decade, the Southern Ocean Observing System (SOOS) has established networks for enhancing regional coordination and research community groups to advance development of observing system capabilities. These networks support delivery of the SOOS 20-year vision, which is to develop a circumpolar system that ensures time series of key variables, and deliver the greatest impact from data to all key end-users. Large-scale, multi-year or sustained, multidisciplinary efforts have been supported and are now delivering observations of essential variables at space and time scales that enable assessment of changes being observed in Southern Ocean systems. This paper reports on a white paper developed for Southern Ocean observing to be delivered to the next Ocean Observing conference later in 2019 (the white paper was led by the Executive Officer of SOOS, Louise Newman). In particular, we describe recent processes in establishing a set of essential variables for routine measurements and an emerging program of work to design the placement of autonomous observing systems, such as moorings and gliders. We invite IMBeR scientists to participate in the development of SOOS, in order to further the capacity for Southern Ocean scientists to assess the status and trends of the rapidly changing Southern Ocean ecosystems.

Future directions of Integrating Climate and Ecosystems Dynamics (ICED) in the Southern Ocean programme

Authors: Nadine M Johnston, Eugene J Murphy, Rachel D Cavanagh and the ICED SSC (Richard G J Bellerby, Andrew J Constable, Daniel P Costa, Eileen E Hoffmann, Walker O Smith Jr, Jose C C Xavier)

Presenter: **Nadine Johnston**

The Integrating Climate and Ecosystems Dynamics in the Southern Ocean programme (ICED) is an international multidisciplinary programme launched in response to the increasing need to develop integrated circumpolar analyses of Southern Ocean climate and ecosystem dynamics. ICED was developed in conjunction with the Scientific Committee on Oceanic Research (SCOR) and the International Geosphere-Biosphere Programme (IGBP) as a regional programme of IMBeR (or Integrated Marine Biogeochemistry and Ecosystem Research programme, IMBeR, as it was known at the time), and is co-sponsored by the Scientific Committee on Antarctic Research (SCAR). ICED is focused on understanding and predicting the responses of Southern Ocean ecosystems to natural climate and human driven change, and potential feedbacks as part of the Earth system. Understanding the climate interactions in this globally important ocean, the implications of change for ecosystem dynamics, and the impacts on biogeochemical cycles is crucial for developing conservation and sustainable management approaches and evaluating the role of Southern Ocean ecosystems in the Earth System. ICED aims to coordinate and foster this research using an international multidisciplinary approach and contribute to global environmental change research programmes to generate sustainable ocean governance. Following the recent transition of ICED, together with IMBeR, under the auspices of SCOR and Future Earth, we outline future priority research areas and scientific approaches. Priority research areas include 1) understanding and quantifying the state and variability of Southern Ocean ecosystems, 2) Improving scenarios and projections of future Southern Ocean ecosystems at multiple scales, and 3) Improving and achieving sustainable Southern Ocean governance. ICED will also remain open to emerging ideas, new analytical approaches and novel technologies as aspects of Southern Ocean climate, ecosystem and biogeochemistry research progress. ICED will also continue to coordinate and develop a range of planned national fieldwork campaigns, foster integration through capacity development (training and education) and outreach, and ensure alignment of our activities with other international research programmes. These priority research areas will capitalise on ICED's achievements over the past 10 yrs and support sustainable governance of the Southern Ocean and its role in the Earth System, in line with the visions and goals of IMBeR, Future Earth, SCOR and SCAR.

Developing models of krill population processes and projections of the impacts of change: krill recruitment processes and post-larval growth

Authors: Eugene J Murphy, Sally E Thorpe, Nadine M Johnston, Rachel D Cavanagh, Andrew Meijers, Geraint A Tarling and Sophie Fielding

Presenter: **Eugene Murphy**

Antarctic krill is a key species in food webs throughout much of the Southern Ocean and the target of a commercial fishery. Krill population processes are influenced by the seasonal transition between winter sea ice and summer open water conditions and show marked interannual variation. Projected future climate-driven changes in sea ice and oceanic conditions are expected to affect the distribution, abundance and population dynamics of krill. Conservation and fishery management strategies that include the potential impacts of climate changes on krill populations are required. This necessitates an improved mechanistic understanding of the major factors influencing krill population processes.

Here we present initial results from a modelling project to assess the potential impacts of environmental change on the circumpolar distribution and abundance of krill. We focus on projected changes in surface ocean temperature and the distribution and seasonal development of sea ice using a series of climate-change scenarios derived from Intergovernmental Panel on Climate Change (IPCC) Coupled Model Intercomparison Project Phase 5 (CMIP5) model projections for this century. We also consider the likely outcome of changing food availability. There are two modelling strands. Firstly, we use an environmentally-driven model of larval development (from spawning to post-larvae) to examine how projected future changes in timing of sea ice extent, formation and retreat influence the circumpolar pattern of successful larval recruitment. Secondly, we use an empirical model to examine how projected changes in ocean temperatures and potential changes in food availability affect the circumpolar pattern of post-larval growth during summer. We also identify the major uncertainties associated with such projections.

This study is a key step towards developing complete mechanistic models of the krill life cycle in order to generate robust projections of future krill distribution and abundance in the Southern Ocean. These projections will be crucial in developing conservation and management strategies that can encompass potential risks associated with future climate change.

Informing ecosystem management in the context of climate change: incorporating ICED science into decision-making.

Authors: Rachel Cavanagh, Eugene Murphy, Nadine Johnston, Susie Grant, Kevin Hughes, Jennifer Jackson, Keith Reid, Mercedes Santos, Claire Waluda

Presenter: **Rachel Cavanagh**

The Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) programme aims to ensure that the science it generates is relevant to conservation and management decisions. As part of this ongoing effort, ICED is increasingly engaging with the Antarctic Treaty System, particularly through the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and the Committee on Environmental Protection (CEP). ICED and CCAMLR recently agreed to develop a series of collaborative activities (including joint workshops, research and publications) focused on understanding and managing the impacts of climate change on Southern Ocean ecosystems. Given the observed and projected physical changes in the region and the potential impacts of these on species and biological processes, this information will be highly relevant to the management of Southern Ocean ecosystems. The CEP has a Climate Change Response Work Programme (CCRWP) and this, together with CCAMLR's draft CCRWP, provides a useful initial framework for ICED to engage with the two bodies to jointly identify, prioritise and address the challenges in understanding the potential impacts of a changing climate and the associated implications for the management of Southern Ocean ecosystems. Key challenges for the marine environment include the need to understand how projected physical changes may affect current fisheries and their management, and the need to establish principles and methodology for monitoring change within designated (and potential) Marine Protected Areas. Recognising that addressing these challenges requires active engagement from relevant disciplines (e.g. climate scientists, ecologists, economists), that the findings will be valuable to a range of stakeholders, and that policy decision-makers need to be engaged from the outset, we propose the establishment of a trans-disciplinary network within ICED to facilitate knowledge-exchange and action for improved ecosystem management in the context of change.

Session 16: Marine governance, challenges for sustainability

How to consider offset governance in the context of Marine Spatial Planning: insights from the management of natural resources

Authors: Céline Jacob, Adeline Bas, Charlène Kermagoret, Pierre Scemama, Anne-Charlotte Vaissière

Presenter: **Pierre Scemama**

Several governments are encouraging the development of economic activities within the marine realm following broader calls for 'Blue Growth'. However, developing marine activities is likely to degrade coastal and marine ecosystems. The mitigation hierarchy, and in particular marine biodiversity offsetting, is a regulatory tool aimed at reconciling economic development and biodiversity conservation.
The implementation of biodiversity offsets in the marine realm must consider specific ecological features (e.g. few marine restorations solutions available, difficulties in assessing impacts) and socio-economic features (e.g. absence of property rights, social acceptability, different organizational systems at different scales) that require to rethink biodiversity offsetting through a planning approach. The current development of Marine Spatial Planning (MSP), allocating the spatial and temporal distribution of human activities in marine areas, can be seen as an opportunity to develop new approaches for the implementation of offset.
We study how marine mitigation hierarchy could benefit from feedbacks from existing instruments used to manage environmental resource (e.g. water, forest, fisheries) integrating a planning dimension. We then discuss the different organizational innovations that could support efficiency of marine offset and how they can be integrated within the framework of MSP.

Ocean Limited: A game-based learning approach for marine sustainability education

Authors: Stefan Koenigstein

Presenter: **Stefan Koenigstein**

Governance of human ocean uses, their impacts on the ocean, and external perturbations such as climate change poses complex sustainability challenges. Preserving ocean ecosystems while securing the livelihoods of ocean user groups requires a social-ecological systems perspective that should be reflected in sustainability education for future generations. Game–based learning approaches can create an improved, integrated understanding of marine sustainability and climate change topics. By encouraging active participation, emotional learning and stewardship, role-playing games can be used to teach and train compromises and solutions of marine governance problems.
We developed Ocean Limited, a table-top role-playing game for high-school classrooms and groups, in which 12 to 22 players slip into the roles of ocean stakeholders and negotiate their uses of the ocean's goods and services. The game provides the players with a high degree of freedom for actions and incorporates a range of ocean usages with different impact strengths, and cooperative and competitive interactions among stakeholder groups. Climate change and other important ocean sustainability topics are incorporated through game events, which increase in severity with progressing game time. The final game was tested in four playtests with audiences ranging from 8th grade students to young environmental education practitioners. We assessed observed in-game decision-making and overall sustainability

outcomes of the playtests.
The game achieved a good coverage of globally relevant marine sustainability topics and conflicts, and motivated players to actively participate in economic ocean uses and group discussions about marine governance topics. Major conflicts emerged concerning spatial competition among users and the risks and impacts of industrial ocean uses (e.g. pollution) on less powerful characters. Marked differences in the proportion of high-impact, high-income ocean uses vs. more sustainable uses were observed among the participants depending on their educational background. All playtest groups developed some creative cooperations and achieved global agreements aiming at increased sustainability of ocean uses, which were not pre-dictated by the game rules.
Ocean Limited shows high potential for use in an integrated marine sustainability education, creating empathy and understanding for marine resource users and providing insights into marine sustainability challenges and governance strategies.

Assessing synergies and conflicts arriving from spatial-temporal proximity between marine human-based uses

Authors: Ida Maria Bonnevie, Henning Sten Hansen and Lise Schrøder

Presenter: **Ida Maria Bonnevie**

The pressures on marine ecosystems and on marine space are increasing due to expanding marine human-based activities. Traditional uses e.g. fishing, shipping, oil and gas development, tourism, and recreation compete for marine space with each other and with relatively new marine uses such as sustainable energy, marine biotechnology, and aquaculture. The Blue Growth Strategy of the European Union highlights blue potentials for economic sectors to increase the use of marine resources and marine space. Within an ecosystem-based approach to maritime spatial planning and to blue growth, it is important to limit cumulated pressures on the environment. While it is crucial to examine synergies and conflicts between human-based uses and the environment, it is also important to examine conflicts and synergies in the interactions between different human-based uses, especially if they experience a close proximity in space and time. A cross-sectoral theoretical framework to assess spatial-temporal synergies and conflicts between marine uses in maritime spatial planning is needed. By knowing potential and actual conflicts and synergies between marine uses and their dependencies on ecosystem services, planners can implement means to avoid or at least minimise conflicts between uses as well as maximising interaction-based synergies. At the same time, a focus on synergies can increase the awareness of options to co-locate marine uses in the future to decrease pressures on space elsewhere and optimise the use of space. A pairwise matrix-based approach to assess conflicts and synergies that arrive from marine human-based uses being in spatial-temporal close proximity to each other will be presented. Firstly, the approach can be used at a larger regional basin-wide scale to produce raster-based maps that show potential conflicts and potential synergies between human-based uses in a marine area based on theoretical knowledge about synergies and conflicts between marine uses. Secondly, it can be used as a survey-based protocol for gathering expert-based knowledge on existing or scenario-based conflicts and synergies at a more local spatial scale, particularly relevant to apply in coastal zones that contain many different marine uses. Thirdly, the approach provides a catalogue for which marine uses that can coexist side by side or be combined into multi-use constellations. Besides the need for local and sector-specific expert-knowledge, the approach needs access to spatial GIS-data of marine human-based uses where the map-based application of the tool depends on the spatial resolution of the data.

Integrated ecosystem analysis in Irish waters; decision support tools for sustainable ecosystem-based management

Authors: Debbi Pedreschi, Paul Bouch, Meadhbh Moriarty, Antony M. Knights & David G. Reid

Presenter: **Dave Reid**

In order to deliver holistic ecosystem-based marine management and governance, managers and policy-makers must know the factors affecting ecosystems if they are to manage, monitor and legislate to protect them. Here, we present a risk assessment framework, based on the ODEMM (Options for Delivering Ecosystem-based Marine Management) approach for the Celtic Seas. The framework traces the multiple sectors affecting the marine environment, the numerous pressures they create, and the ecological characteristics affected by them. Scores are assigned via an expert panel and cross-check methodology which detail the extent, overlap, degree of impact, persistence and resilience for each pressure pathway, based on pre-determined thresholds. From this information, pressure matrices are created that can be used to calculate scores to indicate overall risk score and estimated recovery timelines. Multiple sources (e.g. literature, spatial maps, reports) and methods (e.g. integrated trend analysis) can be incorporated to allow the building of a data support tool. The process functions in several ways. Firstly, it identifies the most “at risk” ecological characteristics, the relative pressures creating the risk, and the relative risk contribution of each sector. This focuses mitigation measures/actions/policies on the most urgent ecosystem pressures/sectors. Secondly, the data support tool can provide confidence levels for the identified pathways, along with a ‘gaps analysis’ for directing future research. Ultimately, this information can then be then used to create easily interpretable and understandable tools for communicating complex messages in a simple format to non-scientists such as policy-makers and stakeholders.
Here we demonstrate the application of this process at two scales: all of Ireland’s marine waters (the Irish Exclusive Economic Zone (EEZ)); and the Irish Sea, which contains international boundaries and jurisdictions between Ireland and the UK. This analysis examines all sectors impacting on the marine environment in both regions, comparing and contrasting risk scores and recovery timelines to highlight areas for management/policy action. The framework has been further developed and traced through to link to the European Union’s Marine Strategy Framework Directive (MSFD) descriptors and criteria, enabling a risk assessment for Good Environmental Status (GES), and providing analysis of priority areas for action and research.
In light of the complex landscape of ecosystem-based management and the Marine Strategy Framework Directive, these tools have a real benefit in the simplicity of their understanding. Together, they can be used to enlighten stakeholders (e.g. through interactive apps) and enable policy-makers to make informed decisions, whilst remaining readily adaptable to a range of scales and scenarios.

Crossing the quantitative bridge to integrate local knowledge into fisheries management

Authors: Priscila Lopes, Leandro Castello

Presenter: **Priscila Lopes**

Fishing resources are being degraded at an alarming rate, whereas knowledge on such resources does not accumulate at the same pace, especially in developing countries. In such places, natural scientists and decision-makers struggle to generate and access affordable and reliable information to minimally manage fish stocks. In the last decades, one such type of knowledge, local ecological knowledge (LEK), has been collected by social and interdisciplinary scientists working closely with fishers. However, only recently have LEK studies made use of robust statistical tools, modeling, scenarios or other quantitative approaches

applied to data-poor situations. It is hoped that quantitative data will be better accepted by decision-makers and other scientists because they allow parallels with conventional data applied to fisheries management. Here we will present how LEK has been used to model species distribution (with examples from reef and rock species, such as Epinephelus marginatus) and to estimate reliable stock reconstruction through historical time series of catching data at a country level (specifically Brazil). This approach can be a safeguard to protect from successive government cuts in science funding and increased neglect towards natural resource management in Brazil and elsewhere.

The cost-effective solution of natural coastline conservation programme in Fujian Province, China

Authors: Yan Yang, Benrong Peng

Presenter: **Yan Yang**

The coastal margins, where shorelines reside, are centers of human activities due to its remarkable biological productivity and high accessibility. It host half of population, production and consumption activity, and the world's primary ports of commerce. Natural shorelines provide various services for human, such as purifying water, buffering floods, reducing erosion, storing carbon, and attracting wildlife to habitat. But human activities are diminishing the capacity of shorelines to provide these services by artificializing the shoreline. Conserving the natural shoreline are attracting the attention of coastal states. Conservation of nature shoreline means losing the development opportunities, especially in the coastal zones with high population density. Thus, there is an urgent need to develop a cost-effective solutions of natural shoreline conservation programme to balance the socioeconomic development and environmental protection.
This study will develop a model to estimate the optimal scheme of coastline protection. Cost-effective natural shoreline conservation is defined as minimum cost solutions to achieve the pre-specified conservation targets. The cost minimization problem can be described by the static nonlinear programming model. Two components are included in the established model: (1) costs functions of natural shoreline conservation. The costs of shoreline conservation is indicated by the cost of lost development opportunity; (2) scale constraints functions indicating the maximum scale of conservation in different regions. The established model will be applied in Fujian Province to develop the optimal natural shoreline conservation scheme in this region.
This study will demonstrate the rationality of the natural coastline retention in Fujian Province of China from an economic perspective. And the results of this study will provide a scientific basis for the formulation of natural coastline protection and compensation standards in Fujian Province.

Using information and communications technology to find and share community owned solutions to sustainability challenges

Authors: Julia Jung, Andrea Berardi

Presenter: **Julia Jung**

Natural resource management policies and governance coming from higher scale structures, such as international bodies and national governments are sometimes incompatible with the realities and needs of local communities in the Global South. Those structures are also often unable to adapt to the current rapid global change and respond to emerging needs. Yet, solutions and mechanisms to deal with those changes have recently been emerging at a local social-ecological scale. This is because challenges within a community can be better solved by identifying positive practices from within that community and trying to promote their use, as opposed to focusing on behaviours that are negative and trying to fix them with solutions that have emerged from outside of the community. This shows both the need, and the potential benefits of governance frameworks where local communities provide the initiative and direction of local conservation and management approaches, so that governments can provide the enabling conditions to mainstream local concerns into national policies. This is also reflected in strategies such as the Convention on Biological Diversity (CBD), which has clear recommendations for actions that include the respect and recognition of governance of natural resources by Indigenous peoples and traditional communities. In practice however, many scientists, policy-makers and professions, and their associated institutions, manifestly lack the skills and knowledge for operationalising such recommendations. The Cobra Collective has developed the concept of 'community owned solutions' and we train facilitators in supporting communities in using smartphones and tablets to record local solutions so that they can share these with other communities, professionals and policy-makers, so that these solutions can be promoted and supported, rather than undermined. The underlying framework we use to link and analyse the interests of various stakeholders at different scales is the system viability framework, which allows participants to characterize a range of strategies in response to environmental challenges to maintain the long-term survival of their particular system of interest. Within the system viability framework, we use participatory visual approaches such as participatory video and photography to enable local participants to analyze their own situation by defining indicators of successful strategies that are meaningful to them. Since 2011, we have raised in excesses of 2.5 million euros to successfully apply our approach to helping communities confront challenges using community owned solutions, including food security, biodiversity conservation, environmental crime, renewable energy, vector-borne diseases, and mental health. Our talk will showcase key concepts, techniques, impact and upcoming projects.

Sargassum Blooming in Mexican Caribbean: Nightmare or Opportunities for Socioeconomic Actors in the Context of Marine Governance

Authors: Julia Fraga, Daniel Robledo, Katia Frangoudes, Denis Bailly

Presenter: **Julia Fraga**

Harvesting sargassum influx on the Mexican Caribbean coasts is quite recent. In 2018 and 2015, Mexico was confronted to the arrival, accumulation and elimination of thousand of tons of marine brown seaweeds. Sargassum species (mainly S. fluitans and S. natans) stranded over 500 kilometers of beaches (more than 200 tons by kilometer). More than 12,000 people participated in the clean-up effort for a total cost of 302 million Mexican pesos and 610 million more for the mitigation (approximately one million US dollars).
Environmental management for this challenge move various socio-economic actors. Firstly, the Federal Maritime Terrestrial Zone agency (ZOFEMAT) and SEMARNAT (Environmental and Natural Resources Ministry) are legally in charge of this coastal crisis. Secondly, important economical actors are the tourism industry and small-scale fisheries that contribute respectively to 33% and 4% of the Gross National Product. This study identifies socio-economic impacts from the proliferation of Sargassum and contributed to understand the local experience to eliminate this pelagic brown macroalgue.
With an ethnographic methodology and proxy data-information from interviews and stakeholders workshops, we understood the problematic associated to Sargassum blooming in Mexican Caribbean region. Other sources like, bibliography, regional and national journals helped us to approximate the mobilization of different socioeconomic actors. An observation protocol in situ with photograms and a social analysis allow us to find stakeholders involved between Cancun and Riviera Maya beaches. With 45 structured surveys and 90 informal interviews were used to integrate the data and information to understand the social perception of the sargassum influx and socioeconomic impact.
The main results of this study reflected the need for more holistic research with a regional perspective on

ocean and society. In 2015, the federal government open a National Commission in order to attend the sargassum problem in the Mexican Caribbean involving 19 universities and 16 research institutes. We need to include all scales of government and private sectors that holds responsible and sustainable interests in the ocean and society relations. In the last four years (2015-2018), the Mexican government slowly implemented solution and mitigation plans but in the meantime the harvesting costs have increased tremendously.
Forum and panels to educate the public and private stakeholders should be a priority. The opportunity to develop industrial processes valorizing Sargassum is a good moment to engage with marine technology companies located in cities like in Brittany, France. Our results will contribute for a future Decision Support System (DSS). We need to take into account new paradigms for science, social Systems including policy makers for future prevention and mitigation of Sargassum in Mexico and the South Atlantic Ocean. The Ocean University Initiative at AMURE-UIEM-UBO in Brest, France should contribute and help to design a long term project for the wider Caribbean, one of the ten Large Marine Ecosystem in Latin America.

Regional Fisheries Management Organizations and the development of best practice

Authors: Bianca Haas, Marcus Haward, Jeffrey McGee, Aysha Fleming

Presenter: **Bianca Haas**

Regional Fisheries Management Organizations are key bodies responsible for managing fisheries on the high seas and in areas under national jurisdiction and are essential to achieve Sustainable Development Goal (SDG) 14, 'Life below water'. SDG Goal 14 addresses the sustainable use and conservation of the oceans and marine resources and is highly linked to other goals, such as poverty reduction (SDG 1) or zero hunger (SDG 2). While millions of people rely on oceans and marine resources for food, income and well-being, concerns over overfishing (fishing above sustainable levels) has, however, led to criticism of the performance of Regional Fisheries Management Organizations. Performance Reviews provide one possibility to assess and improve the functioning of the organizations, discuss and assess current management approaches, and increase awareness of important issues such as climate change. These assessments emphasise best practices among fisheries management organizations, foster cooperation among them, and have considerable potential to positively influence management processes. Performance assessments can be an important tool to improve not only the performance of the fisheries sector but can also play a relevant role in enhancing ocean governance in terms of the aspirations established by SDG14.

Improving the involvement of marginalised fishers in governance processes: Can structured decision-making tools be useful?

Authors: Louise C. Gammage, Astrid Jarre

Presenter: **Louise Gammage**

Small-scale fishers, and the communities they support face a range of challenges brought on by change in their social-ecological systems, which undermine their ability to achieve sustainability. Traditional handline fishers in South Africa's southern Cape region are no exception. Prevailing inequality and lack of access to fishery resources leads to risks at the levels of the person, household and community, and the

local marine ecosystem. There are also implications for decision-making at various scale from national to local. For fishers to apply risk aversion strategies at smaller scales of operation and for managers to apply the principles of an ecosystem approach to fisheries management (EAF) requires that the impact and interplay of multiple stressors at multiple scales be better understood and considered when making decisions.

Scenario planning is generally promoted to present an opportunity for diverse stakeholders to consider pathways for future responses to change while enhancing individual and local adaptive capacity. At the same time, the use of structured decision-making tools in similar contexts enables the integration of different knowledge streams while allowing for the up-scaling of such knowledge from the local to national through an interactive and iterative development process. Using the small-scale fishing community of Melkhoutfontein as a case study, this contribution explores how structured decision-making tools (specifically causal mapping, Bayesian belief networks and scenario planning) can be applied in an interactive and iterative scenario-based approach to change with disenfranchised fishers to promote the development of local level response strategies. This low- to middle-income community displays intermediate levels of adaptive capacity, which currently results in coping with the multiplicity of stressors related to long-term changes on land, in the sea and in the policy and regulatory environment in which they operate. In the causal mapping process, participants mapped out drivers of change, with the most important drivers organized into a hierarchy and probabilities which allowed for the construction of a Bayesian belief network. The causal diagram highlights feedback loops and hidden drivers of changes while the Bayesian belief networks provide important insights into system uncertainty. The outputs of both these tools were used in the construction of future scenario ‘stories’ which were then constructed by research participants in a series of workshops. The results showed that through the use of such decision-making tools, (1) the understanding of the local social-ecological system was enhanced by providing clarity on indirect drivers of changes, hidden feedback loops and uncertainty, (2) it was possible to include disenfranchised fishers who have little to no experience of such tools in such iterative approaches, albeit with a lot of guidance for the more technical aspects of the tool development, (3) the tools provided an excellent opportunity for the synthesis of different knowledge streams in a structured manner. We discuss how these tools can provide a means to addressing challenges regarding up-and down-scaling within the context of governance approaches and management decisions.

Being well-governed: Compliance inspectors and their role in the pursuit of well-being

Authors: Marieke Norton, Astrid Jarre

Presenter: **Marieke Norton**

South Africa, like many other countries, has committed to implementing an Ecosystems Approach to Fisheries (EAF), which promotes well-being in both the human social and ecological spheres, as well as good governance in order to support the goals of well-being. Significant progress has been made in researching, implementing and evaluating EAF in South Africa, particularly in the ecological dimensions, and from the perspective of extractive users of ecosystem services. However, the issues categorised under the labels “good governance” or “the ability to achieve” are largely spoken of in institutional or regulatory terms that do not acknowledge the centrality of people, other than resource users, to this process – such as the vitally important marine compliance inspector. Furthermore, this framework for description of problems does not acknowledge how these men and women work across different fishing and processing sectors, and makes the subsequent understanding of what the related governance problems are, difficult to scale either up or down.

Based on 18-months of ethnographic fieldwork in South Africa's Western Cape province, we argue that by understanding how central people, their relationships and their bodies are to successful marine resource law enforcement and governance, we can much more clearly see where both problems and opportunities

lie. To illustrate how this more qualitative framing can augment understanding in a natural science framework, we suggest ways in which compliance functions can be evaluated at the level of individual fisheries compliance offices or stations, in order to gain a more nuanced - and more accurate - understanding of the state of marine resource law enforcement. We show that these local-level assessments can be scaled up to speak to the state of enforcement in the province more broadly, without losing sight of the needs and value of the individual inspector. A set of objectives and linked indicators is suggested that may be used to identify and assess shortfalls in achieving good compliance. This approach is based on local experiences, but is in line with work being done internationally, where social scientists are contributing to a systems approach to management by investigating indicators of social-wellbeing in fishing communities. This paper contributes to that broader conversation, and aims to open up a new avenue of discussion: how to incorporate wellbeing and social indicators into the “ability to achieve” dimension in ways that take the overlap of the dimensions into account, while still being practical in terms of application and evaluation.

Aligning the sustainable development goals to the small-scale fisheries guidelines: a case for EU fisheries governance

Authors: Alicia Said, Ratana Chuenpagdee

Presenter: **Alicia Said**

Since the launch of the Sustainable Development Goals (SDGs) in 2015, several countries, funding organizations, environmental groups and research communities have pledged support and made commitment to help achieve these goals. SDG14: Life Below Water, for instance, has been embraced as the global goal for conservation and sustainable uses of the oceans, seas and marine resources. Despite being the largest sector utilizing the oceans and a significant contributor to food security, poverty alleviation and employment, small-scale fisheries are mentioned only in one target (14b), related to access to marine resources and markets. The under-rating of small-scale fisheries in the SDG14, as well as in the overall SDGs, points to a major disconnect between development policies that aim at particular sectors and the need for integrative and holistic approach for environmental sustainability. In the context of small-scale fisheries, efforts to rectify this would begin with aligning SDGs with the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries (SSF Guidelines), adopted in 2014 by member states of the Food and Agriculture Organization of the United Nations. Using European small-scale fisheries as illustrations, we argue that such an alignment can help facilitate the implementation of these global instruments in ways that not only optimize human and financial resources required but also result in concerted and sustained efforts for the sustainability of fisheries worldwide.

Tackling cumulative effects: A mountains-to-sea approach from Aotearoa New Zealand

Authors: Kate Davies, Karen Fisher, Gemma Couzens, Melissa Foley, Kath Blakemore, June Cahill, Linda Faulkner, Judi Hewitt, Mary Livingston, Carolyn Lundquist, Catherine Iorns Magallanes, Harry Mikaere

Presenter: **Kate Davies**

Human activities and natural stressors acting over a range of temporal and spatial scales can have cumulative effects on social-ecological system health and well-being. Around the world, the cumulative effects of stressors such as new and existing marine industries and climate change have contributed to a rapid decline in ocean and coastal resources; overwhelmed our ability to set appropriate marine resource targets and limits; and increased the risk of environmental, economic, or social collapse. Cumulative effects assessments aim to identify and manage the effects of human activities on coastal and marine ecosystems, but the current state of practice, science and policy frequently do not align. Meanwhile, the role of economics and investment in the management of cumulative effects is often overlooked. Location-specific issues associated with disjointed science, management and governance, diverse social values, competing interests and power struggles, and capacity all contribute to a daunting implementation puzzle. Institutional and behavioural changes that resolve some of this fragmentation are needed if we are to address cumulative effects in coastal and marine areas. This research used qualitative methodologies to bridge interagency fragmentation and develop collaborative ki uta ki tai (mountains-to-sea) approaches to cumulative effects in Aotearoa New Zealand. These efforts will help protect long-term ocean health; provide industries with the confidence to invest in sustainable resource use; establish a framework through which interest groups can have input in decision making; and facilitate the role of indigenous partners as kaitiaki (caretakers or guardians) and co-managers.

Community rights, conservation rezoning and the implications for sustainable marine governance

Authors: Ella-Kari Muhl

Presenter: **Ella-Kari Muhl**

MPAs can be a crucial strategy for sustainable marine governance, but only if they are designed with coastal communities in mind. Drawing on experiences in South Africa, the objective of my research is to investigate the different perceptions of stakeholders about the rezoning of a marine protected area and the resulting contestations over community rights and access, protection vs. use, and the implications for marine governance. In South Africa, MPAs created prior to 1994 (the end of the Apartheid era) disregarded local communities access rights to the coast for their livelihoods and removed access entirely, with no consultation, marginalizing local people.

The December 2016 re-zoning of the Tsitsikamma National Marine Park from a no-take to a partially open protected area, aims to re-address historical exclusion and provide equitable access and benefits to adjacent communities. However, the loss of custodianship over the ocean, poor consultation with the community and location of open access areas for angling has increased the tension between the regulating authority and the community. There has been a subsequent national outcry from the public, conservation non-governmental organization (NGO) representatives, fisheries scientists and marine biologists who view the re-zoning as a political choice, that does not consider marine conservation objectives.

To examine this situation and the implications for sustainable marine governance, my research draws on 56 semi-structured key informant interviews from the nine different communities adjacent to the Tsitsikamma

MPA, as well as scientists, NGO and government officials. A focus group with eight representatives from South African National Parks (the regulating authority) was also undertaken. Several key findings emerge from this research. First, a lack of consultation and feedback in regard to regulation changes leads to mistrust of other stakeholder groups and increased contestation. Second, different stakeholder groups can perceive the same situation in different ways, but there are shared perspectives about suitable consultation and contextually appropriate management inputs. Had those shared perspectives been incorporated as a baseline to decide what rules should be implemented, a regulation change that is perceived as acceptable across all stakeholder group would have been more likely. Third, using a bottom-up approach that combines inter-generational local ecological knowledge with expert knowledge from researchers is the foundation for a more legitimate set of access rules that the managing authority and communities can use to govern marine resources. As my research highlights, without a careful consideration of community needs and benefits in the context of marine governance, opposition and inequity will emerge and undermine opportunities for sustainable social and ecological outcomes.

Opportunities and challenges in applying human rights to implement socially responsible seafood

Authors: Lydia Teh, Richard Caddell, Edward H. Allison, Elena M. Finkbeiner, John N. Kittinger, Katrina Nakamura, Yohitaka Ota

Presenter: **Lydia Teh**

The sustainability movement in the seafood sector has grown significantly over the past twenty years but to date, seafood certifications have predominantly focused on promoting environmental sustainability while largely ignoring socio-economic considerations. Yet human rights violations such as slavery and human trafficking are widespread in fisheries around the world, and underscore the need for certification bodies and other seafood supply chain actors to improve social performance, in addition to addressing environmental challenges. Calls for socially responsible seafood have referenced human rights law and policy frameworks to shape the guiding principles of socially responsible seafood and to provide the legal mechanisms to implement these aspirations, but practical guidance on how to achieve this is lacking. To provide clarity on this challenge, we reviewed the literature concerning human rights in the seafood supply chain, and prepared an analysis of opportunities and challenges to implement socially responsible seafood through relevant human rights, legal and policy instruments. We observe that human rights laws are generally framed in favour of addressing violations of civil and political rights, but there remains considerable scope for applying economic, social and cultural (ESC) rights in this context. Other challenges include weakly defined ESC rights infringements, a lack of straightforward mechanisms to enforce human rights entitlements, and practical difficulties such as resources to support and secure rights. On the positive side, governments can draw on international instruments to inspire national policies and legislation to eliminate illegalities from the seafood supply chain. Non-binding soft laws are also an alternative avenue to promote objective that have not gained support through binding legislation. For socially responsible seafood principles to translate into tangible actions, these objectives must be rooted in clear legal obligations and be supported by sufficient national capacity and political will.

Investigating the governability of the FAD fisheries: Mediterranean and French-Caribbean Islands

Authors: Alicia Said, Olivier Guyader

Presenter: **Alicia Said**

Fishing rights and their governability are determined by the ecological, economic, social, and political context in which they are developed. Their implementation can exist in various forms, ranging from individualised ownership to communally-owned resources, known as the commons or common pool resources. These arrangements also exist in the fishing activity of moored fishing aggregated devices (MFADs), a fishing activity that is practiced across the world. In this case study, we adopt an interdisciplinary approach to assess the performance of MFADs, as property-rights regimes in two EU fishing settings, the French-Caribbean (La Désirade and Martinique), and Malta in the Mediterranean, through a governance and network analysis approach. Although situated in different geographic contexts, both communities form part of an island economy, and target dolphinfish with fishing aggregate devices (FADs), however the regulatory framework and the governance of the fishery in the two contexts is distinct. Whereas FADs in Malta are legally recognized and governed by the EU Mediterranean Regulation, in the French-Caribbean FADs territorialisation is defined by informal arrangements that are not recognized under any form of law. Given these distinctive situations, we seek to compare how the different kinds of incentives and marine tenure policies have developed to control access to the fishing grounds used for FADs. By understanding these elements within the historical, ecological, political and socio-cultural frameworks that determine human-environmental interactions and institutions, we seek to explore the challenges and opportunities of the institutional arrangements in the different contexts. In this regard, we focus on questions on issues pertaining to (i) equity, excludability and marginalization of territorialization; and 2) the significance of network and power relations which determine the governability of the fishery. Such diagnosis, which will indicate the problems fishing enterprises are trying to solve and what factors help or hinder their efforts, can provide a good foundation for a policy framework that recognizes legal rights and customary livelihoods. Moreover, it could create a political space for legal negotiations, in a way that engenders sustainable institutional governance of common property rights regimes n a way that ascertains the continued sustainability of the fishery, the fleet and the fishing community.

Fisheries management organizations and strategies at the regional and sub-regional levels in the South Pacific Ocean

Authors: Denis Brian Karcher, Elodie Fache, Annette Breckwoldt

Presenter: **Annette Breckwoldt**

While usually categorized as Small Island Developing States (SIDS), South Pacific Island countries are increasingly considering themselves as Large Ocean Island States (LOIS) and as custodians of major ocean areas containing marine resources of high commercial and environmental significance. However, these marine resources face many threats, including legal overfishing and so-called Illegal, Unregulated and Unreported fishing activities (IUU). The largeness of the region's marine spaces (both EEZs and 'Areas Beyond National Jurisdiction') adds up to the challenge of monitoring and governing these resources. Fisheries thus remain one of the most important concerns on the regional policy agenda.
The poster will present the main regional and sub-regional alliances having specific fisheries management mandates, as well as the strategies that they have developed in order to both protect and keep a hand on the South Pacific fisheries resources. In this framework, the tuna fishery appears as the main priority, as tuna species have an outstanding economic relevance in the region, but several species are now considered

overfished or at risk of extinction. Yet, the Pacific LOIS have also recently set common goals for more sustainable coastal fisheries management, for instance through a 'Regional Roadmap for Sustainable Fisheries' (focused on both tuna and coastal fisheries) and the 'New Song for Coastal Fisheries – Pathways to Change'.
This poster reflects endeavors to contribute to a better understanding of the South Pacific Ocean governance and sustainability challenges as part of the research project "A Sea of Connections: Contextualizing Fisheries in the South Pacific Region" (SOCPacific, IRD-ZMT, https://socpacific.net/).

SESSION 17: MODELLING SOCIAL-ECOLOGICAL SYSTEMS: METHODS AND TOOLS FOR SCENARIO DEVELOPMENT AND PREDICTION

Modelling social-ecological systems: methods and tools for scenario development and prediction

Authors: Olivier Thébaud, Jan-Jaap Poos, Jörn Schmidt, Ingrid Van Putten

Presenter: **Olivier Thébaud**

As part of the ecosystem approach to managing ocean uses, there has been a growing call for the development of integrated assessment methods and tools to support the exploration of scenarios for marine socio-ecological systems. Such methods and tools are increasingly being promoted as a useful means to support ocean policy and management decision-making. While many studies have focused on the exploration of possible futures, there is also growing recognition of the need to develop so-called normative scenarios, which consider objectives for the management of ocean uses, and possible pathways for these objectives to be met in the future.
In 2013, a workshop jointly organised by the ICES working group on Integrative, Physical-biological and Ecosystem Modelling (WGIPEM) and researchers attending the "Mathematics of Bio-economics" initiative , a contribution to the international event "Mathematics of Planet Earth 2013", brought together experts to discuss recent advances in this field of research. The workshop identified a number of key domains thought to be crucial to progress both the development of these modelling approaches and their application to actual management decision problems. Key challenges included:

1. Process understanding of marine ecosystem uses (including but not limited to commercial fisheries), how this can be modelled, and coupled to biophysical models in order to gain better understanding of the potential responses to alternative economic, environmental or management scenarios;
2. Accounting for the multiple (economic, ecological and social) objectives as well as the distributional impacts of scenarios in time, space and across stakeholder groups;
3. Addressing the trade-offs associated with increasing the complexity of models that couple representations of ecological, economic and social processes, each of which may be affected by uncertainty;
4. Seeking commonalities between the many different modelling approaches being developed at multiple scales, in order to strengthen the integration of economic and ecological models in the longer term;
5. Avoiding errors of the third kind and building trust in models built for decision support.

The workshop also identified a number of key areas in which further efforts at developing formal models of processes at play would appear to be of strategic importance, including: (i) market dynamics at various scales, and how these drive the prices which influence resource harvesting and investment decisions at local levels; (ii) other individual resource harvesting behaviour, including the insights which may be gained from the application of game theory and other conceptual frameworks addressing strategic interactions; (iii) governance and management decision processes themselves.

As an introduction to the theme session, this presentation will aim to review progress made in addressing these challenges, and assess the areas in which further research is warranted.

Modelling Chance and necessity in natural systems

Authors: Benjamin Planque, Christian Mullon

Presenter: **Benjamin Planque**

Three decades ago, the emergence of deterministic chaos and related studies about the irreducible complexity of natural systems constituted a paradigm shift. In ecology, this provided a potential to resolve a situation of mutual misunderstanding between scientists and non-scientists about uncertainties and predictability in natural systems. In fisheries management, however, there is still today a divorce between the understanding of the fisheries system by non-scientists actors and the numerical modelling principles and terminology used by scientists. We propose that this issue can be addressed in an original way which involves modelling developments based on the principles of chance and necessity (CaN). We show where CaN modelling fits in the history of model developments for fisheries management and how it can support Ecosystem Based Fisheries Management. We outline the conceptual and mathematical principles of CaN models and present an application of the model to the Barents Sea. Because CaN models rely on concepts easily grasped by all actors, because they are explicit about knowns and unknowns and because the interpretation of their results is simple enough, they can be used in a context of participative modelling and management. We propose that CaN can be a practical step to reconcile scientists and non-scientists around the modelling of structurally and dynamically complex natural systems.

Walking backwards into the future

Authors: E.A. Fulton, Fabio Boschetti, Ingrid van Putten, Tony Smith, Rodrigo Estevez, Francisco Bravo, Stefan Gelcich, Nicky Grigg, David Finnigan

Presenter: **Beth Fulton**

The fallacies of human cognition mean we often assume everyone sees the world the way we do. Frustration grows from the assumption that someone knows what we know and thus it is inconceivable that they cannot have reached the same conclusions. Combining different modes of thinking – across cultures, personality types, domains – can help break away from the strictures imposed by the brain's assumption that tomorrow is more of today or so widely different it will be overwhelming to even contemplate it. Drawing on examples from around the world the paper will describe how crossing boundaries, for example marrying models and foresighting, can strengthen the outcomes of both and lay the foundation for discussions about the future, how we shape what that looks like and how we get there.

An empirical analysis of different ways to think about Ocean Futures

Authors: Fabio Boschetti, Cathy Bulman, Alistair Hobday, Ingrid van Putten, Joanna Strzelecki, Lucy Robinson, Hector Lozano-Montes, Stephanie Contardo, Tony Smith

Presenter: **Fabio Boschetti**

A diverse literature describes the approaches humans use to imagine the future. This range from psychological processes at one extreme, influenced by values and attitudes which determine the future we desire or fear, to complex computer models at the other extreme, which explicitly represent the causal drivers of system behaviours. As diverse as this literature may appear, fundamentally it describes models (conceptual or computational), as they are used to make sense of reality as it worked in the past, as it works now and as it is likely to work in the future. What differs are the building blocks of the models (emotions vs stories vs statistical relations vs physical laws) and the logical rigour we impose in assessing their likely impact (emotionally-cognitive assessments vs numerical accuracy).

An important empirical question is the extent to which these alternative ways to think about the future align. Do they suggest similar futures? Can the futures they suggest be compared at all? What we know about the psychological and cognitive tools humans use to think about the future tell us that a positive answer to these questions should not to be taken for granted.

From the available literature, we collate and compare futures as produced via four alternative approaches:

- Numerical projections, understood as numerical estimates of the likely or possible future behaviour of one or more indicators of the performance of different economic sectors which impact the oceans (fishery, tourism, mineral exploration, transport, etc). These projections may be the outcome of trend analysis or explicit numerical modelling.
- Scenarios, understood as ‘plausible, challenging, and relevant stories about how the future might unfold’. One of the most important insights from the scenario literature is the observation that scenarios developed in a wide range of foresight exercises tend to share common themes. Here we selected the four scenarios from the “The Century Ahead: Searching for Sustainability” which imagine futures as driven by markets, institutional reforms, social and moral transformation and ecological and social decline.
- Numerical models, the assumptions underlying the scenarios mentioned above were also simulated numerically via the PoleStar model. This generated numerical predictions for a large number of social, economic and environmental indicators, which the authors then analyse in terms of social and environmental sustainability.
- Overall societal aspirations, as captured by the vision of the Blue economy, which aims to provide “marine-based economic development that leads to improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities”.

By analysing the extent to which the futures as imagined by these approaches align and, when they do not, why it is so, we seek to provide a framing for future thinking as applicable to Australia’s oceans which can assist long-term policy and planning integrated across sectors.

Foresighting to guide scientific investment and preparation for a disrupted future

Authors: Alistair Hobday, Fabio Boschetti, Chris Moeseneder, Cindy Bessey, Cathy Bulman, Stephanie Contardo, Christopher Cvitanovic, Jeffery Dambacher, Leo Dutra, Beth Fulton, Dale Kolody, Andrew Lenton, L. Richard Little, Bruce Mapstone, Karlie McDonald, John Par

Presenter: **Alistair Hobday**

Most scientists produce research that they hope will have long-lasting impact and continue to be useful for many years. We make a wide range of models which are used to predict system behaviours, but often ignore the skill development of scientists themselves. In a fast changing world, scientists must anticipate research requirements, and hence plan for the infrastructure, skills, and policy engagement that will be needed. Foresighting draws on approaches used in long-range and strategic planning, horizontal policymaking and democratic planning, and participatory futures studies. Foresight is concerned with futures that are usually at least 5-10 years away and is action-oriented. Foresighting exercises may lead to development of multiple scenarios, and a set of corresponding scientific responses. Our CSIRO team uses foresighting to prepare for the future across a range of marine-relevant domains. In our structured foresight process, we also develop indicators for each foresight and assess the time-specific probability of each scenario being realised. Our foresight process is repeatable, measurable, and reveals differences between how scientists rate the future. Differences between scientists can reveal when their indicator information-content is particularly noteworthy, and avoids the problem of group-think, or averaging. This approach has also crystallised the responses that scientists and their institutions can make in response to different anticipated futures.

Building scenarios for marine social-ecological systems

Authors: Benjamin Planque, Christian Mullon

Presenter: **Benjamin Planque**

Anticipating future changes in marine social-ecological systems (MSES) several decades into the future is essential in the context of accelerating global change. This is challenging in situations where actors do not share common understandings, practices, or visions about the future. We introduce a dedicated scenario method for the development of MSES scenarios in a participatory context. The objective is to allow different actors to jointly develop scenarios which contain their multiple visions of the future. The method starts from four perspectives: ‘fisheries management’, ‘ecosystem’, ‘ocean climate’ and ‘global context and governance’ for which current status and recent trends are summarized. Contrasted scenarios about possible futures are elaborated for each of the four single perspectives before being integrated into multiple-perspective scenarios. Selected scenarios are then developed into storylines. Focusing on individual perspectives until near the end allows actors with diverse cultures, interests and horizons to confront their own notions of the future. We illustrate the method with the exploration of the futures of the Barents Sea MSES by 2050. We emphasize the following lessons learned: First, many actors are not familiar with scenario building and attention must be paid to explaining the purpose, methodology and benefits of scenarios exercises. Second, although the Barents Sea MSES is relatively well understood, uncertainties about its future are significant. Third, it is important to focus on unlikely events. Fourth, all perspectives should be treated equally. Fifth, as MSES are continuously changing, we can only be prepared to future changes if we collectively keep preparing.

The future of High Seas governance under climate change

Authors: Colette C.C. Wabnitz, Vicky W.Y. Lam, Essam Mohammed, William W.L. Cheung

Presenter: **Colette Wabnitz**

Marine biodiversity and ecosystems in area beyond national jurisdiction (ABNJ) provide substantial benefits to human societies through fisheries. However, such benefits accrue mostly to a few developed countries, and climate change may further exacerbate such inequalities. Improving high seas fisheries governance therefore could help improve the sharing of high seas fisheries resources among countries and reduce their climate risks as well as help support long-term ecological, economic, and social sustainability objectives. Specifically, it is hypothesized that improving fisheries governance in ABNJ could help developing countries – who are also amongst the most vulnerable to climate change – maximize benefits from their own fisheries, on which people strongly depend for their food security and wellbeing. However, the development of such policies is challenged by the uncertainties associated with global environmental and socioeconomic changes, the legislative mechanisms underlying such change and the complex interplay across sectors. By investigating possible 'alternate worlds' and the decisions leading to representative outcomes, scenario analysis addresses this uncertainty and helps decision-makers explore and prepare for the consequences of contrasting political, economic, sociological, technological, legal and environmental choices. The Shared Socio Economic Pathways (SSPs) provide a standardized, internationally recognized, framework that allows for the exploration of how global society, demographics and economics might evolve in the absence of climate policy over the next century. These were applied here, to develop – jointly with a group of interdisciplinary experts – three contrasting storylines of future high seas governance and evaluate the benefits and trade-offs to developing countries' fisheries of such different frameworks. Fisheries management specific indicators were then used to quantitatively represent ecological, economic, and social considerations under each scenario narrative and applied to state of the art integrated simulation models to determine future projections for fish stocks and fisheries on the high seas. Models were also run under two climate change scenarios ('business-as-usual' Representative Concentration Pathway or RCP 8.5 and 'strong mitigation' RCP 2.6) to examine how these governance scenarios may perform under climate change. Results illustrate that political, economic, social, technological, legal and environmental choices associated with each scenario play a substantial role in the projected futures of high-seas fisheries. The findings highlight the importance of integrating climate change and SSPs to further our understanding of potential future outcomes, and its role in meaningfully informing the development of an effective and equitable instrument as part of the current negotiations under the United Nations Convention on the Law of Sea on the conservation and sustainable use of marine biological diversity of ABNJ.

Material Flow Analysis as a Circular economy tool to address the future stakes of fishery dependent costal socio-ecological systems

Authors: le Gouvello, P. Le Floc'h, J. Aubin, and J.B. Bahers

Presenter: **Raphaela le Gouvello**

Circular Economy (CE) has been emerging for the past decade as an economic alternate model, in opposition to the linear economy, in the public debate. It is now proposed as a potential new approach for a sustainable blue bioeconomy in Europe, although the concept is still uncertain in its real definition and scope. Seen as an "umbrella" concept, yet, CE is related to scientific fields such as sciences of sustainability, industrial ecology and ecological economics. After reviewing CE main principles and choosing one CE definition, a first attempt is made to challenge the CE concept to a marine fishery-dependent socio-ecological system (SES) in Brittany, in France. Material flow analysis (MFA), an analytical tool derived from

CE fields, is adapted to the understanding of the flows of the marine fishery marine bioresource into the studied SES. This approach requires the definition of a spatial dimension of an original system which includes a marine side as well as a continental counterpart. MFA derived indicators (e.g. fishery resource productivity and intensity) are coupled to more conventional indicators to represent the system functioning, in all its dimensions, resource, actors, fishery related economics and governance subsystems. A focus is made on one particular activity, the sardine fishery, to further describe the present situation and explore future scenarios for potential future development trajectories, ranging between a "business as usual" scenario, and circular strategic development scenarios. The discussion highlights the stakes, conditions, pitfalls, limits, constraints and potential new visions that such approach could provide to the understanding of fishery-dependent SES stakes. In particular, the critical questions of the scale, the borders and the governance system in such CE approach applied to a fishery dependant coastal SES, are raised.

Beyond adaptive management: modelling regional futures at decadal scale

Authors: Fabio Boschetti, Hector Lozano-Montes, Brad Stelfox, Robert Holmes

Presenter: **Fabio Boschetti**

We address the question of how to provide meaningful scientific information to support environmental decision making at the regional scale and at the temporal scale of several decades. Our application is the management of a network of marine parks in the Kimberley region of Western Australia, where the key challenges to environmental sustainability are slow-dynamics climate change processes and one-off investments in large infrastructure, which can affect the future of a region for decades to come. In this situation, strategic, rather than reactive planning is necessary and thus standard adaptive management approaches may not be effective. Prediction becomes more urgent than adaptation, in terms of assessing the long term consequence of specific economic and conservation decisions. Working at the interface between future studies, socio-economic modelling and environmental modelling, we define 18 scenarios of economic development and climate change impacts and 5 management strategies aimed at ensuring the sustainability of the marine environment. We explore these potential future trajectories using coupled models of terrestrial land use and marine ecosystem dynamics. The Alces model simulates the dynamics of bio-physical and socio-economic processes on land and the pressures these impose on the coastal and marine environment. This forces an Ecopath with Ecosim (EwE) model used to simulate marine processes, foodweb dynamics and human activities in the marine environment. We obtain a projection of the Kimberley marine system to the year 2050, conditional on the chosen scenarios and management strategies. Our results suggest that climate change, not economic development, is the largest factor affecting the future of marine ecosystems in the Kimberley region.

The standard conservation management method of adaptive management is not suitable for this management task, for three reasons. First, economic development in the Kimberley will depend largely on one-off decisions regarding investment in large infrastructure (roads, ports, mining sites and off-shore rigs). Once built, this infrastructure remains in place for decades and is amenable to only minor modifications. Similarly, the establishment of MPAs depends on political processes and one-off favourable circumstances largely disconnected from the normal functioning of adaptive management cycles. Finally, climate change is likely to unfold on a time scale too slow to provide appropriate feedbacks for adaptive management.

As an alternative to adaptive management, we borrow from the Future Studies and Foresight literature. First, we involved the project’s stakeholders in defining the stressors and sources of uncertainty which are perceived to have the largest impact on the future of the region. Next, we asked stakeholders to define a set of available management strategies able to achieve the stated aspiration of ensuring environmental sustainability, economic growth and resilience to climate change. Finally, we use computer modelling to explore the dynamics of biophysical and socioeconomic processes under a series of environmental scenarios and management strategies. The outputs of our models represent the projection of the Kimberley marine system to the year 2050 conditional on the chosen scenarios and management strategies.

Tools for credible decision making; an analysis of successful tool application in ecosystem based management.

Authors: Mark Dickey-Collas, Anna Rindorf, Anna Kristín Daníelsdótir, Ellen Johannesen, Gavin Fay, Howard Townsend, Paul Snelgrove, M. Robin Anderson, Robert L. Stephenson

Presenter: **Mark Dickey-Collas**

A host of tools and models exist to support trade-off analysis in Ecosystem Based Management (EBM). The Atlantic Ocean Research Alliance (AORA) created a task group comprised of experts in tool/model development and application from Canada, the USA, and the EU to improve our understanding of the process leading to successful development and uptake of tools in the EBM process. Criteria were identified to analyse the elements of trade-off analysis tools used in 'successful' applications of EBM. A successful application of a tool would cover some elements of identification, evaluation, and presentation of trade-offs; evidence of the use of the tool in decision-making; and validation of the trade-offs as part of an iterative and adaptive process. This approach of analysis was termed the Marine Ecosystem Based Management System for Trade-off Analysis and Reconciliation (EBM-STAR). Case studies of EBM tools in operation were assessed using EBM-STAR. The constituents of best practice for tool development were also highlighted.
The tool and models considered included conceptual modelling, static spatial planning and evaluation tools, models of intermediate complexity, strategic simulation models, Bayesian belief networks and dynamic spatial models. These were considered as tools within the following frameworks- risk assessment, management strategy evaluation, multi-criteria decision making, ecosystem services framework and strategic environmental assessment. One of the key challenges for the use of tools for EBM is improving the ease of use and uptake of tools in management and better incorporation of socio-economic considerations, especially valuation measures. Many resources have been invested in developing tools for EBM across the jurisdictions of the North Atlantic. However, few tools have been used operationally and even fewer are having their performance validated. Tools need to be applied appropriately. They provide important insight into trade-offs in decision-making and improving transparency of management decisions.

Bayesian models in interdisciplinary policy analysis

Authors: Sakari Kuikka

Presenter: **Sakari Kuikka**

In addition to the fact that Bayesian inference offers a well justified way to assess uncertainties in policy advice, the conditional probabilities of Bayesian networks offer a way to integrate knowledge from several disciplines. One can respect the traditions of various disciplinaries, as long as scientists are willing and capable to provide probabilistic information. This can also be based on expert elicitation, if simulation models or large data sets do not exist.
In this paper, I review the interdisciplinary experiences of my research group, in providing probabilistic interdisciplinary advice, both in fisheries and in oil spill risk analysis. In oil spill analysis, the aim has been to estimate in advance, how big the ecosystem damages can be, given the variance over the year and over the space in the Gulf of Finland.
We find the Bayesian network models to be flexible tools, and they support the traditions of many scientific disciplines. For example, the social scientists are used to apply graphical descriptions of their research problems, which comes close to the critical step in Bayesian networks, i.e. the definition of the model structure. Moreover, social scientists have often large data sets that can be readily used in data-analysis features of Bayesian networks (see for example Weka software).

For some reason, it seems that Bayesian inference is missing from the courses of many economist education programs. The traditions of econometrics may include also Bayesian calculus, but the Markov Chain Monte Carlo – type of parameter estimation for economic causal models is still rare in economic models. In ecology, they have become common. Moreover, in many fields of engineering, Bayesian models are common, which helps to apply many types of engineering knowledge to applied management questions.

Dioxins in Baltic herring and salmon: an inter-sectoral decision analysis for optimal management of the problem

Authors: Annukka Lehikoinen, Päivi Haapasaari

Presenter: **Annukka Lehikoinen**

Ecosystem-based management (EBM) of natural resources requires recognition of the systemic intertwining of ecosystems and human society and an inter-sectoral approach. With a multi-disciplinary research team we constructed a Bayesian influence diagram (BID) to integrate social and ecological knowledge for evaluating alternative sectoral and inter-sectoral strategies to manage the dioxin problem of Baltic salmon and herring fisheries. Dioxin pollution to the Baltic Sea has been decreasing since 1970's, but high levels are still found from marine biota and sediment. Two commercially and culturally remarkable fish species, Baltic herring (Clupea harengus membras) and salmon (Salmo salar), provide a natural source of omega-3 fatty acids and vitamin D to the human population of the area. Unfortunately, due to their high fat content, the species also accumulate high levels of fat-soluble dioxins from their environment and food. Herring and salmon have a predator-prey relationship, creating a dependency between the dioxin concentrations of these two species. Owing to the dioxins, the markets within the EU are partly restricted and the value of the catches low. The BID consists of two interlinked key elements: 1) ecosystem part, covering the dioxin concentrations in herring and salmon acknowledging their prey-predator linkage, and 2) social part, covering the fish consumption of different groups in Finland, Sweden, Denmark and Estonia and the consequent health effects. Independent and joint impacts of nine management decisions affecting different parts of the social-ecological system were modeled in the light of three alternative criteria: 1) the dioxin concentrations of Baltic herring and salmon, 2) the human consumption of Baltic salmon and herring, and the associated health risks and benefits, and 3) the commercial value of herring and salmon catches. Through this analysis we learned that optimal management solution depends on the order in which the decisions are made, thus unsynchronized actions taken in different sectors may decrease each other's effectiveness. The optimal decisions were also dependent on the sectoral assessment criteria used, as well as the consumer group in focus, the elderly men getting remarkable health benefits from increased fish eating, the women in fertile age being the key risk group. Informing consumer groups in targeted manner would lead to best overall effectiveness in the health risk management. The results demonstrate the requirement to understand the effects of management measures in a holistic way: managing the whole human population as one entity or only one fish species or policy domain at a time, may not be effective, and may even have unanticipated systemic effects. This suggests that communication and collaboration between the public health, environmental and fisheries sectors is needed.

Using ecoviability to provide an integrated TAC advice for the management of mixed fisheries

Authors: Florence Briton, Claire Macher, Christelle Legrand, Mathieu Merzeréaud, Olivier Thébaud

Presenter: **Florence Briton**

Ecosystem-based approaches are increasingly being adopted for the management of natural resources, and fisheries make no exception with the proposal of ecosystem-based fisheries management (EBFM) guidelines in the early 2000's.
Among other aspirations, the EBFM aims at accounting for the technical interactions among jointly caught species in mixed fisheries. Joint productions in mixed fisheries constrain the ability of fishing operators to fully use the quotas they have been allocated for different species. In a management scheme where individual quotas are not transferable, if harvesters stop fishing once they have reached their most limiting quota, any quota they have left for the other species is lost. In this situation, unfished quotas may create an incentive for harvesters to continue fishing in order to fully use their fishing opportunities on valuable species while discarding or illegally selling the catches of their "choke species", i.e. the species for which they do not have quota. In addition to putting the concerned stocks under higher pressure than recommended, discards of those "choke species" can compromise the reliability of the stock assessments as it is more difficult to evaluate the quantity of fish that is actually removed from the stock. It is therefore particularly relevant to anticipate any quota under-consumption which may result from joint productions since minimizing them is likely to facilitate compliance with the quota regulation.
The move towards EBFM also calls for the formulation of multi-dimensional objectives that account for the preservation of fish resources as well as the services they provide to society. The viability theory is particularly well-suited to account for the variety of sustainability requirements a socio-ecosystem can face and has been increasingly applied to the evaluation of renewable resource management trade-offs. Often referred to as co-viability or eco-viability when multiple constraints (e.g. biological, economic, social) are to be met simultaneously, the viability approach consists in identifying viable paths where the system's evolutions remain within predefined acceptability boundaries.
The objective of the approach presented is to develop a framework for management advice integrating multiple objectives for mixed fisheries under TAC management. The bio-economic model IAM (Impact Assessment Model for fisheries management) is used to identify eco-viable management strategies for the Bay of Biscay demersal mixed fishery.

Exploring trade-offs in mixed fisheries by integrating fleet dynamics into multispecies size-spectrum models

Authors: Camilla Novaglio, Julia Blanchard, Michael Plank, Ingrid E. van Putten, Elizabeth A. Fulton

Presenter: **Camilla Novaglio**

Understanding the complex interplay between human-induced changes on natural systems and their feedbacks on societies is a crucial step towards integrated ecosystem assessment and management. Such steps are fundamental in advancing management systems that take into account both conservation and societal objectives. A range of modelling approaches is being used to encompass multiple aspects of socioecological systems, to assist in explicit analysis of trade-offs and to identify realistic targets. Many of these models have been developed within a “big-picture” framing, to look at strategic (long-term) rather than tactical (short-term) decision making. Nevertheless, tactical models are becoming a pressing need as they are central to the short term (1-2 year) management decision cycle. Models of intermediate complexity, or minimum realistic models provide a medium for addressing these finer temporal "forecast" scales. Multispecies size-spectrum ecosystem models are an example of such models and could play a particularly useful role as both forecast and strategic support tools. While the ecological component of these models has been developed over decades, the human component has been added only recently and is typically limited to specifications of fishing mortality. Current efforts to improve representation of the human dimension in multispecies size-spectrum models involve integration of fleet dynamics modules. Here we present an example of such an exercise. We detail the ecological and the fleet dynamic components of a multispecies size-spectrum model representing the South East Australia marine ecosystem. We discuss its application to assist in analysis of trade-offs under alternative management frameworks for multispecies and multi-fleet fisheries. This work demonstrates that coupled socio-ecological multispecies size-spectrum models are a feasible toolset for identifying realistic fisheries and conservation targets. Such models will beneficially expand the tools available to resource managers charged with overseeing the status of ocean resources, who must juggle the interplay of complex ecological and human dynamics in their day-to-day regulatory activities.

Using integrated scenarios and models to explore trade-offs in future seafood sustainability under global change

Authors: William W. L. Cheung, Oai Li Chen, Andres M. Cisneros-Montemayor, Vicky W. Y. Lam, Muhammed Oyinlola, Gabriel Reygondeau, Jorge Sarmiento, Charles Stock, Louise Teh, Lydia Teh, Colette Wabnitz

Presenter: **TBD**

Global seafood production from fisheries and aquaculture contributes substantially to the food security, health, economic benefits and livelihood opportunities of our society. Sustainable seafood production is constrained by biophysical, economic and social factors through ocean primary productivity, trophic dynamics, the economics of fishing, market access and dynamics, as well as local and global ocean governance. Simultaneously, human activities and their consequences such as fishing, carbon emission, pollution and habitat destruction are driving ecological and social-economic changes. However, global studies seldom integrate these multiple human and natural drivers and their interactions into a holistic framework to understand the implications of climate change for future seafood sustainability. In this study, we developed a marine integrated assessment model (IAM) that incorporated changes in ocean conditions, fish stocks, fisheries, mariculture and seafood markets at the global scale. Applying the IAM to globally-traded seafood products that account for majority of fisheries catches, we projected substantial impacts of climate change on the conservation status, economic benefits and provision of food and livelihood from these fisheries regionally and world-wide. Fishing and other social-economic scenarios play a significant role in the projected sustainability of these seafood. Trade-offs associated with management interventions for climate adaptation in fisheries vary substantially between regions, with economic trade-offs being most severe in developing regions. The findings highlight the importance of climate change and the potential opportunities and challenges for adaptation in global seafood sustainability.

Scenarios for the future ocean: A FishMIP approach

Authors: Tyler Eddy, Olivier Maury

Presenter: **Tyler Eddy**

The fisheries and marine ecosystems model intercomparison project (FishMIP) aims to partition variability in climate change projections of fish and fisheries according to choice of Earth-system model (ESM), emissions scenario (RCP), fish model, as well socio-economic scenario (SSP). Until this point, FishMIP has used simplistic future fishing scenarios of no-fishing and status quo fishing (holding all fishing constant at 2005 levels) in order to isolate fishing effects from climate effects. Moving forward, FishMIP has recognized the need to include more complex future fishing scenarios, and has created the FishMIP scenarios working group to address this complex challenge. We have developed a methodological approach to include experts from socio-economic, bio-physical, policy, and legal backgrounds, as well as solicit input from stakeholders. Our aim is to develop scenarios that are as simple and few as possible, while being consistent with existing IPCC efforts (SSPs/OSPs), aligned with future IPBES scenario endeavors (Nature's futures), and as relevant as possible for policy-orientated agencies such as FAO and other relevant global (UNEP, UNDP, CBD), regional (RFBs, RFMOs) and national (fishing agencies) bodies. To achieve this goal, we plan to extend the existing contextual SSP/OSP storylines and the development of target-seeking normative pathways (e.g. political roadmaps toward sustainability), at multiple spatial scales (global, regional, local) and multiple temporal scales (mid-term decadal; 2030-2050 and long-term centennial; 2100). Our paper will present details on our methodological approach to developing quantitative and spatially resolved future fishing scenarios that can be used as input by data heavy fisheries and marine ecosystem models.

There is carbon on the shelf! Quantifying and valuing coastal and shelf sea carbon for policy making and management purposes

Authors: Silke Kroeger, Tiziana Luisetti, R. Kerry Turner, Julian E. Andrews, Timothy D. Jickells, Silke Kröger, Markus Diesing, Lucille Paltriguera, Martin T. Johnson, Eleanor R. Parker, Dorothee CE Bakker, and Keith Weston

Presenter: **Silke Kroeger**

The reduction of carbon dioxide emissions to the atmosphere has gained prominence as part of efforts to combat climate change and it is recognised that the marine system plays a significant role in the global carbon cycle. Understanding stocks and flows of carbon within and between the different compartments of the marine system has become an important study area. When quantifying stocks in different marine compartments, it has become apparent that not only "Blue Carbon" habitats such as saltmarshes and seagrass meadows are of importance in this context, but also wider shelf sea sediments. While it is widely accepted that terrestrial and vegetated coastal habitats are under threat from human activities and need careful protection, less thought has been given to carbon stored within sediments. But, how much carbon is actually stored in shelf-sea sediments? What controls this? To what extent is it vulnerable to manageable human activities? And what is the economic value of avoiding carbon dioxide emissions when conserving coastal and marine ecosystems?
We show how seabed carbon stocks could be quantified (through observational and modelling techniques) and valued through a scenario analysis on three different levels of management intervention: a business as usual scenario in which economic activities have an impact on coastal vegetated ecosystems; a scenario in which both economic development and climate change affecting coastal and marine ecosystems, including shelf-sea sediments, ultimately can inflict damages to society at the global scale; and a scenario of

saltmarsh restoration as a 'natural climate solution'.
While it may be possible to manage socio-economic pressure to maintain sedimentary carbon storage, trade-offs with other ecosystem benefits (e.g. fish as food security) must be taken into account when making management decisions. Interestingly, from an economic point of view, conserving rather that restoring might be a better management option. We therefore argue that both coastal and marine carbon need to be appropriately quantified and robust evidence is needed to inform policy to develop effective management measures on marine and coastal natural resources, and effective incentive mechanisms for their preservation within a sustainability governance framework.

A global fisheries model with dynamic regulation: implications for future marine catches

Authors: Kim Scherrer, Eric Galbraith

Presenter: **Kim Scherrer**

The world's marine capture fisheries appear to be operating close to, or beyond their maximum sustainable limits, and the future sustained provision of wild capture fish now relies on protecting and rebuilding over-exploited fish stocks through efficient regulation. Despite this, there have been limited attempts to better understand the dynamics of regulation by modeling spatially resolved fisheries regulation on the global scale. Based on theories of collective action and resource management, we identify elements of regulation that are universal across fisheries. In general, regulation opposes suboptimal individual welfare-seeking behavior through coordinated social action that consists of two main elements: 1) identification of an effort target for fishing, and 2) adjustment of effort towards the target with some degree of effectiveness. We include these universal elements in a bio-energetically constrained model of global fisheries, allowing us to evaluate how regulation interacts with other large-scale drivers of change to determine the prospects for future catches. We find that under continued development of fisheries technology, partially effective regulations extend the time during which benefits (fish and profit) can be obtained from the marine ecosystem, but are insufficient for achieving long-term ecological sustainability. For the future viability of fisheries, technological development must be matched by increasingly effective regulation, besides being offset in the target setting process. Under perfectly effective regulation, simulated harvests are projected to increase until the end of the century, suggesting that a well-regulated global fishery is likely to yield more fish than the maximum global harvest under open access.

Optimizing space-time use by fishermen to reduce depredation risk by sperm whales in the Patagonian toothfish longline fisheries

Authors: Lavinia Suberg, Ching Villanueva, Christophe Guinet, Paul Tixier, Nicolas Gasco

Presenter: **Ching Villanueva**

Marine depredation denotes the removal of catch from fishing gear by (mostly) top predator species. The demersal longline fisheries for Patagonian toothfish within the French Exclusive Economic Zones (EEZs) of the Kerguelen Islands is subject to heavy depredation by sperm whales, which has adverse economic and ecological consequences. In addition to technical mitigation measures (e.g. acoustic deterrence), adjusting the space-time use by fishermen in order to decrease the interaction risks with depredating mammals, could provide a straightforward solution to reduce depredation. Spatio-temporal distribution patterns of

sperm whales in the Kerguelen EEZ from 11 years (2008-20017) of standardized observer data were analysed to investigate the overlap with fishing effort and productive fishing and feeding grounds. The results suggest that fishing effort and whale abundance does not always co-occur. In a next step, a Bayesian Belief Network for the EEZ is being developed to provide optimal space use scenarios throughout the year while taking into account current conservation measure for the ecosystem (e.g. MPAs, seabird bycatch risk areas) and minimize economic loss (e.g. additional fuel costs, lower catch yield) at the same time.

Shared Socioeconomic Pathways (SSPs) for fisheries and aquaculture in Europe

Authors: Katell Hamon, John K. Pinnegar, Cornelia M. Kreiss, Eleni Papathanasopoulou, Sandra Rybicki, Myron Peck

Presenter: **Katell Hamon**

Climate change is anticipated to have long-term and widespread consequences for the fisheries and aquaculture sectors of Europe, however global prices and human factors such as the intensity of fishing, the construction of offshore windfarms, the spatial management of marine and inland waters can also affect how these industries develop. For modelling efforts to be successful it is necessary to consider how such factors might change in the future and their interaction with climate variables. In this study, four socio-political scenarios were developed, based partly on the IPCC SRES (Special Report on Emissions Scenarios) framework and partly on the new system of Shared Socio-economic Pathways (SSPs). For each of these scenarios, a set of quantitative outputs has been generated to allow the simulations with bio-economic models. Specifically, projections are provided for energy, fishmeal/fish oil and fish price trends, management targets, international agreements, technological development and marine spatial planning.
Scenarios are neither predictions nor forecasts of future conditions. No single scenario will ever come true in its entirety. The socio-political scenarios developed in the EU project CERES have been used to evaluate the relative impacts of climate change versus management of other human pressures on wild-capture fisheries, freshwater and marine aquaculture throughout the European continent. We provide examples of how these scenarios have been ‘regionalized’ for applications in the North Sea and we argue that it would be beneficial if a similar framework could be adopted elsewhere in order to facilitate cross-comparison and communication of results.

Adaptive fisheries management under changing environmental and economic conditions: socioeconomic scenarios in the Alaska Climate Integrated Modeling (ACLIM) Project

Authors: Alan Haynie, Amanda Faig, Kirstin K. Holsman, Stephen Kasperski, and Anne B. Hollowed

Presenter: **Alan Haynie**

The Alaska Climate Integrated Modeling (ACLIM) project is a multidisciplinary effort to examine how different climate scenarios are likely to impact the Bering Sea ecosystem – and to ensure that our management system is ready for these potential changes. ACLIM integrates climate scenarios with a suite of biological models that include different levels of ecosystem complexity and sources of uncertainty. This talk focuses on coupling the project’s bio-physical models with models of fisher behavior and management scenarios. The complexity of the economic models varies to match the scale of the biological models with which they are coupled.

We identify groups of economic and management factors that are the core drivers of fisheries. For management, there are many possible future policy choices, such as changes in target and bycatch species allocations or expanded spatial protective measures that can reduce the vulnerability of different stakeholders. Building on shared socioeconomic pathways (SSPs), we define the primary measures that have been demonstrated to impact past fisher behavior and define a range of future economic changes and policy interactions under which we predict future integrated modeling outcomes. We demonstrate how different policy tools can have a large impact on how effectively we can adapt to environmental change and variation. We compare our approach with the approaches of several other large integrated modeling projects and discuss the specific features of the Bering Sea ecosystem and management system that make our approach the most effective for marine resource management in the North Pacific.

Using climate and adaptation scenarios to understand vulnerabilities and opportunities for Northeast U. S. fishing communities

Authors: Katherine E. Mills, Michael Alexander, Andrew Allyn, Lisa L. Colburn, Steve Eayrs, Bradley Franklin, Troy Hartley, Mary Hudson, Brian Kennedy, Sabrina Kerin, Jonathan Labaree, Andrew Pershing, James Scott, and Jenny Sun

Presenter: **Katherine Mills**

Ocean waters on the Northeast U. S. continental shelf have warmed rapidly in recent years, and climate models project this warming to continue. Associated changes in species distributions and productivity are already affecting fishing communities, as they face declines in traditionally-fished species and the appearance of emerging species in their fishing areas. The local impacts of these changes depend on the nature and rate of ecosystem change, patterns of dependence on marine resources, and adaptation capacity and choices. We use climate projections to drive species models as a basis for conducting port-scale assessments of social-ecological vulnerabilities to climate-related species changes. Results of this assessment provide insights into relative vulnerability of 75 fishing communities from Maine to Virginia and help identify key risks in specific ports. For four focus communities, we integrate projected species changes into economic models of the fishing sector and regional economy to quantify their impacts. We also consider a suite of adaptation scenarios within the economic models to assess the extent to which different adaptation approaches would buffer the impact of species changes and create new opportunities for fisheries in the community. Interviews with fishermen and municipal officials enable us to evaluate factors that facilitate or constrain implementation of specific adaptation strategies. Ultimately, this information provides a foundation for decision-making and climate adaptation planning at community and regional scales as well as insights into policy and institutional needs to support the resilience and vibrancy of fishing communities in the context of climate change.

From data compilation to model validation: A comprehensive analysis of a full deep-sea ecosystem model of the Chatham Rise

Authors: Vidette McGregor, Beth Fulton, Peter Horn, Matt Dunn

Presenter: **Vidette McGregor**

The Chatham Rise is a highly productive deep-sea ecosystem that supports numerous substantial commercial fisheries, and is a likely candidate for an ecosystem based approach to fisheries management in New Zealand. We present the rst end-to-end ecosystem model of the
Chatham Rise, which is also to be best of our knowledge, the rst end-to-end ecosystem model of any deep-sea ecosystem. We describe the process of data compilation through to model validation and analyse the importance of knowledge gaps with respect to model dynamics and
results. The model produces very similar results to fisheries stock assessment models for key fisheries species, and the population dynamics and system interactions are realistic. Con dence intervals based on bootstrapping oceanographic variables are produced. The model components that have knowledge gaps and are most likely to in uence model results were oceanographic
variables, and the aggregate species groups `seabird' and `cetacean other'. We recommend applications of the model, such as forecasting biomasses under various shing regimes, include alternatives that vary these components.

A fishery system approach using socio-ecological model: a case study of Fujian swimming crab fishery in China

Authors: Zelin Chen, Edward H Allison, David Fluharty, Ray Hilborn

Presenter: **Zelin Chen**

China’s ecological civilization has advanced the sustainable development of the coastal fisheries in the nation’s policy agenda. As one of the main fisheries reform measures, the quota-based fisheries pilot program has been developed in the recent years to explore the best management practices and generalizable experience that fits into China’s unique context. However, the insufficient knowledge of the fishery’s social aspects has compromised the effectiveness of the fisheries management. To optimize the management system in the future implementation, we identify the Fujian swimming crab pilot program as a case study and model its social-ecological systems to advise the management system. A social-ecological model is developed based on qualitative data collected from stakeholder interviews, literature review, and field investigation to understand the ecological, socioeconomic, community, and institutional characteristics in the natural, human, and fishery management systems (Charles, 2008). Based on the systematic analysis of the Fujian swimming crab fishery, we propose X scenarios in its future management implementation, including 1) developing adaptative management mechanism grounded in the multifaceted aspects of the fishery system, 2) establishing new institutional mechanism to increase science consultants and communication in the decision-making process, 3) engaging stakeholders into the management system to increase the compliance, 4) optimizing the existing legal framework to support the new management. Given the similarities in China’s coastal fisheries, the study also provides management implications to a larger scale.

Making the Most of Mental Models: Advancing the Methodology for Mental Model Elicitation and Documentation with Expert Stakeholders

Authors: Kelsey LaMere, Samu Mäntyniemi, Jarno Vanhatalo, and Päivi Haapasaari

Presenter: **Kelsey LaMere**

The rapidly developing field of participatory modelling (PM) seeks to increase understanding of complex socio-ecological systems and identify solutions to problems within them, by pairing the expertise of researchers with the wisdom of stakeholders. Frequently, PM efforts begin by eliciting and visually representing stakeholders' mental models, which are conceptualizations of a system built on personal knowledge, experience, and values. This information is essential for knowledgebase formation and idea generation, particularly in novel or data-poor contexts when time is limited and action cannot be delayed while more traditional scientific information is generated. Consequently, ensuring the accurate and holistic translation of stakeholders' mental models from their brains to paper is an essential PM skill. However, the depictions of mental models published are often simple, potentially indicating failure or reluctance to fully capture stakeholders' ideas, resulting in a dilute and ineffectual knowledgebase. As a solution, we propose the Dual Elicitation Approach, which combines direct and indirect mental model elicitation techniques to ensure the development of holistic depictions of stakeholders' mental models, while maintaining the integrity of their ideas. The approach also seeks to promote the opportunity for learning provided by the elicitation process itself, as stakeholders engage with their own cognitive structures. We describe the approach and its utility in the context of a problem-framing study, which we conducted to determine the effects of climate change on salmon and their fishery in the Baltic Sea. In an effort to encourage the development of best practices in the burgeoning field of PM and provide the impetus for the further development of elicitation studies, we also share the challenges faced and lessons learned during our implementation of the Dual Elicitation Approach.

Developing a partnership bio-economic decision-support framework for fisheries management with stakeholders: challenges and opportunities towards trans-disciplinary approaches

Authors: Claire Macher, Michel Bertignac, Katia Frangoudes, Christelle Le Grand, Mathieu Merzereaud, Olivier Thebaud

Presenter: **Claire Macher**

Complexity of observation and understanding of marine socio-ecosystems has given a particular place to science and scientific advice in marine environmental management and particularly in fisheries management. It generated high demands from decision makers and other stakeholders for integrated knowledge on potential environmental and socio-economic impacts of alternative options to support decision. It also challenged the methods and approaches towards operational decision support and implementation of the ecosystem approach to fisheries. The paper proposes to share lessons learnt from the partnership Bio-economic Working Group Project conducted in three case studies located in the English Channel, the Bay of Biscay and the Mediterranean Gulf of Lion. The project aimed at developing a decision-support framework for fisheries management with stakeholders. It highlights the complementarity and roles of technical protocols and modelling on the one hands and partnership engagement on the other hands to fill in the gap between inter-disciplinary and trans-disciplinary approaches towards a better integration of academic and non-academic knowledge and a better salience and impact of science.
Keywords: decision-support, bio-economic modelling, partnership approach, stakeholders, transdisciplinary approach

Overcoming challenges in conducting management strategy evaluation in a complex multi-species, multi-sector, multi-gear, and multi-government fishery system, with application to bycatch harvest policies for Pacific halibut in the Bering Sea and Aleutian I

Authors: Carey McGilliard, Curry Cunningham, Dana Hanselman, Allan Hicks, Jim Ianelli, and Diana Stram

Presenter: **Carey McGilliard**

Best practices for management strategy evaluation (MSE) call for having stakeholders develop goals and measurable objectives, preferably through workshops that include representatives of all user groups. Objectives may include factors such as keeping biomass above a target level, minimizing variation in catch, and maximizing profits. Having user groups identify measurable objectives can be time-consuming, requiring iterative meetings and discussions, even in single-species fisheries when there are only a limited number of trade-offs. However, for systems of governance that preceded the development of MSE, and complex systems with multiple stakeholder groups or governments involved, each with competing objectives, alternative tactics may be required. In this study, we illustrate the challenges when established harvest policies require revision with competing objectives and diverse stakeholder groups. The US groundfish fishery is constrained by bycatch limits of Pacific halibut, a species that is managed internationally, but with catch limits allocated domestically within several regions and among the stakeholder groups. These limits have changed slightly over time but historically have been unrelated to their abundance. In addition, catch limits for the directed fishery for halibut in the Bering Sea and Aleutian Islands are determined after accounting for predicted halibut bycatch. We present a set of alternative abundance-based procedures and show the approach used to engage stakeholders for discerning objectives and developing harvest policy alternatives. Results to date highlight the issues of working within existing institutional structures, as well as multiple gear- and sector-types, and separating clear policy choices and trade-offs from the scientific characterization of uncertainty.

Visions for nature and nature's contributions to people for the 21st century

Authors: Carolyn Lundquist, H. M. Pereira, R. Alkemade

Presenter: **Carolyn Lundquist**

Ongoing declines in biodiversity and the ecosystem services that humans depend on to meet their needs require global coordination and innovative policies that move beyond business-as-usual solutions and scenarios. The Convention on Biological Diversity (CBD) is entering a crucial phase to develop a post-2020 strategy and a revised set of goals after limited success on reaching the Aichi biodiversity targets. The post-2020 strategy faces the challenge of shifting the current negative trends in biodiversity towards positive targets which put society on track to achieve the CBD vision for 2050. A key step identified is the development of transformative scenarios that allow for the diversity of local value systems, socio-cultural contexts, governance systems, resource utilisation, and biodiversity. Scenarios are an important tool to assess the feasibility and implications of different management and policy interventions. However, existing scenarios fail to explicitly include social-ecological feedbacks, instead typically including biodiversity and ecosystem services as endpoints, acted on by societal and environmental drivers. In addition, much of nature's contributions have proved difficult to quantify, including values such as cultural and social recognition of nature existence for its own sake, and the inclusion of humans as an integral part of nature as reflected in many indigenous knowledge systems. Early discussions on the post-2020 framework involving scientists, civil society organizations and governments display a rich diversity of ideas and

proposals including ideas such as Half Earth (which can be broadly characterized as protecting half of the planet), Whole Earth (which can be broadly characterized as ensuring sustainability through ecosystem-based management practices), or a simple revision of the existing set of Aichi targets.
Here we outline the Nature Futures Framework, a novel scenarios framework developed by the IPBES Expert Group on Scenarios and Models of Biodiversity and Ecosystem Services, that can be used at multiple scales to identify positive futures for nature, elaborate associated targets for multiple indicators, and generate ideas for pathways and policy options. The Framework emphasises the plurality of human visions for nature futures – there is not solely one vision, nor is there only one way humans relate to nature; rather, there are multiple positive futures for nature that can be adapted to facilitate identification of locally and regionally relevant policy and governance options. The inherent power of the NFF is its ability to be context-dependent, driving different behavioural changes associated with particular political, legal, and socio-cultural perspectives. This framework has been developed to support a new generation of IPBES ecosystem assessments, and support scenario development at the interface of science, society and policy.

Approaches to integrate customary management with biological sustainability of a data poor sea cucumber fishery in Torres Strait, Australia

Authors: Eva Plaganyi, Leo Dutra, Nicole Murphy

Presenter: **Eva Plaganyi**

The Australian Torres Strait bêche de mer (sea cucumber) fishery is fully indigenous owned. It provides an example of a complex marine socio-ecological system that involves highly valuable yet biologically vulnerable stocks harvested by indigenous communities. There has been an expressed desire for improved management and economic returns from the fishery to be balanced with considerations of the need to maintain customary practices, utilise local ecological knowledge and maintain the lifestyle, autonomy and livelihoods of traditional inhabitants. Models and methods for managing this fishery have therefore to be tailored to the unique regional requirements, limited data availability and need mapping a pathway towards increasingly meeting multiple objectives. This talk will provide a summary of the processes and methods used to integrate the above considerations into a new harvest strategy that has recently been developed in close consultation with stakeholders, as well as ongoing modelling and experimental developments to comprehensively address the multiple economic, social and ecological objectives of management.

Stakeholder perception on social-ecological systems – the case of Western Baltic cod fishery

Authors: Heike Schwermer, Raissa Borgmann, Christian Möllmann

Presenter: **Heike Schwermer**

Sustainable management of marine resources benefits from the participation of a multitude of interest groups representing science, politics, environmental conservation organisations (eNGO) as well as commercial and recreational fisheries. Typically conflicts between these stakeholder groups result in mutual distrust and unaccepted management decisions. In order to solve such conflicts, it is not only important to identify who is involved in this stakeholder network, it is also essential to know how the stakeholder perception of the system look like.
In this case study, we applied fuzzy-logic cognitive mapping (FCM) to analyse the perception of individuals

and groups across six stakeholder types (fishery, recreational fishery, eNGO, politics, tourism, science). We used data from a previous study on social network analysis to identify the stakeholders involved in the Western Baltic cod (Gadus morhua) fishery. In total, we conducted 30 face-to-face interviews, which were composed of a short introduction on the topic of social-ecological systems (SES) and FCM. Further, stakeholders were given a 10 minutes presentation on how to build a FCM and were shown an unrelated map about bushmeat trade in Africa. The interviews lasted on average 90 minutes. Subsequently, to translate each stakeholder map, we used MentalModeler, a software to develop models and scenarios for future, such as for social-ecological system. With FCMs we were able to investigate i) how individual stakeholders as well as stakeholder groups perceive the SES of Western Baltic cod, and ii) which areas of conflict exist within the groups but also between the groups.
The findings of our study represent a starting point for further research on decision-making processes between stakeholder groups within the social-ecological system (SES) of Western Baltic Sea fisheries. Our study also shows a good example of application at the interface of science, society and policy.

Including multiple Ecosystem Services (ES) assessment in the Maritime Spatial Planning (MSP) context: an operational tool for marine ecosystems management and conservation.

Authors: Laura Basconi, Fabio Pranovi, Silvia Rota

Presenter: **Laura Basconi**

Every European Member State has been asked to deliver before 2021 an exhaustive Maritime Spatial Planning (MSP). The Ecosystem-Based Approach (EBA) required by MSP can be achieved with the Ecosystem Service (ES) assessment. In this context, multiple ES in the 3-dimensional scale of the marine environment (sea surface, water column, seabed) should be modelled together taking into account side-effects and feedbacks. The pitfall not to consider these externalities can give a rather blurry picture of the reality of ecosystem functioning. Furthermore, ES assessment is developing fast and in a scenario even more difficult to define: climate change.
My PhD project will focus on the marine coastal ES (up to 12miles from the shore) evaluation as support at the Italian MSP. A Petri net model has already been implemented in the Venice lagoon case-study as a dynamic operation tool for exploring how ES interacts among each-others and how they behave under different scenarios of Business-As-Usual (BAU), Climate Change (CC) and different management options up to the end of the 21st century. Geospatial ES within MSP context, allows stakeholders to identify priority area of conservation and suitable indices can summarize conflicts between uses and sustainability. The best alternatives in the management of natural resources, explored in the operational model above cited, at the sea can support environmental policies at the national level for natural capital conservation.

Cooperation Mechanism in Island socio-ecological system Network Governance in Macao

Authors: Mingbao Chen, Dianhong ZHAO, Guangzhi LIN

Presenter: **Mingbao Chen**

Island is a typical socio-ecological system complex and the most representative of the land-sea interaction system. Different from the coastal land-sea socio-ecological system, the island is relatively weak in social system, and it is more dependent on the external stakeholders of the island to participate in governance, which forms a relatively loose cooperation network between stakeholders. It is characterized by a contractual connection among the stakeholders, and there is a significant difference in density between the island and the outside of the island. The existence of this relationship will be adjusted in time due to changes in the island's social-ecological changes, thus promoting adaptive governance more effectively. This paper takes Macao of China as a research case, uses the analysis framework of land-sea social-ecological system governance, applies the methods of SNA, and analyzes the different stakeholders and their connections in Macao's social-ecological system governance, and discovers the network governance of social-ecological system is dominated by stakeholders on the island. In the future, with the increasing intensity of Macao's development and utilization of the sea area and the construction of the bay area of Guangdong, Hong Kong, Macao District, Macao's social-ecological system will change, and more external stakeholders will join the network governance, which will affect governance performance.

SESSION 18: MULTIPLE DRIVERS AND THEIR ROLE IN OCEAN GLOBAL CHANGE BIOLOGY

Interactive Effects of warming and acidification on heterotrophic bacteria and phytoplankton communities during induced bloom and post-bloom in Mediterranean coastal waters

Authors: Justine Courboules, Behzad Mostajir, Thomas Pacoureau, Sébastien Mas, Francesca Vidussi

Presenter: **Justine Courboules**

To study the effects of warming and acidification on bacterial and phytoplankton communities, an in situ mesocosm study was conducted in coastal Mediterranean waters. Plankton communities were studied under increased water temperature (3°C), acidification (actual pCO_2 +400 ppm), both stressors and without stressor (control). A phytoplankton bloom was induced by addition of nutrients. Growth and grazing rates of phytoplankton and bacteria were estimated during bloom and post bloom periods with a two point modified dilution method and then compared with those found in the control mesocosms.
During the bloom, both warming and acidification applied alone generally stimulated growth and grazing rates of 3 over 4 bacterial groups detected by flow cytometry (LNA1, HNA1 and HNA2), while those of the last group (LNA2) were depressed. During post-bloom bacterial growth and grazing rates showed a more complex pattern depending on group suggesting a nutrient or temporal-dependent responses. For instance, growth was still stimulated by both stressors for HNA1, while it was depressed for LNA1, and their grazing rates were depressed too. For HNA2 group, only warming stimulated growth and grazing rates, while acidification depressed both rates.
For phytoplankton, 3 groups were identified by flow cytometry, namely cyanobacteria, eukaryotic phytoplankton of 1-2 µm (EUK1-2 µm) and eukaryotic phytoplankton of 2-10 µm (EUK2-10 µm). The effect of both warming and acidification on their growth and grazing rates were generally positive. In fact, this

was the case for EUK2-10 µm growth as well as the grazing rates on both EUK1-2 µm and EUK2-10 µm during the bloom. Only the growth of EUK1-2 µm was depressed during this period. In the post-bloom, the growth rates of both phytoplankton groups were enhanced even more than what was observed during the bloom. On the contrary, grazing activity on EUK1-2 µm was decreased by both stressors and that of Euk2-10 µm by acidification only, while enhanced by warming. In general, larger phytoplankton (Euk2-10 µm) as well as their grazers were positively affected by both stressors. However smaller phytoplankton (Euk1-2 µm) had more complex responses; as their growth were positively affected in post-bloom and negatively during the bloom; and vice versa for their grazers.
The interaction between warming and acidification in the present study was generally antagonistic, based on the definition provided by Piggot et al. (2015). The magnitude of the antagonistic responses was between or lower than the magnitude of responses resulting from single stressor. This suggests that the effect of simultaneous warming and acidification on plankton communities is not higher than their separate effects.

Present and future impact of atmospheric deposition on the structure and functioning of plankton communities in the Mediterranean Sea (Peacetime project)

Authors: Frédéric Gazeau, and the Peacetime minicosm team

Presenter: **Frédéric Gazeau**

Our understanding of the exchange of energy, gas and particles at the ocean–atmosphere interface has advanced rapidly over the past decade although we remain unable to adequately parameterize fundamental controlling processes. A critical bottleneck is the representation of the key processes associated with atmospheric deposition in Low Nutrient Low Chlorophyll (LNLC) regions such as the Mediterranean Sea. In this region, ecosystem functioning is known to be modulated by pulsed atmospheric inputs, especially during the stratification period, by relieving the macro- and micro-nutrient limitation. The PEACETIME (Process studies at the air-sea interface after dust deposition in the Mediterranean Sea) project aims at extensively studying and parameterizing the chain of processes occurring in the Mediterranean Sea after atmospheric deposition of Saharan dust and to put them in perspective of on-going environmental changes.
During a cruise on board of the R/V "Pourquoi Pas?" in May/June 2017, three experiments in minicosms were conducted with water collected in the Tyrrhenian Sea, Ionian Sea and close to the Balearic islands. These are large tanks (300 L) equipped on their top-end with LEDs that can be modulated to fully reproduce the sun spectrum and irradiance intensity of surface Mediterranean waters during the period of investigation. Thanks to their volume and conical-end shape, minicosms allow following a large number of chemical, biological and physical parameters and to accurately quantify particle export. Six of these experimental units were used to follow simultaneously and with a high temporal resolution, the evolution of biological activity (metabolism, 13C flow), nutrients stocks, dissolved organic matter as well as particles dynamics and export both under present environmental conditions and following a realistic climate change scenario (ca. +3°C and -0.3 pH units). The most interesting feature of these experiments is that the response of the communities was significantly different between the three sampling stations, depending on their initial composition and metabolic requirements.

Impact of dust enrichment on the metabolism of Mediterranean plankton communities under present and future conditions of pH and temperature

Authors: Frédéric Gazeau, E. Marañón, S. Alliouane, C. Stolpe, M. Pérez-Lorenzo, F. Van Wambeke, C. Guieu

Presenter: **Frédéric Gazeau**

The PEACETIME (Process studies at the air-sea interface after dust deposition in the Mediterranean Sea) project aims at extensively studying and parameterizing the processes occurring in the Mediterranean Sea after atmospheric deposition of Saharan dust and to put them in the perspective of on-going environmental changes such as ocean warming (OW) and ocean acidification (OA). During a cruise on board of the R/V "Pourquoi Pas?" in May/June 2017, three experiments in climate reactors were conducted with water collected in the Tyrrhenian Sea, Ionian Sea and Alboran Sea. Six experimental units (tanks of 300 L) were used to follow simultaneously and with a high temporal resolution, the evolution of biological activity (Oxygen and carbon community metabolism, bacterial production, 13C flow) among other parameters and processes, after dust addition both under present environmental conditions and following a realistic climate change scenario (ca. +3 °C and -0.3 pH units). In the Tyrrhenian Sea, no clear impact of dust addition both under present environmental conditions and OW/OA was observed on community metabolism (14C or 13C incorporation rates) while the heterotrophic prokaryote compartment significantly responded to both drivers. In the Ionian Sea, the productivity of phytoplankton and bacterial communities was significantly enhanced by dust addition with higher rates observed at lower pH and higher temperature. Interestingly, in the Alboran Sea, although dust addition led to much higher activities for both autotrophic and heterotrophic compartments, OW/OA only positively impacted bacterial metabolism with no detectable effects on phytoplankton activity. This study highlights the importance of initial community composition and metabolic requirements on the response of surface plankton communities to nutrient enrichment (dust addition) and to ongoing environmental changes.

Dissolution of Fe and Si from desert and volcanic aerosols and impact on phytoplankton

Authors: Carla Geisen, Celine Ridame, Damien Cardinal, Emilie Journet, Joelle Kombo

Presenter: **Carla Geisen**

In the LNLC areas of the ocean, atmospheric input plays a major role in the nutrient supply of primary producers and therefore impacts the entire pelagic food web.
The main goal of the study is to determine the phytoplankton response to a deposition on the sea surface of two types of natural aerosols: volcanic ash and desert dust. To quantify the bioavailability of macro- and micronutrients (Si, Fe, Cu, Mn, Ni) released by these deposits, we first measured their dissolved fraction released in a series of abiotic experiments in trace metal clean conditions. We compared the dissolution of dry and wet deposition modes of several dusts (three Saharan samples from Algeria, Morocco and Niger, and one South American sample from Patagonia) and ashes (Chaitén in Chile, Eyjafjallajökull in Island and Tungurahua in Equator).
In dry deposition mode, desert dust released more Fe than volcanic ash, and Patagonia dust released less Fe than other desert aerosols. Concerning the dissolution of Fe in rain water, no pattern between the types of aerosol was visible after 24h of contact time in our preliminary results.
For the same experimental conditions, dust from Patagonia released more Si than Saharan samples in both deposition modes. For the volcanic aerosols, ash from Eyjafjallajökull discharged more Si than the other volcanos for both dry and wet depositions. No clear pattern was distinguishable concerning the solubility

of Si in rain and seawater: For a same contact time, some aerosols such as Eyjafjallajökull ash and Douz dust released more Si in rainwater, whereas Tungurahua ash released more Si in seawater. The solubility of Si in other samples did not vary according to the media.
Desert dust releases globally more Si per gram of aerosol than did volcano ash for a same contact time despite the more amorphous nature of the later. However in conditions more representative of natural particle charges, a single ash deposition event can release much higher quantities of aerosols to the sea surface than a dust event. Indeed, comparing an artificial ash deposition of less than a millimeter on the sea surface (25mg ash/L sea water) to a big dust event (2mg dust/L sea water), volcano ash released more Si than desert dust.
Dry deposition released more Si than wet deposition for any of the tested aerosols, corresponding to over 350 nmol/L in sea water for Eyjafjallajökull ash and over 100 nmol /L for Patagonia dust in our representative experimental conditions.
In a second step, in order to assess the biological response of natural phytoplankton assemblages to aerosol deposition, we set up a series of on-board trace-metal clean microcosm experiments in contrasted biogeochemical conditions, including the LNLC area of the South Indian Ocean and different High Nutrient Low Chlorophyll stations (high N- low Si and high N - high Si) of the Southern Ocean.
We will present preliminary results of primary production and phytoplankton abundances from these incubations.

Exploring the effect of nitrogen limitation on phytoplankton acclimation to warming

Authors: María Aranguren-Gassis, Emilio Marañón

Presenter: **Maria Aranguren-Gassis**

Ongoing global change is pressuring researchers to predict the response of marine ecosystems to different environmental drivers. To do so, we need information on the effect of those drivers on the metabolism of marine phytoplankton, which constitute the base of the marine food chain. The phytoplankton response to warming has been widely studied, but many experimental studies have been done assuming that the short-term metabolic responses (typically over 24-72 hours) can be extrapolated to long-term (acclimated), more realistic responses. Moreover, there is little information about the combined effect of temperature increase and nutrient limitations on phytoplankton metabolic response, despite the fact that these environmental drivers are key in constraining phytoplankton metabolic rates and species distribution. We present here results from recent laboratory experiments with a widely distributed marine diatom (Thalassiosira rotula). Using continuous cultures in a chemostat, we have explored how the diatom's short-term (2 days) response to warming differs from the acclimated response (2 weeks), and how that difference can depend on the degree of nitrogen limitation.

Pathway of inflow of cold bottom water in the Bohai Sea and its ecological effects

Authors: Yanfang Li, Cheng Tang

Presenter: **Yanfang Li**

The Bohai Strait is the only waterway for the Bohai and Yellow Sea, the exchanged waters through the strait would play an important role in temperature and salinity structure of the Bohai Sea. The possible pathway of cold water from the Yellow Sea was investigated based on observations and simulations. Recent observations have found that the cold pools in the Bohai Sea seemed to get weak, in some years the stratification was not so obvious, the flux of persistent cold water flowed into the Bohai Sea directly influenced the formation of cold pools, which was related to the hypoxia in the bottom of Bohai Sea, and the intruding pathway of cold water from the Yellow Sea influenced the movement of fish directly. Experiments demonstrated that the intrusion pathway was related to the strength of Yellow Sea Warm Current, which had a fluctuation with El Nino. Therefore, the movement pathway of cold water was finally related to climate change.

The various faces of trace metal limitation in a changing ocean

Authors: Florian Koch, Sara Beszteri and Scarlett Trimborn

Presenter: **Florian Koch**

Large areas of the world ocean consist of high nutrient low chlorophyll (HNLC) areas. Although macro nutrient concentrations are high, phytoplankton biomass is low, limited primarily by the trace metal (TM) iron. The Southern Ocean (SO) is the largest high nutrient low chlorophyll area, responsible for 20% of global carbon dioxide uptake and especially sensitive to climate change. Thus perturbations of the system such as ocean acidification (OA) or TM abundance and can have large impacts on primary productivity, species composition and thus the efficiency of the biological pump. In addition to iron, other TM/vitamins shape plankton community composition and primary production. Here we present laboratory data on the interactive effects of OA and iron limitation on the physiology of Phaeocystis antarctica, a key SO species. While OA had limited effects on the physiology, Fe limitation resulted in reduced growth rates and cellular carbon and TM contents. We will present data from three phytoplankton species, that demonstrates that when phytoplankton are limited by one micronutrient (iron ,zinc, cobalt or vitamin B12) it leads to a drastic reduction of the cellular quotas of most others. This potentially causes a more ‘severe’ secondary limitation by another TM. Lastly, data from two TM/vitamin amendment experiments, conducted with natural phytoplankton assemblages from different regions of the SO will be presented. Not surprisingly, the addition of iron increased plankton biomass three-fold in both experiments while cobalt and zinc additions increased plankton growth in the first and second experiment, respectively. Size fractionation revealed that while the total biomass was altered, the addition of iron in conjunction with other TMs significantly changed the size distribution of the plankton community. Together these results highlight the interactive effects of OA and other TM/vitamins with iron and illustrate their role in shaping plankton community composition and biomass in the SO.

Relative contribution of internal vs. external sources of phosphate to the surface mixed layer in the P-depleted Mediterranean Sea (Peacetime cruise)

Authors: Elvira Pulido-Villena, Van Wambeke F., Desboeufs K., Petrenko A., Barrillon S., Djaoudi K., Doglioli A., D'Ortenzio F., Fu Y., Gaillard T., Guasco S., Nunige S., Raimbault P., Taillandier V., Triquet S., Guieu C.

Presenter: **Elvira Pulido-Villena**

The Mediterranean Sea is one of the world's most oligotrophic oceanic regions and it exhibits very low nutrient concentrations, particularly phosphate, with a West to East decreasing gradient. Previous studies have highlighted the key role of atmospheric deposition in supplying new nutrients to the surface layer, particularly during the stratification period. The general objective of the PEACETIME cruise (Western/Central Mediterranean Sea, May 10–June 11, 2017) was to study the fundamental processes, and their interactions, that are brought into play by atmospheric inputs to the surface layer in the Mediterranean Sea, and to highlight the impact these processes have on the pelagic ecosystem's functioning. During the cruise, we conducted cross-basin nanomolar measurements of phosphate and dissolved organic phosphorus (DOP) concentration with emphasis on upper waters, where biological activity is P-limited. Vertical distribution of phosphate concentration in the upper waters was characterized by two distinct layers: a phosphate depleted layer (PDL), above the phosphacline and deeper than the surface mixed layer, and a phosphate replete layer (PRL), across the phosphacline to the base of the euphotic zone. Phosphate concentration averaged 11.6 ± 4.0 nM in the PDL and 208 ± 114 in the PRL. The performed sensitive phosphate measurements in the PDL allowed detecting a low but measurable positive gradient indicative of diapycnal fluxes of phosphate above the phosphacline. In this presentation, we will discuss the relative contribution of external (diapycnal fluxes and atmospheric deposition) vs. internal (DOP mineralization) sources to upper waters across the Mediterranean basin. Atmospheric deposition of phosphate was obtained from on board sampling of rainfall and aerosols. DOP mineralization was obtained through concomitant measurements of alkaline phosphatase activity and DOP concentration. This study provides important knowledge on the different sources of phosphate potentially sustaining biological activity in the present oligotrophic ocean as well as in the more stratified and warmer future ocean.

Interactive effects of light, CO_2 and iron on growth and species composition of a natural phytoplankton assemblage of the Drake Passage

Authors: Franziska Pausch, Florian Koch, Jasmin P. Heiden, Sonja Wiegmann, Astrid Bacher, Corina Brussaard, Christel S. Hassler and Scarlett Trimborn

Presenter: **Franziska Pausch**

Climate change will cause changes in various environmental drivers, which in turn can affect growth and productivity of Southern Ocean phytoplankton. Two contrasting climate scenarios are currently predicted. Increased sea surface temperatures and the resulting enhanced sea ice melt could lead to a more stratified mixed layer. As a result, higher light availability could enhance primary production, but the reduced iron input from deeper layers could counteract this positive effect (scenario 1: +L-FeOA). Other climate models forecast strengthening of westerly winds, deepening the surface mixed layer where phytoplankton would encounter reduced irradiance levels, but may benefit from more iron input from deeper layers (scenario 2: -L+FeOA). Under both scenarios, ocean acidification (OA) may reduce the bioavailability of iron to phytoplankton. To gain more insight on the complex interplay of these environmental factors, bottle manipulation experiments with a natural iron-limited phytoplankton assemblage from the Drake Passage were conducted. The influence of low and high irradiance (30 and 80 µmol photon m^{-2} s^{-1}) in combination with current and future higher pCO_2 levels (390 and 1000 µatm) under different iron availabilities (no addition and +0.9 nM FeCl3) on Southern Ocean phytoplankton growth and species composition was examined. The treatment simulating climate scenario 1 +L-FeOA resulted in higher growth rates of the investigated diatom genera *Pseudo-nitzschia*, *Chaetoceros* and *Fragilariopsis* as well as of the prymnesiophyte *Phaeocystis antarctica* compared to treatments grown under present day CO_2 conditions with low light and iron availability. Particulate organic carbon (POC) production was not altered in the scenario 1 treatment compared to present day conditions. In the treatment representing scenario 2 (-L+FeOA), growth rates of Pseudo-nitzschia species and Chaetoceros species as well as POC production were reduced compared to present day conditions. These findings indicate that in an acidified and more deeply mixed Southern Ocean with higher iron supply (scenario 2), the reduced growth of some diatom genera could alter the community composition. Less POC production together with the loss of diatoms in particular, which act as efficient carbon vectors, could reduce the efficiency of the biological carbon pump. The increase of light availability as a result from more stratified waters (scenario 1) may not change POC production, but could promote particularly the growth of certain diatom genera in Southern Ocean phytoplankton communities already adapted to low iron conditions, thereby potentially strengthening the biological sequestration potential of CO_2.

Multiple drivers of the spatial distribution of primary productivity in the Humboldt Current system

Authors: Pierre-Amaël Auger, Berger T., Villegas V., Belmadani A., Gorgues T., Bento J.P., Donoso D., Morales C.E., Di Lorenzon E. And Hormazabal S.

Presenter: **Pierre-Amaël Auger**

The offshore extension of coastal productivity is not uniform in the Humboldt Current system, being restricted to a narrow coastal band off northern Chile while high productivity is still observed hundreds of kilometers from the coast in the coastal transition zone off Peru and central-southern Chile. Superimposed on this are persistent mesoscale variations. Using hindcast physical-biogeochemical simulations (ROMS-PISCES for Regional Oceanic Modeling System - Pelagic Interactions Scheme for Carbon and Ecosystem Studies) at an eddy-resolving resolution, we find that the interplay of iron limitation of the phytoplankton growth and mesoscale activity drives the regional distribution of primary productivity. Minimum coastal productivity off northern Chile is attributed in the model to strong iron limitation due to a narrow continental shelf, which limits iron inputs from the sediments. This then translates into the adjacent coastal transition zone through iron limitation of primary production, especially inside cyclonic eddies detached from the coast. The organization of the mesoscale eddy field as preferred eddy tracks, at least off central-southern Chile, then drives mesoscales variations of this regional pattern mostly associated to the trapping of coastal-rich (offshore-poor) waters by cyclones (anticyclones), respectively, from both side of the coastal upwelling front.

Mapping the fitness landscape of marine diatoms

Authors: Jana Hinners, Phoebe Argyle, Martina Doblin, Naomi Levine, Nathan Walworth, Sinead Collins

Presenter: **Jana Hinners**

To understand how phytoplankton may adapt to environmental changes, it is important to understand what the actual room for their traits to evolve is. This room can be visualized by a fitness landscape, in which some trait value combinations lead to a high fitness, and thus a fitness peak, and others lead to a lower fitness, and thus a valley. Evolution experiments suggest that the number of allowable trait combinations is limited, but what phytoplankton fitness landscapes look like still needs to be understood. We aim to map how connected different fitness peaks are for marine diatoms of the Thalassiosira genus. In form of mutation accumulation experiments, we force the diatoms from their current fitness peak into fitness valleys. In a subsequent evolution experiment we investigate in which direction they evolve out of their valley again under different environmental settings. Moreover, in the frame of this project, a high-throughput analysis for phytoplankton traits is being developed, and the data on diatom fitness landscapes is used to simulate in which ocean regions evolution may play a critical role in the light of global change. Here, we present the current progress of the project and preliminary results.

The Oligotrophic to UlTra-oligotrophic PACific Experiment (OUTPACE)

Authors: Thierry Moutin, OUTPACE team

Presenter: **Thierry Moutin**

In the context of global warming, the ocean is changing quickly, and initiating large scale oceanographic research programmes is of major importance if we wish to be able to predict the likely future patterns of change in carbon sequestration. The OUTPACE project was the culmination of a long process that has allowed scientists from different fields (from physicists specialising in Lagrangian navigation to biologists specialising in genes and biodiversity/function at the single-cell level) to work together to study the biological carbon pump (BCP) in the Western Tropical South Pacific (WTSP). The original coupling between satellite imagery, Lagrangian floats, turbulence profilers, biogeochemical sensors and molecular tools allowed real time acquisition of physical, chemical and biological parameters. In addition to the transdisciplinary field work approach, the modelling work performed in this project has delivered interesting results which contribute to finding the answers to the scientific questions raised in the course of the project and provide interesting new findings as a basis for simulations of the future ability of the oligotrophic Ocean to sequester carbon. The OUTPACE project, led by the MIO (Mediterranean Institute of Oceanography) has brought together around 50 scientists from 7 French research laboratories and collaborators in 7 other countries. An overview of the main results concerning the regulation of the biological carbon pump will be presented.
The specific results are detailed in 27 papers of a Biogeosciences special issue 'Interactions between planktonic organisms and biogeochemical cycles across trophic and N2 fixation gradients in the western tropical South Pacific Ocean: a multidisciplinary approach (OUTPACE experiment)' Editors: T. Moutin, S. Bonnet, K. Richards, D.G. Capone, E. Marañón, and L. Memery :
https://www.biogeosciences.net/special_issue894.html

Co-limitation drives competition between phytoplankton and bacteria in the Southern Ocean

Authors: Lavenia Ratnarajah, Ingrid Obernosterer, Marion Fourquez, Stéphane Blain, Philip Boyd, Alessandro Tagliabue

Presenter: **Lavenia Ratnarajah**

The availability of iron and light co-limit phytoplankton growth across large areas of the Southern Ocean. From the onset of spring, the balance between iron supply and removal mechanisms determines the magnitude and dynamics of phytoplankton blooms. Here we develop a quantitative model to examine the competition between phytoplankton and bacteria driven by co-limitation in the Southern Ocean. As heterotrophic bacteria can be co-limited by bioavailable iron and labile dissolved organic carbon, the steady state model output demonstrates that the increasing availability of labile dissolved organic carbon stimulates competition between phytoplankton and bacteria for the bioavailable iron fraction. The seasonal transition from new to regenerated sources of iron causes shifts from autotrophic to heterotrophic microbial communities as these regenerated sources also represent a key mechanism for the supply of dissolved organic carbon.

How new experimental knowledge of sediment particulate iron may change our understanding of the global ocean biogeochemical cycles ? Insights from numerical model experiments

Authors: Houda BEGHOURA, Thomas GORGUES, Olivier AUMONT, Hélène PLANQUETTE, Marie CHEIZE, Pierre-Amaël AUGER, Alessandro TAGLIABUE

Presenter: **Houda Beghoura**

Besides light and macronutrient, photoautotrophs' productivity is limited by the availability of micro-nutrients in the ocean. Among those micro-nutrients, iron (Fe) is known to limit primary production over ~40% of the ocean and consequently the efficiency of the biological carbon pump. Moreover, iron supplies have been demonstrated to have a regulatory effect on the phytoplankton community structures. However, there are still substantial uncertainties in the iron biogeochemical cycle, including the nature and the magnitude of its external sources. Recent in situ observations and modeling studies have highlighted that an amount of iron larger than anticipated is being delivered from continental slopes and margins. To date, most studies have focused on the supply of dissolved iron (an iron form considered as the most bioavailable) to the ocean from the margins, the role of the particulate fraction of iron being largely ignored. Yet, over the latter areas most of the iron is actually present in the form of resuspended particulate iron. To date, particulate iron has mostly been viewed for its role in the biogenic iron remineralization, the scavenging, and aggregation processes.
Here, we challenge this traditional view. We postulate that the dissolved iron distribution may also be modulated by sediment lithogenic particulate iron dissolution, sinking, and transport. Indeed, the exchange between the particulate and dissolved fractions results in a net flux from the particulate iron to the dissolved fraction inducing a source of dissolved bio-available iron that potentially sustain productivity in shallow coastal waters but also in the open ocean. Lithogenic iron particles of sedimentary origin may thereby impact the ocean phytoplankton communities and production.
The aim of this study is then to use new acquired knowledge of the significance of particulate iron dissolution from sedimentary sources to assess its first order impact on global ocean biogeochemistry. To this end, we propose a modelling approach focused on the importance of iron supply to the open ocean by dissolution of the lithogenic sedimentary particulate iron. Results from the first ever done lithogenic

particulate iron dissolution experiment have then been used to set up a numerical modeling approach using the biogeochemical platform NEMO-PISCES. Simulations have been implemented, with an added parameterization of lithogenic sedimentary particulate iron, to assess the impacts of those particles on biogeochemical cycles and phytoplankton biomass at global scale. Our simulations show that the dissolution of those particles, along their transport by large scale horizontal currents, impacts the dissolved iron concentration in coastal area but also significantly in open ocean. This alteration of the dissolved iron distribution is then driving (i) a modification of the phytoplankton growth limitations patterns and (ii) changes in phytoplankton concentration mostly noticeable in coastal to open ocean gradients.
This work represents a first step towards studies coupling the experimental and the modeling approaches. In particular, further experimental work is needed to assess the underlying mechanisms and kinetics of the release of dissolved iron from the sedimentary particles to feed future modelisation experiments.

Emergence of novel climates in environmental drivers of marine ecosystems

Authors: Stephanie Henson, Claudie Beaulieu

Presenter: **Stephanie Henson**

Climate change is expected to modify ecological responses in the ocean, with the potential for important effects on the ecosystem services provided to humankind. Here we address the question of when, where and how rapidly novel climates develop in future ocean biogeochemistry, including in multiple stressors of marine ecosystems. By analysing an ensemble of models we find that, within the next 15 years, the climate change-driven trends in multiple ecosystem drivers emerge from the background of natural variability in 55% of the ocean and propagate rapidly to encompass 86% of the ocean by 2050 under a 'business-as-usual' scenario. However, we also demonstrate that the exposure of marine ecosystems to climate change-induced stress can be drastically reduced via climate mitigation measures; with mitigation, the proportion of ocean susceptible to multiple drivers within the next 15 years is reduced to 34%. Mitigation slows the pace at which multiple drivers emerge, allowing an additional 20 years for adaptation in marine ecological and socio-economic systems alike. We also investigate the spatial distribution of 'best analog' climates, which offer the possibility of 'corridors' connecting regions of similar conditions, and therefore the potential for migratory routes or refugia for species affected by changing ocean biogeochemistry.

The effect of multiple stressors on anti-predator defences

Authors: Sara Mynott, Martin Stevens, Stephen Widdicombe

Presenter: **Sara Mynott**

To understand the impact of climate change on ecosystems, we need to know its affects not just on individual species, but on the relationships between them. Predation ecology presents an ideal avenue to tackle this question, given that the relationships between predators and prey affect ecosystem structure and function. This project addresses the impact of two major marine climate stressors (ocean acidification and warming) on camouflage, the most widespread anti-predator defence in nature. We used digital photography and models of predator vision to determine the rate at which shore crabs (*Carcinus maenas*) change colour to match their habitat under different climate change scenarios. By placing crabs on different substrates and monitoring their changes in coloration over a ten-week laboratory trial, we quantified the extent to which different temperatures (15 °C and 20 °C) and CO_2 levels (400, 650 and 950 ppm) impacted

their plasticity and camouflage. Since more active individuals are more likely to be exposed to predators, these studies were paired with behavioural trials to assess how multiple stressors might impact activity. Crabs were found to match their background better over time. While acidification had little impact on this process, warming resulted in faster changes in coloration. Effects on activity (foraging and self-righting) varied with stressor combination, illustrating the complex nature of climate change impacts on predation risk. These findings highlight the importance of studying not only multiple stressors, but also multiple responses when assessing the ecological impacts of climate change. These results have implications for the success of this species and the shape of predator-prey relationships in the intertidal zone.

Phytoplankton Response to Multiple Environmental Stressors

Authors: Uta Passow, D'Souza N., Sweet J., Romanelli E.

Presenter: **Uta Passow**

Increasing atmospheric pCO_2 leads to changes in all the environmental conditions important for phytoplankton success: Direct effects include an increase in temperature and pCO_2 in the surface ocean; the stronger vertical temperature gradient will lead to changes in nutrient and light availability. Each phytoplankton species has the capability to acclimatize within a finite range of these environmental parameters. However, the response of phytoplankton to multiple simultaneous stressors is frequently complex and may include antagonistic, infra-additive, strictly additive, supra-additive, or no interactive response patterns. Using cultures of an open ocean and coastal diatom strain (*Thalassiosira pseudonana* CCMP1014, CCMP1335) we investigated the interactive response patterns to light, temperature and pCO_2 in full factorial design. Temperature and light interactions showed various additive or no interference responses in growth rate, with highest growth rates leading to stress as measured by quantum yield (QY). Increased pCO_2 resulted in either antagonistic or synergistic response patterns, depending on pCO_2 level and temperature. The QY was highest at low temperature and light conditions, if pCO_2 was near ambient, but at high pCO_2 the QY was mainly a negative function of temperature.

Interactive effects of temperature and nutrient supply on the abundance of PSII and RuBisCo proteins in *Synechococcus* sp.

Authors: Cristina Fernández González, M. Pérez-Lorenzo, N. Pratt, C. M. Moore, T. S. Bibby and E. Marañón

Presenter: **Cristina Fernández González**

Nutrient supply and temperature are two critical factors that control phytoplankton metabolic rates and resource allocation. To understand their interactive effects, we studied the response of a marine cyanobacterium (Synechococcus PCC 7002) to multiple combinations of temperature and nutrient supply. The assayed temperatures were 18, 22, 26 and 30°C, while the nutrient treatments included nutrient-limited, continuous growth in chemostats at two dilution rates (0.1 and 0.3 d^{-1}) and nutrient-replete conditions during exponential growth in semicontinuous batch cultures. We measured the abundance of two key photosynthetic proteins, the RuBisCo (RcbL) and the D1 protein of PSII (PsbA), the cellular content of chlorophyll a and organic carbon and nitrogen and the rates of photosynthesis and respiration. We found an increase in the abundance of both RbcL and PsbA with increasing nutrient supply, whereas temperature had an effect only on PsbA content, which was strongest in the nutrient-replete treatment. These results suggest a preferential resource allocation into PSII instead of RuBisCo as temperature rises, likely due to the temperature dependence of RuBisCo activity. The increase of both temperature and nutrient supply stimulated the carbon-specific photosynthetic rate, but the effect of temperature was very weak under nutrient limited conditions. We conclude that the temperature effect upon the photosynthetic physiology and metabolism of Synechococcus sp. is nutrient dependent. These findings contribute to our understanding of the strategies for photosynthetic energy allocation in phytoplankton inhabiting contrasting environments.

Aligning multiple driver research through video tutorials

Authors: Christina McGraw, Jon N. Havenhand, Sinead Collins, Philip W. Boyd

Presenter: **Christina McGraw**

Scientific Committee on Oceanic Research (SCOR) Working Group 149 (https://scor149-ocean.com/) has developed resources to help in the design of multiple driver experiments. As part of this work, we have produced a series of video tutorials from experts in the field. These videos, which are freely available on YouTube, are approachable introductions to the most challenging aspects of multiple driver experiments. The video series consists of three sections: (1) a general introduction to the videos; (2) essential background information, e.g. Setting Up a Driver Inventory and Experimental Design for Multiple Driver Experiments, and (3) topical tutorials that explore specific aspects of multiple driver experiments, e.g. Microevolution and Incorporating Environmental Realism. These videos complement Working Group 149's Decision Support Tool and MEDDLE simulation software, but were developed as a result of consultation with early career researchers, who expressed a strong preference for videos over traditional tutorial formats. Limited release of the first videos has been overwhelmingly positive: students enjoyed the video's informal style, short length, and familiar YouTube format. Current work to develop multilingual transcripts for each video will extend their reach and encourage further alignment of multiple driver research efforts.

Loosing C as a strategy against ocean acidification in CCM efficient algae

Authors: Kunshan Gao, Jiazhen Sun, Tifeng Wang, Ruiping Huang, Xiangqi Yi, Di Zhang, John Beardall, David A. Hutchins, Gang Li, Guang Gao

Presenter: **Kunshan Gao**

Oxygen is essential to most marine organisms, but its concentrations are declining in both open ocean and nearshore waters as a consequence of global warming and coastal eutrophication. As a result, the extent of hypoxic waters is expanding and habitable environments for a wide range of marine biota are deteriorating. At the same time, increasing anthropogenic CO_2 emissions are leading to ocean acidification and a consequent drop in pO_2/pC O_2. However, it is still unknown how marine photosynthesis will respond to climate-driven deoxygenation in combination with ocean acidification. Here, we show that under low O_2 experimental conditions, the diatom Thalassiosira weissflogii grows faster, respires less and has faster rates of photosynthesis. CO_2 concentrating mechanisms (CCMs) are significantly up-regulated under low O_2 conditions, although this is counteracted to some extent by elevated CO_2 concentrations. Stimulation of CCMs is associated with inhibition of photorespiration as Rubisco-catalyzed carboxylation and oxygenation shift to favor CO_2 fixation, which in turn enhances photosynthesis and net O_2 production. Field measurements show increased phytoplankton primary productivity at reduced O2 concentrations, supporting our laboratory findings. Deoxygenation can thus stimulate algal photosynthesis, suggesting some marine primary producers may benefit from anthropogenic reductions in ocean O_2/CO_2 ratios.

Endangered species in hypoxia environment: analysis of the impact of hypoxia to the prey of the endangered endemic Maugean skate in Macquarie harbour as an indirect threat

Authors: Marion Angelini, Jayson Semmens, Jeff Ross, Quinn Fitzgibbon, Jeremy Lyle, Kilian Stehfest

Presenter: **Marion Angelini**

Low dissolved oxygen (hypoxia) is now considered a major threat to marine ecosystems. Natural circumstances can cause depletion of oxygen, but human activities exacerbate this phenomenon. Given the highly stratified water column of Macquarie Harbour (West Tasmania, Australia), with naturally low mid- and bottom-layer dissolved oxygen (DO) and the presence of anthropogenic inputs that can further lower DO, this site provides a unique opportunity to study the impact of hypoxia on marine biota. Furthermore, the harbour hosts an endangered endemic species, the Maugean Skate, for which it is crucial to determine the potential threats to its continued presence in the harbour. Until now, studies have focused on the direct impacts of decreasing DO on this skate; in this study, we focus on the indirect threat, namely the response of their prey to the degrading health of the environment. The key prey species are crustaceans, one of the most sensitive taxon to hypoxia. Firstly, field assessments of abundance and distribution of two key skate prey species, the crab *Paragrapsus gaimardii* and the shrimp *Palaemon* spp., will be compared to benthic conditions. Following these assessments, respirometry, blood chemistry and behaviour analysis of the crab species in response to low DO conditions, will provide information on how the skate's prey distribution/abundance may change in response to the changing environment in Macquarie Harbour. By analysing the responses of benthic crustaceans to DO, this study may also provide a method for assessing the early stages of hypoxia in an environment.

Understanding the interactive effects of Ocean Acidification and the availability of iron on the two Southern Ocean key phytoplankton groups - diatoms and cryptophytes

Authors: Marianne G. Camoying, Scarlett Trimborn

Presenter: **Marianne Camoying**

Long-term phytoplankton monitoring studies, specifically in the coastal areas of the Western Antarctic Peninsula, have shown the recurring succession of diatoms and cryptophytes wherein diatoms usually dominate during the early summer when Fe concentrations are high, which are then replaced by cryptophytes in late summer at lower Fe availability. Laboratory incubation experiments were conducted to examine how increasing pCO_2 levels (400, 1000 and in case of the diatom also 1400 µatm) and different iron availability (0.2 and 0.9 nM) will impact the two Southern Ocean phytoplankton key species Pseudo-nitzschia subcurvata and Geminigera cryophila. Results of this study exhibited a different pattern between the two species as the cryptophyte manifested generally lowered growth rates and photochemical efficiencies compared to the diatom Pseudo-nitzschia subcurvata for all pCO_2-Fe treatment combinations. This suggests that G. cryophila had higher Fe requirement than the latter. The diatom was particularly sensitive to increasing pCO_2, as growth strongly declined with increasing pCO_2, this negative response was even more pronounced under low Fe availability. In comparison, growth of the cryptophyte was stimulated by high pCO_2 under high Fe availability, but remained unaffected under low Fe availability. Hence, the two species showed varying responses wherein G. cryophila appears to be less vulnerable to ocean acidification yet greatly affected by Fe-limitation while the susceptibility of P. subcurvata to OA is enhanced under Fe-deplete conditions.

Arctic Sensitivity? Shifting Species Distributions due to Changing Environmental Drivers

Authors: Paul E. Renaud, Philip Wallhead, Jonne Kotta, Maria Włodarska-Kowalczuk, Richard Bellerby, Dag Slagstad, Merli Rätsep, Piotr Kukliński

Presenter: **Paul Renaud**

Arctic marine ecosystems are commonly assumed to be highly sensitive, and their structure and function are predicted to suffer significantly from ongoing climate change. Community shifts are likely to result from changes in key physico-chemical drivers, such as increased temperature and CO_2, but there is little autecological data on most Arctic species to support any specific predictions as to how sensitive they are, or how future communities may be structured. Lacking such empirical data, we extracted collection records for 90 Arctic and boreal taxa from the Barents Sea region from the OBIS database. A coupled climate-ocean model (SINMOD) was used to both hindcast and project temperature and carbonate saturation states (omega) for sample locations. These data provided ´realized niche´ distributions in three dimensions (depth, temperature, omega) for each benthic taxon, and this niche space was compared with projected values for these variables in the region for 2090-2099. Preliminary results indicate that, contrary to many predictions, calcifying taxa are no more sensitive to changing environmental conditions than non-calcifiers. In addition, Arctic taxa were similarly no more susceptible to predicted changes than boreal taxa. These results highlight the weakness of general statements regarding sensitivity of taxa on biogeographic or physiological grounds, and suggest that more basic biological data on Arctic taxa are needed for improved projections of climate impacts.

The IMBeR Ocean Data Hub: linking high-value global data sets online to inspire analyses and exchange.

Authors: Tilla Roy, Laurent Bopp, Eric Galbraith, Daniele Bianchi, Pearse Buchanan, Matthew Burgess, and the wider IMBeR data hub team

Presenter: **Tilla Roy**

The IMBeR ocean data hub is a new, online community initiative that is providing a ‘field-guide’ to high-value data products that can be used to drive, constrain, and evaluate global ocean models and their associated fisheries/ecosystem components. The data products may be used to force past, present, and future model experiments and can be downloaded via the links provided on the hub. Our approach is actively multidisciplinary and includes dedicated platforms for gathering physical, biogeochemical, ecological, and social data sets that are considered critical to understanding how the ocean—and everything in it—functions, interacts, and responds to anthropogenically- and climate-driven change. The community driving this data hub is composed of IMBeR-related and associated researchers working at the global scale.

The mission is to provide an easily comprehensible resource for a broad range of users and scientists, thereby raising the level of awareness and use of the available data and reducing the boundary of expert knowledge needed to make a pragmatic selection of data products with confidence. The hub provides an internally-consistent online framework to—with as little effort as possible—i) browse key information on each data product, ii) facilitate access to the data depositories, and, iii) share detailed, product-specific practical knowledge amongst users. This framework will assist users, inspire new aspects of data analyses and model-data comparison, and encourage exchange across the greater oceanic research community.

Arctic diatom Chaetoceros socialis showed high resilience under future projected CO_2 concentrations

Authors: Haimanti Biswas, Anya Waite

Presenter: **Haimanti Biswas**

Ongoing climate change is impacting the earth's sensitive ecosystems such as those in the Arctic Ocean. The Arctic region is experiencing a rapid increase in sea surface temperature and CO_2 levels as well as changes in salinity due to loss of sea ice. Phytoplankton, forming the base of the food web, are highly sensitive to environmental change, and may exert strong positive feedback to the global warming by reducing carbon sequestration potential via the biological carbon pump under the changing climate. To address this issue, a laboratory experiment was conducted with the Arctic diatom *Chaetoceros socialis* [strain Cpd2.2014 isolated from Kongs fjord, Svalbard in 2014]. The species was grown in the laboratory at 4°C temperature under low and high CO_2 concentrations (240µatm and 800µatm). Two light levels (50µmol and 100µmol Einstein m^{-2} s^{-1}) were selected to create a multi-stressor matrix of light and CO_2 conditions in the future ocean. The culture was pre-acclimatized under the defined laboratory conditions for several generations before conducting the main experiment. We show that *C. socialis* was highly resilient to increasing CO_2 levels and was able to accumulate biomass (particulate organic carbon, particulate nitrogen) almost equally under low and high CO_2 levels. Cellular particulate organic carbon, particulate nitrogen and C:N ratio showed no significant difference between the treatments indicating no apparent impact of CO_2 or light on carbon and nitrogen metabolism. Light seemed to favour a strong carbon concentration mechanism under low CO_2 concentrations. Pigment signatures showed high degree of light adaptability under the two light levels, although a signal for non photochemical quenching was noticed under high light at both CO_2 levels. Our study suggests that for this Arctic bloom forming diatom, no significant change in carbon capture is likely to occur in the future ocean based on changes in light and CO_2 alone. However, the temperature impacts would need to be resolved.

Are we ready for populations (meta)genomics ? Challenges for understanding abiotic drivers shaping genetic patterns of plankton in the Mediterranean Sea.

Authors: Ophélie Da Silva, Ser-Giacomi Enrico, Leconte Jade, Pelletier Éric, Madoui Mohammed-Amin, Jaillon Olivier, Ayata Sakina-Dorothée, Bittner Lucie

Presenter: **Ophélie Da Silva**

The Mediterranean Sea is a miniature model of oceans which could provide answers on how Ocean Global Change will impact marine realm. This sea is characterized by tortuous seashores, many environmental gradients and a dynamical circulation. Among survey techniques on marine biomes, high-throughput sequencing methods went through constant developments over the last decade and allows today the unprecedented access to the natural communities and their potential activities. Especially, genetic diversity, which allows populations to adapt to a changing environment, can be now explored in depth and for multiple actors simultaneously. In the Mediterranean Sea, only few studies have tried yet to link the genetic diversity and its potential drivers (e.g. environmental parameters, circulation), especially for planktonic protists. In this context, the aim of our study is to understand which spatial factors influence the genomics of planktonic protist populations in the heterogeneous Mediterranean environment. A whole pipeline of analysis had been built in order to infer the population structure of protists from the Tara Oceans Expedition metagenomics data. In parallel, we integrated geographical data, environmental data and dispersal simulations from a biophysical model. We then performed mantel tests and multiple linear regressions to assess the relationship between the variables (i.e. metagenomics, geography, environment and circulation).

Our study had faced several issues : for instance, the lack of genomic references, the quantification of connectivity with biophysical model, or even the identification of relevant environmental variables. We nevertheless detected trends, which allow making promising and innovative assumptions about mechanisms shaping metagenomic diversity of largely poorly studied but incredibly diversified planktonic protists. In conclusion, our population (meta)genomics study, by providing clues on abiotic drivers influencing underlooked organisms in their changing environment, is an original work that could be extended to other oceanic regions.

Spatiotemporal Variability of Coral Reef Biogeochemistry

Authors: Deniz DISA, Matthias Münnich and Nicolas Gruber

Presenter: **Deniz DISA**

When investigating the impact of e.g., ocean warming and ocean acidification on coral reefs, it is commonly assumed that all corals within a reef are exposed to the same temperature, nutrients, pH, and saturation state with respect to mineral forms of CaCO3. Yet, the relatively limited measurements indicate a substantial amount of within reef variance in these conditions, leading to substantial variations in exposure for the individual corals. These variations are the result of within reef variations in photosynthesis, respiration, and calcification interacting with the three-dimensional flow over the coral reef leading to a complex time-varying mosaic of conditions, which need to be known in order to fully assess the health of a coral reef. To study the magnitude and processes controlling this mosaic, we incorporated a module simulating coral polyp respiration, photosynthesis, and calcification into a 3D numerical ocean model (COAWST), setup at a horizontal resolution of about 20 meters for the northern shore of Moorea Island. Preliminary results from our model simulations show that the metabolic rates of the corals indeed exhibit substantial spatiotemporal variability in response to variations in the physical and chemical conditions they are exposed to. Within reef variations light and flow rates are the main drivers of these variabilities. Light matters as it drives not only photosynthesis, but also coral calcification, resulting in a strong uptake of dissolved inorganic carbon (DIC) by the coral and low DIC in the surrounding seawater. During the day, this uptake exceeds the calcification driven uptake of alkalinity (Alk), leading to a strong reduction in the pH and pCO_2 of the surrounding waters. At night, the situation reverses, leading to a strong release of DIC, increasing pH and pCO_2. The flow regime matters not only by transporting and mixing the gradients induced by the corals, but also because it controls the rate at which corals can take up of DIC and Alk. The spatiotemporal variations in ocean chemistry induced by these processes are of similar magnitude as the decadal changes induced by ocean acidification. Thus, in order to fully assess the impact of large-scale changes in the environmental conditions on corals, it is necessary to also assess how these conditions are locally modified by the corals themselves.

Can we use open ocean biomes as an integrated measure for future physio-biogeochemical change?

Authors: Nadine Goris, Siv Lauvset, Jörg Schwinger

Presenter: **Nadine Goris**

Open ocean biomes capture different levels of biological productivity at the scale of ocean gyres. Biological productivity is dependent on nutrient and light availability, which is set by the physical environment. Hence different open ocean biomes represent not only different levels of biological productivity but moreover

regimes of different oceanic mixing, temperature, nutrient availability and ice cover. At the same time, biological production is an important driver of the annual cycle of the oceanic partial pressure (pCO_2) and open ocean biomes can be seen as a proxy for its seasonal variability. Several studies have shown that the contemporary annual cycle of oceanic pCO_2 is regionally related to the a model's future carbon uptake, which could lead to biomes being powerful predictors of future oceanic carbon uptake. Given these characteristics, it seems intuitive that open ocean biomes can be used as a tool to holistically quantify future physio-biogeochemical change. However, common definitions of open ocean biomes use static thresholds as criteria, which cannot readily be applied to results of state-of-the art climate models because of model-biases. On the other hand, when dynamical criteria for biomes are present, some models fit the dynamical criteria but do not reproduce the associated level of biological productivity. Finding criteria for accurately defining open ocean biomes that actually relate to a model's levels of biological productivity remains a challenge and hence future changes in open ocean biomes remain difficult to quantify.
In face of this challenge, we propose to use a new criterion for defining open ocean biomes that utilizes the annual cycle of oceanic pCO_2 and relates this dynamical criterium to statical productivity thresholds for each considered model. Moreover, we relate the dynamical criterion to nutrient availability, mixing and ice cover. The new approach allows us to evaluate the performance of each model in a dynamical and holistic way and to utilize well-performing models to project future changes in open ocean biomes.

Exploring the mechanisms underlying diverse responses to climate change in the FishMIP project

Authors: Ryan Heneghan, Eric Galbraith, Tyler Eddy, Derek Tittensor, Cheryl Harrison, Olivier Maury, Jerome Guiet, Beth Fulton, Ricardo Oliveros-Ramos, Cathy Bulman, Marta Coll, Jeroen Steenbeek, Hubert Du Pontavice, Didier Gascuel, Phoebe Woodworth-Jefcoats, Coll

Presenter: **Ryan Heneghan**

Marine ecosystem models are extremely heterogeneous, reflecting their diversity of purpose and scope, and a lack of understanding of critical processes. As a result, model intercomparison is crucial to gauge the credibility of responses to projected future climate change, and to highlight gaps in our understanding of the marine ecosystem. The international Fisheries and Marine Ecosystem Model Intercomparison Project (FishMIP) brings together over a dozen regional and global marine ecosystem models, d driven by common environmental forcings. Here we explore the model and ecological mechanisms that underlie the responses of FishMIP models to two key climate drivers – primary production and temperature. I will begin by discussing the ways in which temperature and primary production are incorporated into participating models, before exploring our results from a series of simulation experiments in which primary production and temperature inputs were manipulated to isolate the response to individual climate components. I will finish by exploring how the results of this study help to clarify our understanding of the range of projections of the marine environment over the coming century, and how they help to identify the most pressing processes to improve in marine ecosystem models.

Using machine learning to assess how climate change alters ocean biogeochemical provinces

Authors: Siv K. Lauvset, Nadine Goris

Presenter: **Siv Lauvset**

Terrestrial ecosystems are categorized into biomes, which are regions of similar climate and dominant plant types, but for the oceans a similar categorization has proven to be more challenging. Several concepts of partitioning the global oceans have been proposed, usually using some combination of key characteristics such as temperature and mixed layer depth. Also contrasting terrestrial studies, machine learning techniques, apart from self-organizing maps, have to our knowledge not commonly been applied in the ocean. In this study several supervised machine learning methods were used to classify the ocean into biogeochemical regions. The initial classification was based on Longhurst provinces. A separate classification was made for each year using annual mean model output. In this way the spatio-temporal changes of the oceanic regions can be assessed and correlated with changes in ocean climate (e.g. temperature, salinity, currents, stratification), oxygen, and carbon cycle. Presented here are results of the analysis using output from the NorESM model for the historical run, and the RCP8.5 and RCP2.6 future emission scenarios.

Sensitivity of Ocean Biogeochemistry to the Iron Supply from The Antarctic Ice Sheet explored with a Biogeochemical Model

Authors: Renaud Person, Olivier Aumont, Martin Vancoppenolle, Laurent Bopp

Presenter: **Renaud Person**

Iron (Fe) delivery by the Antarctic Ice Sheet (AIS) through ice shelf and iceberg melting enhances primary productivity in the largely iron-limited Southern Ocean (SO). To explore this fertilization capacity, we implemented a simple representation of the AIS iron source in the global ocean biogeochemical model NEMO-PISCES. We evaluated the response of Fe, surface chlorophyll, primary production and carbon export to the magnitude and hypothesized vertical distributions of the AIS Fe fluxes. We will show that (i) surface Fe and chlorophyll concentrations are increased up to 25% and 12%, respectively, over the whole SO, (ii) the AIS Fe delivery is found to have a relatively modest impact on SO primary production and C export but significant in the Atlantic sector and along the coast of Antarctica, (iii) the response of surface Fe and chlorophyll is maximum downstream of the tip of the Antarctic Peninsula and along the East Antarctic coasts, (iv) icebergs are predicted to have a much larger impact on Fe, surface chlorophyll and primary productivity than ice shelves in the SO, (v) the iceberg Fe delivery below the mixed layer may, depending on its assumed vertical distribution, fuel a non-negligible subsurface reservoir of Fe, and (vi) the Fe supply is effective all year round and seasonal variations in iceberg melting have regional impacts which are almost negligible for annual-mean primary productivity and C export at the scale of the SO.

Natural and anthropogenic atmospheric deposition and their effects on bacterial community assembly in the northwestern Mediterranean

Authors: Francesc Peters, Marín-Beltrán I., Logue J.B., Andersson A.F.

Presenter: **Francesc Peters**

Atmospheric inputs from natural and anthropogenic sources are increasing in the oceans due to desertification and industrialization, respectively. While the impact of mineral dust in the Mediterranean (mainly from the Saharan desert) on phytoplankton has been the primary focus of research, the effect of aerosols, especially from anthropogenic sources, on marine bacterial assemblages remains poorly studied. Bacteria are active competitors of phytoplankton at the low ambient nutrient concentrations. In addition, anthropogenic aerosols also carry a larger share of organic carbon that bacteria can potentially take advantage of. We assessed the effect of Saharan dust and anthropogenic aerosols on marine bacterioplankton community composition across a spatial and temporal range of trophic conditions in the northwestern Mediterranean Sea. Results from 16S rDNA sequencing showed that overall bacterial diversity varied with seasonality and geographical location, but not so much with the type of aerosol added. Still, atmospheric deposition yielded significant changes in community composition at certain places and during certain times of the year, which accounted for shifts in the bacterial community's relative abundance of up to 28%. The effect of aerosols was overall greatest in summer, both types of atmospheric particles favoring the growth of Alphaproteobacteria, Betaproteobacteria, and Cyanobacteria in the location with the highest anthropogenic footprint. Other bacterial groups were stimulated by one or the other aerosol depending on the season and location. Although large uncertainties seem to be related to initial nutrient and community composition, anthropogenic aerosols increased mainly the growth of groups belonging to the phylum Bacteriodetes (Cytophagia, Flavobacteriia and Sphingobacteriia), while Saharan dust stimulated primarily Cyanobacteria and, more specifically, Synechococcus. As upper ocean nutrient limitation becomes exacerbated with global warming and aerosol deposition increases, we may expect larger impacts on overall bacterial stimulation and bacterial composition shifts.

Argonauts as indicators of long-term interannual variability in the Southeastern Brazilian Bight

Authors: Carolina C. Araújo, Gasalla M.A.

Presenter: **Carolina Araújo**

Cephalopods are keystone players in coastal, oceanic and deep-sea food webs, and because of their rapid growth, short life spans, and plasticity respond rapidly to environmental change affecting upper and lower trophic levels. In previous studies, we examined the biodiversity and spatio-temporal distribution patterns of cephalopod paralarvae in a historical archive of plankton samples collected across the continental shelf (up to 200m isobath) of the Southeastern Brazilian Bight from 1974 to 2010. These investigations indicated a strong link between paralarval diversity and abundance and the dynamics of water masses. Interestingly, Argonautidae represented more than 50% of all paralarvae found, and was the only cephalopod group to display high interannual variability in abundance. Here, we examined whether the distribution and abundance of Argonautidae paralarvae could be explained by major oceanic-atmospheric events over the Southwestern Atlantic Ocean. During the sampling period, conspicuous abundance peaks of Argonautidae paralarvae were observed in the years 1976 and 2002, which corresponded to conditions of moderate ENSO events. This potentially causal relationship has been similarly found for the sardines and anchovy eggs in the study area. Moderate El Niño events also correlated to the lowest record of sea surface temperatures in a coastal upwelling center (Cabo Frio) in the northern sector of the study area. This study highlights the

importance of long-term observations to verify how fluctuations of planktonic species reflect environmental changes. Moreover, we suggest Argonautidae paralarvae as sensitive reporters of interannual variability of environmental conditions in the Southeastern Brazilian Bight.

Future scenarios of Food Web dynamics in the Rocas Atoll's coral reef ecosystem (South Atlantic) under climate change

Authors: Leonardo Capitani, Ronaldo Angelini, Julio Araujo, Guilherme Longo

Presenter: **Leonardo Capitani**

Climate change is shifting the abundance and distribution of marine species with consequences for ecosystem functioning, seafood supply, management and conservation. Quantifying future trends in natural ecosystems due to climate change, including estimates of uncertainties, is critical in order to understand the biodiversity adaptation. The objectives of our study were to do a quantitative description of the Rocas Atoll's coral reef ecosystem, a pristine environment, and to explore the potential effects of global warming on the Rocas Atoll's ecosystem. We employed input values based on fish biomass underwater visual census (2012 reference year) and local scientific literature to balance the food web model using Ecopath with Ecosim approach. Next, we included the impact of rising temperatures, relative to species' thermal ranges, in order to assess the cumulative effect of future climate change on selected target species. This impact was tested using future temperature values from IPCC Representative Concentration Pathways (RCPs) scenarios. The climate-change scenarios were run for a historical (2012-2018) and future period (2018-2100). We showed that, Rocas Atoll's coral reef ecosystem has a higher overall biomass within the first trophic level: algae groups account for more than 90% of the total living biomass and the majority (65%) of the energy flows to trophic level II are originated from detritus rather than from primary productivity, indicating that secondary production is based mainly on detritus and net primary production enters to coral reef food chain through heterotrophic benthic organisms. Transfer efficiency from primary producers and detritus were 7.86% and 9.98% respectively. The Keystone species identified are (in order): lemon shark (Negaprion brevirostris), Sea birds, zooplankton, Lutjanus jocu and Carangidae fish group. Our modeling simulations showed that the stress of warming reduced energy flows from the first trophic level (primary producers and detritus) to the second (herbivores), and from the second to the third trophic level (carnivores). Warming also reduced the efficiency of energy transfer from primary producers and detritus to herbivores and detritivores, and the living biomass of detritivores, herbivores, and carnivores. Our results show how future climate change can potentially weaken marine food webs through reduced energy flow to higher trophic levels and a shift towards a more detritus- based system, leading to food web simplification and altered producer–consumer dynamics, both of which have important implications for the ecosystem resilience and functioning.

Session 19: Ocean governance in the face of change: confronting the challenge of rebuilding fish stocks, fisheries and viable coastal communities and preparing for future change

A three-dimensional perspective on creating viable fishing communities amidst a changing ocean

Authors: Prateep Kumar Nayak

Presenter: **Prateep Nayak**

Rebuilding fishing communities as viable entities cannot succeed without first responding to existing vulnerabilities and creating pathways toward viability. However, both vulnerability and viability are hard to define and remain as elusive terms that mean different things to different people. This paper aims to discuss a three-dimensional view on vulnerability-viability that can inform governance responses in a changing ocean, with particular reference to small-scale fisheries communities. The three-dimensional view of vulnerability-viability will include critical examination of (1) the absence or presence of wellbeing, (2) lack of or better access to various types of capitals, and (3) loss or building of resilience as contributing factors. The underlying assumption is that vulnerability is a “wicked problem” due to which fishing communities will continue to remain vulnerable to multiple drivers, but they also have certain strengths. These strengths are real - building on these existing strengths may be an effective strategy to increase viability. Case study examples from Bay of Bengal, Java sea and south China sea will be used to outline an initial list of possible strategies that can be used to identify and build on the strengths of fishing communities to counter the various challenges they face and achieve long-term viability?

Sustainability through transdisciplinarity: A framework for the Ocean’s Sustainable Development Goal (SDG) in the context of small-scale fisheries governance

Authors: Alicia Said, Ratana Chuenpagdee

Presenter: **Alicia Said**

The UN Sustainable Development Goal for the ocean (SDG14) calls for effective governance systems that are robust enough to resolve the prevailing conundrum of fisheries sustainability. Although major advances through enhanced scientific production of knowledge have been targeted towards addressing the fisheries crisis, we are still lagging in adopting a holistic approach towards fisheries sustainability especially in the context of small-scale fisheries. In this article, it is argued that global concerns such as overfishing and depleted marine ecosystems cannot be resolved through mere technical fixes, for these do not address the multifaceted realities hovering within the bigger picture of fishing communities. If they are to be effective, solutions need to be harmonized to the social, economic, political and ecological systems within which they are implemented, and it is asserted that this can be principally attained through a transdisciplinarity lens. We recognize that transidisciplinarity is the right toolbox for the way forward in fisheries and ocean governance as it offers an interactive platform that goes between, across and beyond disciplines ‘all at once’. This also comprises an ongoing process of bottom-up participation of stakeholders who engage in an open learning process that is experimental, interactive and deliberative. Through transidisciplinarity we hope

that the co-production and cross-fertilization of knowledges engenders ownership amongst multiple disciplines, and provides a common language that strengthens collaboration in our common mission for sustainable marine resource management.

Climate Challenges to Fisheries Management in a Rapidly Changing Ecosystem

Authors: Lisa Kerr, Andrew Pershing, Katherine Mills, Samuel Truesdell, Gavin Fay, Steve Cadrin, Jonathan Cummings, Sarah Gaichas, Min-Yang Lee, Anna Birkenbach

Presenter: **Lisa Kerr**

The Northeast U.S. shelf ecosystem has warmed rapidly, with a long-term warming trend that is four times the global average rate and recent decadal warming that is faster than most of the global ocean. Climate-mediated change in this region is unprecedented, and the impacts of climate change on marine fisheries resources, such as changes in productivity and shifts in distribution, are increasing. These changes are challenging the U.S. fishery management system and as the effects of climate change become more apparent, acknowledging the realities of non-stationarity and developing methods to integrate climate information into the fishery management process will be essential for sustainable fisheries management in this century. The goal of this research is to review the U.S. fishery management process and consider how climate change impacts different components of the system. We evaluate the following aspects of the management process: 1) scientific components (system observations and understanding, and stock assessment), 2) policy and governance components (risk tolerance, setting catch advice, and allocation of quota), and 3) regulatory components (monitoring, enforcement, fishing behavior and catch/bycatch). We focus on how changes in species distribution and productivity impact the different components of the fishery management system. We identify short-term solutions that could be implemented within current management or fishery decisions and highlight longer-term solutions that may require more systematic changes or adjustments to major policies. Our analysis is focused on commercial fisheries and the federal fisheries management system in the Northeast U. S., but the conclusions apply broadly to fisheries around the world.

Taking stock of research on gender, fisheries and aquaculture as we seek to improve ocean governance in the face of change

Authors: Barbara Neis, Christine Knott, Nicole Power, Katia Frangoudes

Presenter: **Barbara Neis**

Marine fisheries and aquaculture comprise marine ecology, harvesting, processing, distribution, marketing, sales and transportation, as well as fisheries development, science and management and related policies and practices. They also include the social reproduction of households and communities involved in the sectors. Since at least the 1980s feminist scholars and others in the North, and increasingly in countries of the South, have been carrying out research on the very active roles played by women in fisheries and aquaculture and related communities, as well as on masculinities and gender relations more broadly at various points from ocean to plate. This presentation will present the results of a critical review of key reports, publications, and other documents on gender, fisheries and aquaculture since 1980, assess existing North Atlantic research in relation to key parts of the international literature on this subject, outline some of the strengths, weaknesses and gaps in our current understanding of gender and fisheries and aquaculture that need to be addressed in efforts to improve ocean governance in the face of change.

Fishing for health: Is there alignment in the world's national policies for fisheries and aquaculture to health and nutrition?

Authors: J. Zachary Koehn, Edward H. Allison, Ray Hilborn, Chris M. Anderson

Presenter: **Zach Koehn**

The nutritional benefits of seafood are widely recognized, but there is an opaque understanding on the connection of fisheries and aquaculture to food security and nutrition policies. Fishery and aquaculture policy is production-focused on objectives for biological and economic sustainability; the prevailing assumption is that contributions of fisheries to communities are considered in terms of income and employment: not vitamins and minerals. On the other end, food security and nutrition policies such as dietary guidelines tend to recommend seafood consumption, but may not consider how to integrate seafood production into the food system and as a likely consequence, consumption remains far below recommended guidelines across much of the world. This lack of alignment is a problem: the hidden hunger of micronutrient deficiency and overconsumption of nutrient-poor energy-dense proteins is a serious public health concern in developing and developed country contexts. Recently academic literature has begun to focus attention on the importance of fish and shellfish production to public health particularly for human communities that are most vulnerable to diet-related disease, especially within the context external climate variability. Given that we know seafood is nutrient rich and that among animal-sourced proteins fish and shellfish have comparatively low environmental impacts, improving the utilization of nutrient-rich seafood can maximize its contribution to alleviating nutrient deficiencies while minimizing global environmental impacts. Unfortunately, we have yet to determine the degree of integration in policies between fishery and aquaculture sector and the food and nutrition sector around the world. If strategic interventions are to improve the connection, a systematic analysis to establish a baseline is required; that is the primary goal of this research. To meet this goal we developed semi-quantitative method that implements a four score metric to evaluate how well (a) national fishery policies include food security and nutrition objectives and (b) health policies identify the role of fish in intervention strategies. Results of this analysis develop a global distribution of where the goals of fishery and health national policies are most and least integrated. Additionally, scores for the two sectors are regressed over existing global indicators of governance, socioeconomics, health and fisheries to determine conditions under which greater integration between sector policies tends to arise. Especially given the dual specters of hidden hunger and global environmental change, fisheries governance must better integrate with other sectors of society, including public health and the food system. As fisheries continue to rebuild and the benefits from sustainable management are realized it is imperative that discussions take place to ensure that these benefits extend outside of purely biological or profit-based objectives into more inclusive improvements that can be witnessed by all.

Economic and social benefits of fisheries rebuilding: six Canadian case studies

Authors: Louise Teh, U. Rashid Sumaila

Presenter: **Louise Teh**

Many fish populations in Canada are depleted and at risk of further decline, jeopardising the social, economic, and health well-being of thousands of Canadians. However, rebuilding plans have been developed for only 3 fish stocks nationally, thus highlighting the urgency to intensify Canada's fisheries rebuilding efforts.

One of the challenges facing rebuilding fisheries is that it invariably involves forgoing certain short-term benefits in order to gain the benefits of rebuilt fish stocks in the medium and long term. To investigate the

economic and social implications of rebuilding Canada's fisheries, this study analysed the socio-economic costs and benefits of rebuilding Canada's fisheries under six different scenarios of species' recovery rate and management strategies. We conduct the analysis for six fish stocks: i) Pacific herring Central Coast stock; ii) West Coast Vancouver Island Chinook salmon, both AABM and ISBM components; iii) Yelloweye rockfish outside population; iv) Atlantic cod NAFO Division 2J3KL; v) Gulf Atlantic herring spring spawners NAFO Division 4T; and vi) Atlantic redfish Units 1 & 2.

Our results indicate that for the time period studied, all case study fish stocks except yelloweye rockfish, which is a long-lived species with low natural growth rate, would likely experience economic gains relative to the status quo from fisheries rebuilding. In most cases, a management strategy involving fishery closure results in higher potential economic gains compared to a low fishing strategy overall, regardless of the rate of fish stock recovery. An intergenerational discounting approach, which seeks to explicitly incorporate the interest of future generations in the analysis, increases projected economic benefits compared to conventional discounting, thereby emphasizing the importance of taking a long-term perspective to fisheries rebuilding.

In terms of social impact, an estimated 5,100 fishers are currently involved in fisheries for the case study fish stocks, and thus can potentially benefit from this projected increase in fish catch in the future. The overall benefits of rebuilding are magnified if we consider the thousands more in coastal communities who have food, cultural, and other social connections to the case study fish stocks. While rebuilding may likely incur short term costs for fishers and coastal communities, our results suggest that bearing this short-term cost can lead to economic benefits which in the long term are an improvement over maintaining the status quo. This suggests that accounting for social impacts is crucial in developing rebuilding plans, especially in terms of access to, and allocation of, projected economic benefits from rebuilt fish stocks in the future.

Access theory and marine fisheries: Integrating analyses of access to resources and to markets in the Newfoundland context

Authors: Courtenay E. Parlee, Paul Foley, Grenfell Campus

Presenter: **Courtenay Parlee**

Using a social science theory of access, this paper will analyze social relationships that enable or constrain actors to benefit from fisheries. This theory has recently been used by marine social scientists to understand and explain political and policy dimensions of access to fisheries and oceans spaces. These applications tend to emphasize dynamics of physical and legal access to marine resources and spaces, rather than mapping the social relations, conditions and flows that affect the ability of actors to benefit from fisheries, including market access dynamics. Thus, this paper seeks to broaden the scope of analyses by examining both access to fisheries and access to markets. It does so by tracing mechanisms by which fisheries benefits are gained, maintained and controlled in Newfoundland and Labrador fisheries. Using a document analysis and literature review, the findings suggest that the ability of actors to benefit from fisheries are influenced by different patterns of access social-ecological relations, institutions and power dynamics. In addition to persistent social relationships and institutions that protect small-scale fisheries, the ability to benefit from fisheries are also increasingly impacted by combined, changing and cumulative effects of two general processes: 1) "creeping enclosure" resource access processes and 2) proliferating, globalized and corporate-dominated food quality, safety, security, and sustainability market access processes. The paper argues that understanding the distribution of benefits in fisheries requires an innovative and integrated analysis of mechanisms that enable or constrain access to markets and to fisheries in the context of social-ecological change. From a practical perspective, this paper suggests that decision makers can better address questions about the distribution of benefits by integrating evidence and knowledge about the ways in which benefits from fisheries are influenced by a range of factors including rapidly changing environmental conditions, fisheries management and other government policies, markets, capital, technologies, different forms of knowledge, gender, ethnicity and social class.

Key Words: Access; Benefits; Resources; Fisheries; Markets; Newfoundland and Labrador.

Deploying I-ADApT for an assessment of the Coastal Communities of Northern Newfoundland, Canada

Authors: Jack Daly, Ratana Chuenpagdee

Presenter: **Jack Daly**

Coastal communities are facing increasing pressure globally, from both ecological and social stressors. Newfoundland and Labrador is no stranger to such pressures and is undergoing a transition currently due to declining rural populations and diminishing fishing stocks. The Great Northern Peninsula, one of the most fishery reliant regions of the province, offers, for instance, a window into how rural, coastal communities are coping in the face of new social and ecological pressures, just twenty-five years after a cod collapse that severed a blow to the region. In order to take stock of and rapidly assess the current situation in the region, the I-ADApT Framework was deployed. I-ADApT, which refers to an Assessment based on Description and responses, and Appraisals for a Typology, is developed as a tool to examine the entire fisheries systems, looking in particular at what makes them vulnerable, governable, and sustainable. As a decision support tool, it helps researchers, policy actors, community members, and others to make decisions efficiently, triage and improve responses, and reduce vulnerability and enhance the resilience of coastal people. Findings from this approach show that community sustainability is enhanced when governance of resources, be it financial or otherwise, are led at the community or regional level, rather than through hierarchical regimes. The main contribution of this research is to systematically lay out the many factors facing coastal communities to inform policies that will reduce vulnerability and enhance resiliency. Providing systematic tools to strengthen coastal communities can directly aid in effective management of fish stocks and good governance of coastal areas.

The changing principles in Newfoundland and Labrador fisheries: A historical analysis

Authors: Nathan Stanley, Ratana Chuenpagdee

Presenter: **Nathan Stanley**

This paper investigates the history of changes in the governing principles of the Newfoundland and Labrador (NL) fisheries, and the policies which influenced or were affected by them. Ever since NL joined Canadian confederation in 1949, there have been numerous debates about fisheries management practices and goals. This study focuses on provincial and federal government policies, international obligations, socio-economic concerns, and other factors influencing the management of the fisheries from 1949 until the present day. This period has been marked by declining groundfish stocks, a moratorium on the northern cod fishery, and shifting focuses on available resources from the harvesting sector. Examining the extent to which the principles and policies play a part in this turbulent history will lay a foundation for a more successful management regime for Canada's Atlantic fisheries, and could possibly help inform international fisheries as well. Drawing from secondary sources, including peer-reviewed publications, government publications, fisheries reviews and recommendations from stakeholder councils, and news publications, our analysis reveals that principles such as precautionary, ecosystem-based approaches, and social justice result in changes in policies related to fleet ownership, access to resources, and fisheries upgrading. Yet, how these changes affect fisheries sustainability and viability of the fishing industries, especially small boat fisheries, need to be examined in the context of a changing climate, interaction with domestic and international markets, and other broader, international agreements.

Acceptability of aquaculture by local communities in Greece

Authors: Katia Frangoudes, Alexis Conides

Presenter: **Katia Frangoudes**

The first steps to develop intensive aquaculture in Greece were realised at the beginning of 1980’s and concretised in the mid of 1990’s with the adhesion of the country to the European Union. Intensive aquaculture was viewed by EU and Greek authorities as a source of economic development and employment in rural areas and remote islands that had few jobs opportunities and little touristic development. Aquaculture sector development was financially supported by the EU. Greek authorities had the objective to create a big number of aquaculture units with the idea that it will provide a high number of jobs.
At the beginning aquaculture units were established by self-employed persons (lawyers, medical doctors, biologists), mainly Greek, searching profitable sectors to invest their capital and also to take advantage of tEU subsidies. Many of these farms collapsed few years later due to the lack of knowledge and experience and also to the hostility of the local communities. Except for few of them, aquaculture did not turn into the promised new Eldorado of the Greek Economy. As result Greek aquaculture sector concentrated in the hands of few large companies. Small companies did not resist long in face of this big power. Nowadays these majors have encountered difficulties and some middle scales companies managed to develop.
The governance system supporting aquaculture development was poor and the first units were installed in places chosen by the farmers with only two criteria, the absence of archeologic ruins and tourist infrastructure. This principle of first arrived first served dominated the sector until the date that the EU required Member States to adopt planning schemes designating the areas devoted to aquaculture development. Planning scheme have been designed but still waiting for adoption by the Parliament and a Presidency Decree. Adoption of the planning scheme becomes urgent if Greece wants aquaculture to contribute to Blue Growth.
The causes for the non-adoption of the management plan by Greek authorities and the perception of aquaculture by Greek society is analysed from material collected through semi-structured interviews with the main actors at local and national levels and an internet survey.

Exploring the diversity of institutional arrangements in small-scale fisheries systems in the Wider-Caribbean Region

Authors: Eric Wade, Ana Spalding, Kelly Biedenweg

Presenter: **Eric Wade**

Global environmental change, economic uncertainty coupled with the inherent diversity of small scale fisheries are driving recent reforms in small-scale fisheries around the world. These changes are especially true for fisheries industries in the Wider-Caribbean region where communities and governments depend on a well-managed fishery to sustain social and economic well-being. With the goal of fostering the sustainable management of their resource, countries in the region are now looking at new ways of managing their industry amid uncertainties and threats. Understanding the interaction between stakeholder’s perceptions and responses to policy and institutional arrangements in small-scale fisheries represent an important connection that is central to understanding and fostering these reforms. This study investigates this interaction using three case studies in the Caribbean – Belize, Jamaica, and St. Lucia. This paper assesses the institutional and policy arrangements that govern the management of these systems. We contrast the recent introduction of Belize’s reform from an open access system to a rights-based fishery to policy arrangements in St. Lucia and Jamaica. The potential success of these policies brings with them an interaction of actors and institutions at the local, regional, and international scale that contributes to the compliance and adherence by resource users. In order to address our goals, we outline Belize's journey to implementing its new fisheries management system to those arrangements in St. Lucia and Jamaica through marine and coastal property rights framework. We further discuss these goals within the guiding principles of small-scale fisheries in Latin America and the Caribbean.

The future of Sakura shrimp fishery: a comparative analysis of two stories from Japan and Taiwan

Authors: Yinji Li

Presenter: **Yinji Li**

Japan and Taiwan are only two regions in the world where Sakura shrimp (Sergia Lucens) is taking place, Suruga Bay in Shizuoka Prefecture, Japan, and Donggang area in Pingtung County, Taiwan. In Japanese Sakura shrimp fishery, there was enormous resource depletion in 1970s, mainly due to excessive competition. To cope with the issue, a pooling system was introduced among fishermen in 1977, since then the catch volume has been kept in a stable way till recent years, where the resource has fallen down again. On the other hand, Taiwan faced their resource deterioration in late 1980s and in 2002. In response to such depletion, a full-scale control on catch was started in 1994 and strengthened from 2002. Its resource has been recovering since then, as can be seen from the catch volume of 2017 reached 1,689 tons, the highest in past 10 years, while in Japan fishermen have to close half of the fishing season due to extreme depletion in 2018. The aim of this study is three-fold. Firstly, it clarifies the history of Sakura shrimp fisheries in two regions. Secondly, it analyzes the differences of two governance systems as well as their impacts and effects on Sakura shrimp fishery. Lastly, it attempts to propose some important perspectives for the future of Sakura shrimp fishery.

"Who" participate and "who" are not in the internal governance systems and "how" does it relevant to adaptation to climate change? Insights from the selected fishing villages in the Coromandel Coast of Tamil Nadu, India.

Authors: Devendraraj Madhanagopal

Presenter: **Devendraraj Madhanagopal**

Significant studies have argued that the complexities of internal governance systems of small-scale fishing communities bring different outcomes in managing the fishery resources at the local levels, which, in turn, make impact on the higher levels of ocean governance. What is less explored, however, is how the complexities of internal governance systems associated with the power dynamics "include" and "exclude" certain stakeholders of the fisheries community, which impacts their collective adaptive capacity to respond to climate change and extremes. This paper, which arises from my doctoral work, by taking the case of selected self-governing small-scale fishing villages, which have the rich vulnerability history of climate change and coastal hazards and examines the power relations of the small-scale fisheries stakeholders and "who" possesses the power and "who" are not in the internal governance systems, and it attempts to correlate the "power-relations" among the fisheries stakeholders with adaptation to climate change. Intensive field visits were conducted to collect the data from the diverse stakeholders of small-scale fishing community. My analysis on the "power-relations" within and among the fishing villages reveals that

"inclusion", "exclusion" and "lobbying" have historical roots and it determines the levels of community resilience to respond to climate change and extremes. Highlighting the internal governance systems of the fishing community which structures the stakeholders on the basis of "power", this paper argues the understanding of "power-relations" among the small-scale fisheries stakeholders can enable a better understanding of how to plan for the future ocean governance in the face of climate change.

Politics of management of marine and fisheries resources (study of power relation between fisherman groups in Palabuhanratu steam power plant area)

Authors: Eva Royandi, Arif Satria and Saharuddin

Presenter: **Eva Royandi**

This study aims to analyze the structure of power relations between parties in the use of marine resources: (1) analyze the power of actors to access (control) rights-based marine resources, (2) analyze the power of actors to access structure-based and relational marine resources, (3) analyze the formation of power relations between various actors in the utilization of the Palabuhanratu marine resources. The research location is at the Palabuhanratu Marine Fisheries Port (PPN), Sukabumi Regency. This study uses a qualitative approach. The results showed that power and rights-based access mechanisms were obtained through formal regulations and conventions among local fishermen, ethnic Bugis migrant fishermen, ethnic Javanese migrant fishermen, fishermen from outside (Banten fishermen) to obtain marine resources, while steam power plant managers (PLTU)) use formal law from the authorities from the local to national level to obtain the Palabuhanratu marine resources. Power and access mechanisms of actors to access structure and relational-based marine resources through types of power: technology, capital, markets, knowledge, authority, social identity and social relations. Differences in interests and types of power in obtaining Palabuhanratu marine resources encourage the emergence of power relations in the form of conflicts and negotiations between fishermen groups and in the form of resistance between fishermen and PLTU managers.

Vulnerability Analysis in Newfoundland, Canada Capture Fisheries Over the Last 60 Years

Authors: Chelsea Boaler, Gabriela Sabau

Presenter: **Jack Daly**

Vulnerability, defined as a function of a system's exposure to change, its sensitivity to such change and its capacity to adapt to it (IPCC, 2007), is largely embedded within fisheries due to their nature as complex, dynamic socio-ecological systems exposed to multiple perturbations or stressors which can impact them ecologically, economically or socially. The Newfoundland and Labrador (NL) capture fisheries have experienced numerous changes in their long existence, including the traumatic collapse of cod in the 1980's. More recently, vulnerabilities are set within the context of climate change, shifts in ecological composition, competition amongst industries, and unbalanced international trade regimes.

The purpose of this paper is to identify the multiple vulnerabilities of the NL capture fisheries over the last 60 years, by using Turner et al.'s 2003 framework for vulnerability analysis. The vulnerability framework allows identification of a broad range of vulnerabilities and their linkages to endogenous and exogenous factors, including the various responses that influenced the system's adaptive capacity. Through the

research, 31 vulnerabilities and responses were identified and analyzed in chronological order. Vulnerabilities included a mix of ecological and anthropogenic drivers that have led to both individual and regulatory decision-maker interventions on some level; many of these decisions lead to unintended consequences and have influenced adaptations to responses. Assessment of responses was performed using the five specific evaluation criteria used by the OECD in results-based management (OECD 2002) - relevance, efficiency, effectiveness, impact, and sustainability. Preliminary results show that even if 17 interventions have had a positive impact, and 14 have had a negative impact on the fishery, overall, there were few responses that are sustainable, mostly alleviating vulnerability only in the short-term.

SESSION 20: OCEAN RECOVERY – STRATEGIES TO MITIGATE ANTHROPOGENIC PRESSURES AND SUPPORT MARINE ECOSYSTEM RECOVERY FOR A SUSTAINABLE FUTURE OCEAN

Ocean health and recovery

Authors: Thorsten Blenckner, Lowndes JS, Griffiths JR, Belgrano A, Boström C, Fraser M, Humborg C, Jiang N, Möllmann C, Neuenfeldt S, Nilsson A, Ojaveer H, Olsson J, Quaas M, Rickels W, Sobeck A, Viitasalou M, Wikström SA, and BS Halpern

Presenter: **Thorsten Blenckner**

Open oceans and coastal areas resources play an essential role in human well-being and are under high pressure with multiple and cumulative drivers affecting these ecosystem functioning, and the services they provide across scales. Under these circumstances assessment tools are required that include a social-ecological dimension with linked human and biophysical components that equally considers ecological, economic, and social objectives. We calculated the Baltic Health Index for the whole Baltic Sea, which is based on the global Ocean Health Index approach. The aim is to measure progress towards a suite of key societal 'goals' representing the benefits and services people expect healthy oceans to provide: food provision, fishing opportunities, natural products, coastal protection, tourism, carbon storage, coastal livelihoods, sense of place, clean waters and biodiversity. The results will be discussed in the context of the recovery potential and in which way novel conditions may influence the recovery pathway of some of the goals.

Challenges in Marine Restoration Ecology: How techniques, assessment metrics and ecosystem valuation can lead to improved restoration success

Authors: Charles Cadier, Gustavo Guerrero Limon, Laura Basconi

Presenter: **Charles Cadier**

Evaluating the effectiveness and success of coastal marine habitat restoration is often highly challenging and can vary substantially between different habitat types. The current article presents a state-of-art review of habitat-level restoration in the coastal marine environment. It sets out most successful techniques across habitats and suggestions of better metrics to assess their success. Improvements in restoration approach is outlined, with a particular focus on selective breeding, using recent advancements in genetics. Furthermore, the assessment of ecosystem services, as a metric to determine restoration success on a spatio-temporal scale, is addressed in this article. As the concept of ecosystem services is more tangible for

a non-scientific audience, evaluating restoration success in this manner has the potential to greatly contribute to raising awareness of environmental issues and to implement socio-economic policies. Moreover, habitat-based restoration has been proven to be an effective tool to address the issue of ecosystem services sustainability and poverty alleviation.
Appropriate conservation management, prior to the implementation of restoration activities, is crucial to create an environment in which restoration efforts are likely to succeed.

Are the European Nature Directives' legal expectations realistic as to the availability of scientific information needed to designate the marine Natura 2000 network?

Authors: Bettina Kleining

Presenter: **Bettina Kleining**

The European nature conservation network „Natura 2000" consists of terrestrial as well as marine sites. Its objective is to preserve European biodiversity. Currently, its terrestrial components cover about 18% of the EU's land surface while the marine part covers only about 6% of European seas. While this represents the largest co-ordinated supranational conservation network in the world, European biodiversity is, however, still deteriorating.
The main legal instruments for building Natura 2000 are the European nature directives – the Flora and Fauna Habitats Directive and the Birds Directive. Their regulations describe how to set up and manage Natura 2000. They require the European Member States to propose lists of sites on their national territory that host protected natural habitats and species. According to the law, these lists need to be established on the basis of 'relevant scientific information'. For protected aquatic species which range over wide areas, the law furthermore requires that only sites can be proposed that contain a clearly identifiable area representing the physical and biological factors essential to the species' life and reproduction.
In 2015, the European Commission evaluated the nature directives' success. It turned out that the Member States were struggling to obtain the required scientific background information to comply with the legal requirements. This lack of knowledge has led to the situation that Natura 2000 is still not completely set up even though the legal deadlines expired years ago. Especially regarding the designation of marine conservation sites, the network is far from complete. Corresponding legal actions have been scarce and showed little effect. Moreover, as existing sites have not always been set up considering the relevant scientific information, it might well be that they are not responding to the actual needs of protected species. While the effectiveness of setting aside nature for conservation purposes is open to discussion, it is for the time being, the method chosen by the European legislator and thus to be followed. To support the objective of halting marine biodiversity loss it might be worthwhile, however, to look at the link between legal and scientific actors. The necessary scientific information might well be existent but might need to be communicated differently to allow the European Member States to comply with their legal obligations to finalise the European nature conservation network Natura 2000.

Who is affected most by a social norm nudge encouraging compliance behaviour in a recreational fisheries experiment and why?

Authors: Mary Mackay, Satoshi Yamazaki, Ingrid van Putten, Sarah Jennings, Hugh Sibly, Shane Richards

Presenter: **Mary Mackay**

Non-compliance is a complex problem in recreational fisheries management and evokes uncertainty in marine conservation and socio-ecological systems by, for example, undermining management efforts and creating conflict between resource user groups. In fisheries management, deterrence-based approaches have traditionally been used to tackle non-compliance. However, enforcement is often limited in recreational fisheries and by integrating new and evolving knowledge into management to influence decision making increased compliance may be achieved. We explore the learnings of behavioural economics to improve the impact of science for policy outcomes and apply nudge theory as the basis of alternative management approaches to boost compliance. Nudge theory argues that through positive reinforcement or indirect suggestions non-forced compliance can be achieved. Nudges have worked successful in other fields, and encompasses some of the best knowledge available in terms of influencing human decision making, however, they have yet to be explored in a marine context. There is an opportunity to test the effectiveness of nudges on compliance behaviour in recreational fisheries, which as of yet, has not been done. We test the influence of a nudge based on a descriptive social norm through an economic laboratory experiment in a recreational fisheries context. Our results show that the presence of a nudge can increase compliance behaviour with a bag limit regulation by 10%. We find that a nudge was more effective when deterrence is low, but its effects become weaker when deterrence is already high. We find that there is heterogeneity across individuals whether they respond to nudge and that personal attributes, such as risk and values are significantly correlated with compliance behaviour. This study suggests that nudges are applicable to recreational fisheries since the scale of the compliance decision is on the individual level, in which behavioural incentives, such as social norms, personal morals and values, play a large role. We anticipate that nudges may have the potential to complement and bolster traditional deterrence methods of boosting compliance and this approach could prove successful as a cost-effective compliance policy tool in the marine environment.

The United Nations Decade of Ocean Science for Sustainable Development (2021-2030): achieving the ocean we need for the future we want.

Authors: Karen Evans, Elva Escobar-Briones, Craig N. McLean, Fangli Qiao

Presenter: **Karen Evans**

In December 2017, the United Nations General Assembly proclaimed the UN Decade of Ocean Science for Sustainable Development (2021–2030). This was in response to a proposal put forward by the Intergovernmental Oceanographic Commission (IOC) of UNESCO that recognised that a large scale, multidisciplinary effort was required to address two important findings on the state of world's ocean: first that we are running out of time to effectively protect the world ocean from multiple interactive stressors as detailed by the First Global World Ocean Assessment and second that, of eight challenges identified by the Scientific Advisory Board of the UN Secretary General for the future of the people and the planet improving ocean science and effective management is important for the development of sustainable ocean knowledge-based economics.

The IOC has been requested to prepare an Implementation Plan in consultation with Member States, UN partners and other relevant stakeholders for the Decade. As a first step in this process, with the assistance

of an Interim Planning Group, the IOC has prepared a "Roadmap for the UN Decade of Ocean Science for Sustainable Development". This roadmap provides an initial guide detailing the governance arrangements, a tentative Decade strategy, an outline of what is required to achieve a draft Implementation Plan by the first quarter of 2020, as well as the preliminary objectives and expected outcomes of the Decade. The Roadmap, will serve as a guiding framework to an Executive Planning Group, composed of appointed experts across science, management and policy fields and a stakeholder forum composed of Member States, specialized agencies, funds, programmes and bodies of the United Nations, as well as other intergovernmental organizations, nongovernmental organizations and relevant stakeholders, the two main interlinked processes supporting the achievement of the Implementation Plan.
Central to the success of the decade in achieving "the ocean we need for the future we want" will be first the generation of transformational change in our understanding of ocean processes, coastal and marine environments and the socio-economic pathways required for ensuring ongoing sustainable use of the ocean and enhancing blue partnerships. Second is the knowledge brokering of that understanding to provide key information that can be utilised and applied to address management and policy needs at local, regional and global scales. Importantly, the decade's success will be reliant on improving the scientific capacity particularly in regions and groups that are presently limited in capacity and capability by mobilizing partnerships and increasing investment in priority areas where action is urgently needed. In order to ensure that vital information that achieves the societal outcomes required is generated, input from the ocean observation community, managers and policy makers is critical. This presentation will discuss the overarching aims of the decade and the roadmap for how this might be achieved, progress made in developing the implementation plan for the decade and pathways for the development of strategic linkages and collaborations for facilitating the science required by the decade.

A typology of area-based management tools for achieving the targets of Sustainable Development Goal 14

Authors: Julie Reimer, Rodolphe Devillers, Joachim Claudet

Presenter: **Julie Reimer**

The management of oceans and ocean resources often involves the spatial delineation of users and uses of the marine environment, resulting in the proliferation of area-based management tools (ABMTs) across ocean sectors. As nations are promoting a blue economy, embracing opportunities to develop ocean industries without jeopardizing ecosystem health, selecting and implementing appropriate ABMTs is critical to achieving good environmental status and maintaining this status into the future. Sustainable development goal (SDG) 14 provides guidance to ensure the conservation and sustainable use of oceans and ocean resources as the blue economy expands; however, decision-makers are faced with selecting the best ABMT among many options. ABMTs can vary greatly in their capacity to deliver social, economic, and environmental goals, and are characterized by individual strengths and weaknesses. In this talk we present a typology of tools that describes the ability of ABMTs to achieve the SDG 14 targets. Based on a review of prominent ABMTs identified in the scientific literature, this typology classifies 14 ABMTs driven by conservation, industry, and cultural needs and draws from international case studies to demonstrate their utility in delivering conservation and sustainability benefits related to SDG 14. Further, we suggest that a layering of multiple ABMTs may simultaneously contribute to multiple targets as ABMTs offer synergistic benefits. Providing guidance for those seeking to achieve the targets of SDG 14, this talk highlights the best use of existing ABMTs in achieving conservation and sustainability goals.

Counteracting declining ocean productivity by artificial upwelling

Authors: Ulf Riebesell

Presenter: **Ulf Riebesell**

Climate change is expected to weaken ocean productivity, particularly in low to mid latitudes, due to increased thermal stratification. This will likely cause a decline in fish production in these areas, with possible negative effects on fishery yields. At the same time, fishing pressure is remaining high, which in combination narrows the window for recovery of overexploited fish stocks. A possible intervention to counteract further degradation of marine productivity and trophic transfer would be artificial upwelling, i.e. the forced transport of nutrient-rich deep waters to the sunlit surface layer. While such a measure has been previously proposed, both in connection with marine food production and carbon dioxide removal strategies, there is little scientific information on which to judge the usefulness of this approach for these purposes. The ERC project Ocean artUp (https://ocean-artup.eu) therefore aims to investigate the feasibility and effectiveness of artificial upwelling in fertilizing ocean productivity and enhancing energy transfer to higher trophic levels with the potential of raising fish production. It also collects data to assess the practicality of this approach for oceanic CO_2 sequestration. I will present preliminary results from on an in situ mesocosm study simulating artificial upwelling in the oligotrophic waters off Gran Canaria. The study examined trophic transfer efficiency and export efficiency as a function of mode (pulsed vs. continuous) and intensity of simulated upwelling. I will allude to possible ecological side effects and discuss constraints for upscaling artificial upwelling to economically viable scales. If technically feasible, ecologically acceptable, and economically viable, the use of artificial upwelling for ecosystem-based fish farming could make an important contribution to an ecologically sustainable marine aquaculture.

Can we prevent fishing our living resource beforehand? The real-time dynamic protection of hake nurseries as a ready-to-use science to take action on overexploited species

Authors: Jean-Noel Druon, Fiorentino F., Mannini A., Knittweis L., Colloca F., Murenu M., Tserpes G., Jadaud A.

Presenter: **Jean-Noël Druon**

The European hake is one of the most important overexploited species in the Mediterranean Sea with a notable impact of fishing in nurseries by bottom trawling. The recruits of this species are widely distributed along the shelf and shelf break, however environmental preferences of the most abundant nurseries were identified and interannual variability of preferred habitat in space and time was shown to be high (up to ±30%, Druon et al., 2015). The general negative trend of -20% per decade of preferred habitat for age-0 hake after the increase of seabed temperature furthermore highlights the need to actively protect nurseries. The accuracy of the most abundant nurseries' habitat was estimated to be of about 70% in the entire Mediterranean Sea. Habitat-derived avoidance maps are produced daily and made available on the web by the JRC with the aim to actively limiting catch of undersized fish by bottom trawlers. Alternatively, daily maps are available to fisheries authorities for better targeting control. This real-time avoidance information is an example of dynamic fisheries management that replies to both mandatory needs of protecting recovery areas (Article 8 of the Common Fisheries Policy) and reducing by-catch after the implementation of the landing obligation in 2019. The use of such operational product would proactively and sustainably allow increasing the protection of juveniles and so further recruitment, fishing yields, fisheries profits, fishermen acceptance as well as compliance.

Druon, J.-N., Fiorentino, F., Murenu, M., Knittweis, L., Colloca, F., Osio, C., et al. (2015). Modelling of European hake nurseries in the Mediterranean Sea: an ecological niche approach. Prog. Oceanogr. 130, 188–204.

Using marine macrophytes to mitigate global climate change

Authors: Fanny NOISETTE, Damon BRITTON, Catriona HURD, Martin WAHL

Presenter: **Fanny Noisette**

Marine macrophytes (i.e. seaweeds and seagrasses) are engineer species of coastal systems, providing essential ecosystem services as sequestering and storing "blue" carbon from the atmosphere and oceans. Their role as essential piece of the solution to global climate change is reinforced by their capacity of modifying their local chemical (e.g. O_2, pH) and physical (e.g. water flow) environment because of their structure and metabolism. These environmental modifications, including changes in oxygen, carbon, nutrient and pH, occur at the microscale of the diffusion boundary layer above blades as at the larger canopy scale. Creating favorable conditions in their vicinity compared to the surrounding seawater, the shaping of microenvironments by macrophytes might offset the negative effects of global changes in coastal communities. These favorable conditions could provide refuge zones e.g. enhancing the fixation of spores and larvae at the surface of coralline algae and kelps and sheltering calcareous benthic species under the canopy of seagrasses and brown algae. Combining field observations with rigorous laboratory experiments, the ability of macrophytes in buffering global changes are investigated using a multidisciplinary approach. Better understanding the importance of macrophytes in mitigating global changes is a key to improve the conservation, protection and restauration of macrophytes meadows in coastal waters and support marine ecosystem recovery for sustainable oceans.

Cost-efficient Solution of Coastal Wetlands Restoration: A Case Study of Xiamen Bay

Authors: Yanhui Zhang, Benrong Peng

Presenter: **Yanhui Zhang**

Coastal wetlands provide divers essential ecological goods and services for human being, such as climate regulation, pollution control, air quality maintenance, water purification, storm protection, nutrient cycling and recreational opportunities. Most of these goods and services cannot be replaced at any reasonable price. Rapid economic growth, increased human population and weak planning and management in coastal region have led to substantial loss of key coastal and marine habitats, continued degradation of water quality and depletion of living resources. Globally, at least 35% of mangrove forests, 29% of seagrass beds and 25% of saltmarsh were lost since 1940s due to coastal reclamation, engineering and urbanization and eutrophication. Restoration of damaged coastal wetland is thought to be an imperative and effective approach to maintain the health and resilience of coastal ecosystems and so on to promote the coastal sustainability. While producing benefits, coastal wetland restoration involves large amount of investments. It is therefore urgently needed to develop the restoration plan that can balance the coastal economic development and ecosystems protection.

This study will build a systematic framework and models to estimate the cost-efficient solution of coastal wetland restoration. The cost-efficient solutions consist of an optimal mix of restoration habitats (such as Mangrove, saltmarsh and seagrass, etc.) and an optimal localisation of the restoration habitats, so that a specified goal of coastal ecosystems health is obtained and net benefits of restoration is maximized. Four components are included in the model (1) Benefit functions of different restoration habitats located in different region, which are denoted by the values of ecosystem services provided by the restored habitats; (2) Cost functions of different restoration habitats located in different region, including engineering costs and the opportunity cost due to restoration; (3) Suitability of restoration model, i.e. suitability degree of different restoration habitats in different area; and (4) Connectivity model to considering the connection of the habitats. The estabilished model will be employed in Xiamen Bay, China to find optimal solutions for restoration habitats networks and spatially allocated.

Evaluation of effective bioremediation methods on oil contaminated sand: A long- term outdoor mesocosm experiment

Authors: Bong-Oh Kwon, Changkeun Lee, Junsung Noh, Junghyun Lee, Seongjin Hong, Myung Gyun Na, Kae Kyoung Kwon, Un Hyuk Yim, Jong Seong Khim

Presenter: **Bong-Oh Kwon**

While various bioremediation methods have been widely used at oil spill sites, in situ efficiency in PAHs degrading bacterial communities in intertidal areas remains in question. Here, the performance of bioremediation tools that are commonly used to remove sedimentary oils were evaluated in relation to the enhance the PAHs degrading bacterial community. A 70-day field experiment was performed to test efficiency of bioremediation for the 8 treatments of combined application of 1) fertilizer, 2) multi-enzyme liquid, 3) microbes, 4) rice-straw, and 5) activated carbon. Efficiency in the removal of saturate, aromatic, resin, and asphaltenic (SARA) components in sediment, residual toxicity reduction, recovery of bacterial community was comprehensively evaluated. It was found that the concentrations of aromatic compounds were decreased after 15 days, but amphipod mortality for all the treatments decreased within the 50 days. In the fertilizer and multi-enzyme liquid treatments, they were able to improve on the significant PAHs degrading bacterial populations, primarily the genus Cycloclasticus, was evidenced after 15 days. Among the 8 treatments, the combination of fertilizer and multi-enzyme liquid treatments was found to be the most effective bioremediation methods to enhance the PAHs degrading bacteria. Of note, the “no action” and “tilling” treatment shows delayed time to peak enhancement in PAHs degrading bacteria; thus, a natural restoration allowing “no cost” might be one alternative measure against oil pollution. Overall, the application of target- or endpoint-specific techniques would be of significance to enhance the efficiency of technical remediation in time and space.

An evaluation of management strategies to buffer the effect of mass mortality in early life stages of fish

Authors: Lucie Buttay, Øystein Langangen, Jan Ohlberger

Presenter: **Lucie Buttay**

Mass mortality events affecting early-life stage can have strong and long-term consequences for both the ecological properties of the population and the economic activity supported by exploited stocks. Such events can derivate from natural or anthropogenic perturbations (e.g. heat waves, oil spill, etc.) and, in some cases, adverse effects can be alleviated by management actions.

The present work focuses on Northeast Arctic cod (Gadus morhua), which is a fish stock of high economic value. Cod individuals are recruited to the fishery around the age of 4 which gives a window of opportunity, between a potential eggs or larval mass-mortality event and the noticeable effects on catches when this weakened cohort recruit, to take actions to mitigate adverse effects.

In order to assess the effects of mitigation strategies we employed a hindcasting approach and simulated scenarios of mass mortality on cod eggs and larvae followed by fishing reductions of different duration (from 1 to ten years) and intensity (from no reduction up to total ban). We used the Bayesian parameter estimates from a life cycle model for Northeast Arctic cod and compared the distribution of catches and their inter-annual variance over a period of ten years after the disturbance. By accounting for the inaccuracy of the observations and stochasticity in the population dynamics, this approach allows to quantify the range of potential effects that arise by reducing fishing pressure.

Our results demonstrate that severe fishing reductions always lead to an important increase of the catches during the 10 years following the mass mortality events, however it also led to an increase in the year to year variability of the catch. Intermediate duration and intensity of fishing reduction allows to obtain a

more sustainable situation, inducing less variability in the catches. The smaller fishing reduction required to counter the effects of mass mortality events on catches differs between years according mainly to the spawning stock biomass and the age structure of the population. Those results demonstrate the potential benefits of an adaptive approach to fisheries management.

Global change vulnerability of North Sea plankton and associated ecosystem services: towards optimized management

Authors: Cédric Léo Meunier, Elisabeth Groß, Martin Köring, Hugo Moreno, Nelly Tremblay, Maarten Boersma

Presenter: **Cédric Léo Meunier**

Global change puts coastal marine systems under enormous pressure, threatening community structure and functioning, and altering the associated ecosystem services. Given the magnitude of this threat, a number of mitigation strategies have appeared over the past two decades. However, those efforts rely on incomplete scientific knowledge since most studies to date have focused on single stressors. Because planktonic organisms are key indicators of ecosystem change, in the PlanktoSERV project we realistically assess the impact of simultaneous changes in temperature, pH, and nutrients on plankton communities. We then translate these biological and ecological information in indices, such as nutrient turnover, provision of food to higher trophic levels, and carbon sequestration/export, which are related to ecosystem services. Ultimately, these scientific findings will be used to conduct an impact assessment which will be integrated in reports addressed to decision makers in order to optimize mitigation strategies.

Behaviour and welfare of herring (Clupea harengus) and mackerel (Scomber scombrus) caught in purse seines

Authors: Thomas Riedinger, Bjørn Totland, Jostein Saltskår, Jan Tore Øvredal, Maija Tenningen, Mike Breen, Joakim Haugen

Presenter: **Thomas Riedinger**

Purse seining is a fishing practice commonly used to catch pelagic, schooling fish of different sizes (e.g. tuna, mackerel, herring). During the fishing process the shoal of fish is surrounded by the net and progressively crowded as the net is hauled on board. This exposes the fish to stressors including hypoxia, crowding and injury. Not all fish experiencing this stress are retained. Unwanted catch, due to the size of the fish or the species composition, can be released by "slipping" the animals over the float line or by opening the bunt-end of the net.

Studies with herring, mackerel and sardine have shown that these stressors can be fatal for a high proportion of the released catch, if they are excessively crowded in the net. Furthermore, the quality of the meat from the retained fish may be negatively affected by these capture stressors prior to their slaughter. Therefore, fish welfare, which has rarely been considered in the past, may be an important factor that contributes to survival of released fish and should be considered as a valuable component of a sustainable fishery.

The objective of this master's project* is to study the behaviour of herring and mackerel during the capture process in a purse seine related to the different stressors induced by the fishing method. Individual fish behaviour (e.g. tail beat frequency, swimming speed and schooling behaviour) can be indicative for the

stress experienced by the animal and its state of well-being.
Observations were conducted in commercial purse seine fisheries. Monitoring probes containing oxygen-, depth- and temperature-sensors, 360° cameras and stereo cameras were deployed (by a canon) into the net during the capture process. The behaviour of the fish (from video footage) was reviewed and analysed, together with other variables (e.g. dissolved oxygen concentration and crowding density and duration) to determine what effect capture related stressors may have on the behaviour and potential welfare of the catch.
Improving the knowledge about individual and species-specific behaviour of herring and mackerel inside of the net can help identify and mitigate some sources of stress induced during the purse seine capture process. This can help improve the animal's welfare and post-slipping survival and contribute to a more sustainable fishery.
*linked to "Fangstkontroll I not/ catch control in purse seines" project funded by FHF ("Fiskeri og Havbruksnæringens Forskningsfond")

Study of layout of submerged breakwater in Panjang Island, Jepara

Authors: Jagad Aji Wijoyo, Denny Nugroho Sugianto, Muhammad Helmi, Anindya Wirasatriya

Presenter: **Jagad Wijoyo**

Since 2011 the Panjang Island area has been used as a conservation area in accordance with Jepara District Regulation No. 2 of 2011 concerning Regional and Spatial Planning for 2011-2031. The eastern region of Panjang Island was found to undergo an erosion process due to the absence of wave energy dampers. Since 2016 to January 2018 there has been a coastline decline as far as 7,231 meters landward in this region. The submerged breakwater is proposed to be constructed for reducing wave energy and restore shoreline. The main objective of this study is to find out the good layout of submerged breakwater from the aspect of wave parameters to overcome erosion problems that occur. Determination of the location of the study was carried out using a purposive sampling method. Wave forecasting uses the equation from Sugianto et al. 2017 and processing of modeling data in the form of scenarios for the location of coastal protective structures in mathematical modeling. The simulation results of the model with the scenario of wave direction based on refraction will show the highest wave damping efficiency. The simulation results of the wind direction scenarios based on seasons will show the best efficiency for damping. These two aspects, it can be seen to determine the layout of a good submerged breakwater and good layout formation for wave damping.

Study of the effectiveness of submerged breakwater in Panjang Island, Jepara

Authors: Denny Nugroho Sugianto, S.T., Aulia Putri Aji and Ir. Muhammad Zainuri

Presenter: **Aulia Aji**

Panjang Island has abundant biodiversity, includes mangrove vegetation, seagrass, and coral reefs. But unfortunately, there was a coastline decline on Panjang Island, Jepara caused by several factors both natural factors and factors caused by living things. To cope with abrasion, especially in the western part of the island facing the Java Sea directly, the local government of Jepara has carried out the construction of the Talud and as a coast guard. Construction activities took place from June to November 2011.
In addition to these efforts, in order to reduce the impact of erosion and abrasion, a breakwater was planned. Breakwater is a construction that is built parallel to the coastline which serves to protect the coast from damage caused by waves and currents. There are various types of breakwaters, one of which is a submerged breakwater which has several advantages including being able to protect the coast from waves but not disturbing the beauty of coastal scenery so that it has an advantage in the tourism sector, can increase the coastline because it reduces transportation sediments so that sedimentation occurs, and the building mimics the principle of natural protection by coral reefs so that it is also beneficial in terms of conservation.
In order for development to proceed smoothly, an initial analysis of the construction of a submerged breakwater is needed, and knowing the value of the effectiveness of the development. For the effectiveness of the breaking structure in protecting the coast from erosion and abrasion, it can be seen from how much wave energy is decrease by the building. The more the wave energy is decrease, the better the building will be to protect the coast from wave attack. Therefore, it is deemed necessary to conduct studies related to wave attenuation through underwater structures.
Keywords : Abrasion, Protect, Coastal line, Submerged Breakwater, Panjang Island, Wave

Mangrove Restoration and Rehabilitation : KeSEMaT Rehabilitate Mangrove Ecosystems Become Mangrove Education Center of KeSEMaT (MECoK)

Authors: Aulia Putri Aji

Presenter: **Aulia Aji**

Indonesia has coastline 99.093 km in total but about 3 million hectare of them are used to grow mangrove, precisely 95.000 km. This number represent 23% of all mangrove trees in the world. Unfortunately those numbers is followed by highly rate of cutting down mangrove trees.
In few decades, Indonesia has lost it's 40% mangrove trees. In other words, has the highest number in mangrove deforestation. Heavily damaged forest causes loss of 190 million metric ton CO_2 annually. Thus means 20%, in other words 700 million emission produced from used field. Indonesia produces 42% greenhouse effect gas emission and damaged coastline, swamp, mangrove and seaweed ecosystem. In order to problem resolve, some groups of college activist and skate holders strive for it. With bring up hot issues such as 'Blue Revolution' and 'Global Warming', all of them are trying their best to resolve mangrove deforestation.
Kelompok Studi Ekosistem Mangrove Teluk Awur, or in short KeSEMaT, has been contributed directly to recover damaged mangrove ecosystem. One of them are the development of Mangrove Education Center of KeSEMaT (MECoK) in Teluk Awur Beach, Jepara, Central Java.
At 2003, KeSEMaT received fund to rehabilitate the coastal area in Teluk Awur, Jepara with a mangrove seeding, planting and maintenance program contained in Mangrove REpLaNT (MR) 2003 in collaboration with Wetlands International Indonesia Programme (WI-IP). Since then, KeSEMaT actively rehabilitating and

replanting mangrove and now MECoK currently overgrown with mangrove trees up to ten meters since first planted.
Lastly, with MECoK will become a great education facility to tell more about planting, rehabilitation of mangrove ecosystem and doing mangrove care campaign, so all people in coastline still hold to their identiy.
Keywords : mangrove, restoration, rehabilitation, MECoK, KeSEMaT

Latent effects of embryonic oil exposure on the growth, lipid storage and over-winter survival of juvenile polar cod (Boreogadus saida).

Authors: Louise Copeman, Benjamin Laurel, John Incardona, Sonnich Meier, Carlissa Salant, Michelle Stowell

Presenter: **Louise Copeman**

In the Arctic, potential future oil spills associated with increased fishing, shipping, and oil production pose largely unknown risks to keystone species and the marine ecosystems they support. This includes Polar cod, Boreogadus saida, an energy-rich key-stone forage fish. The cardiotoxic impacts of oil on embryonic marine fish are well known, but transcriptome studies suggest a parallel dysregulation of lipid metabolism. Altered bioenergetics in oil-exposed polar cod could be highly detrimental to higher trophic levels as a reduction in polar cod energy density during the first year of life would interrupt the normal flow of lipids through Arctic food webs. To address this, we exposed embryos to dispersed microdroplets of Alaskan crude oil for 3 days during heart morphogenesis and measured subsequent growth and lipid storage during hatch, yolk-sac and during four months of juvenile development. There were no long-term survivors among the higher dose exposures following yolk-sac absorption, while visibly normal feeding larvae from the low dose exposure showed significant long-term growth impairment. Storage and fuel lipids (triacylglycerols and free fatty acids) were increased in exposed yolk-sac larvae, but triacylglycerols were reduced in older surviving juveniles. A reduction in storage lipids in older juvenile polar cod exposed to oil represents a critical issue for successful polar cod overwinter survival. We ran separate overwintering experiments on non-exposed food-deprived age-0 polar cod in the laboratory. The rates of lipid loss for these polar cod was both size and temperature (-1, 1, 3, 5̊ C) dependent and indicates that the latent sub-lethal effects of embryonic oil exposure will negatively impact the ability of juvenile polar cod to survive their first long Arctic winter. Future Arctic oil spills could thus cause irreversible lipid-bioenergetic deficits in polar cod, that in turn, can be expected to affect their overwintering survival and also cascade through higher trophic levels of Arctic ecosystems.

Environmental effects on population annual mean length of polar cod (Boreogadus saida)

Authors: Nicolas Dupont, Joël Durant, Øystein Langangen and Leif Christian Stige

Presenter: **Nicolas Dupont**

The Arctic Ocean is changing following pressure from global change. Hence, we expect changes in the marine populations present in the Arctic ecosystem. Here, we focus on the polar cod (Boreogadus saida), a key species in the Arctic food web, which links the zooplankton secondary producers to the higher trophic levels. Knowledge about the ecology of the species is sparse, for example the relationships between environmental variables and population dynamics remain to be fully explored. We investigate a 30 year time-series of annual mean length, i.e. length-at-age of the different cohorts of polar cod sampled in the Barents Sea and its relation to abiotic and biotic environmental variables, i.e. sea ice cover, sea temperature and zooplankton prey abundance. Our results show associations between food items and sea ice cover on the length-at-age of polar cod depending on their age. Preys like amphipods are positively related to the length-at-age of 1 year old, and decrease in sea ice cover appears related with positive change in length at-age for the three first year of life. Our results thus contribute to identify mechanisms by which climate variability affects the population of polar cod, with implications for the effects of future climate change.

Challenges for sustainable monitoring and evaluation of the EU Marine Strategy Framework Directive in the Atlantic offshore waters: the iFADO project

Authors: Marie-Fanny Racault, Shubha Sathyendranath, Robert Brewin, Dionysios Raitsos, Thomas Jackson, Trevor Platt

Presenter: **Angus Atkinson**

Oceanic primary producers respond rapidly to a complex spectrum of climate-driven perturbations, confounding attempts to isolate the principal causes of observed changes. A dominant mode of variability in the Earth-climate system is that generated by the El Niño phenomenon. Recently, marked variations have been observed in the centroid of anomalous warming in the Equatorial Pacific under El Niño, associated with quite different teleconnection patterns. Here, using observational and reanalysis datasets, we differentiate the regional forcing mechanisms, and compile a tropical-extratropical atlas of associated impacts on oceanic primary producers caused by two extreme types of El Niño. We find robust evidence that during Eastern Pacific (EP) and Central Pacific (CP) types of El Niño, impacts on primary producers can be felt everywhere, but tend to be greatest in the tropics and mid-latitudes, encompassing up to 67% of the total affected areas, with the remaining 33% being areas located in high-latitudes. Our analysis also highlights considerable and sometimes opposing regional effects. During EP El Niño, we estimate decreases of −56 TgC/y in the tropical eastern Pacific Ocean, and −82 TgC/y in the western Indian Ocean, and increase of +13 TgC/y in eastern Indian Ocean, whereas during CP El Niño, we estimate decreases −68 TgC/y in the tropical western Pacific Ocean and −10 TgC/y in the central Atlantic Ocean. We advocate that analysis of the different teleconnections patterns forcing the biophysical interactions under El Niño variability may provide a useful guide to improve our understanding of projected changes in the marine ecosystem in a warming climate and support development of adaptation and mitigation plans.

Mothocya parvostis Bruce, 1986 (Isopoda: Cymothoidae), infesting juvenile black sea bream, Acanthopagrus schlegelii Bleeker, 1854

Authors: Hiroki Fujita, Kentaro Kawai, Satoshi Tomano, Gustavo Sanchez, Ryota Taniguchi, Takashi Kuramochi, Tetsuya Umino

Presenter: **Hiroki Fujita**

Species of the genus Mothocya (Isopoda: Cymothoidae) are common parasites of important commercial fish distributed in Japan with still unclear classification and lack of genetic information. This study aims to provide insights on the classification of this genus and the effects of parasites (mancae) on juveniles of black sea bream Acanthopagrus schlegelii Bleeker, 1854, a highly commercial fish in Hiroshima Bay.

Morphological characters in a mature female of these parasites found in the halfbeak fish Hyporhamphus sajori Temminck and Schlegel, 1846 were revised. Further, sequences of the mitochondrial DNA cytochrome oxidase I (COI) and 16S ribosomal RNA from species infesting the halfbeak fish, black sea bream, largescale blackfish Girella punctata Gray, 1835, gray mullet fish Mugil cephalus Linnaeus, 1758 and the grass puffer fish Takifugu niphobles Jordan and Snyder, 1901 were used for phylogenetic analysis. Also, the prevalence of parasite of genus Mothocya in black sea bream was monitored in 4 years. In addition, body length of juveniles of black sea bream infested and not infested parasites were also evaluated.

Similar morphological characteristics were found between the parasite infesting the halfbeak fish and the previous reported Mothocya parvostis in Bruce, 1986. From the genetic distance and phylogenetic analysis, these all parasites were classified as M. parvostis. This study used molecular and morphological analysis in this genus for the first time. Here, the infestiation of mancae to black sea bream was found on only from June to August and thus, our results might suggest that infested black sea bream may be an optional intermediate host before mancae infest the halfbeak fish. In addition, significant difference of growth rate was found in juveniles of black sea bream infested and not infested 4 years. Further studies about this host-parasite relationship may provide basic data to elucidate cause of host- specificity of cymothoidae and details of fish's immune system against parasites.

The vertical distribution of zooplankton in the OMZ of the Eastern tropical Mexican Pacific. Inter-annual Differences

Authors: Jaime Färber Lorda, B. Färber Data, D. Rivas, M. Rentería, O. Molina.

Presenter: **Jaime Färber Lorda**

Samples obtained with a MOCNESS net, and CTD information for two cruises, during different seasons, but during different years, were used to study the vertical distribution of zooplankton in the OMZ in the entrance of the Gulf of California. On the seven layers sampled (0-50, 50-100, 100-150, 150-200, 200-300, 300-400, 400-500 m), zooplankton was concentrated in the first 150 m, for both cruises, we found that zooplankton was mostly not migrating through the water column, a 48 hours sampling period showed that most zooplankton groups stay above the oxycline, for both cruises; a difference of 1/24 was found between the 0-50 m layer and the 150-200 m layer, for the autumn 2009 cruise, and a difference of 1/18.32 between the 0-50 m and the 400-500 m layer for the spring 2018 cruise. The oxycline was present at around 100 m for both cruises; it rises from Open Ocean to the shelf, especially during the spring cruise. The mean biovolumes of the first 100 m was 3.12 times higher than the next 400 m sampled in the autumn cruise, and 2.28 times higher during the spring cruise. The mean biovolume of the spring 2018 cruise was roughly half of the 2009 autumn cruise. Thus the same vertical distribution pattern was verified for two different seasons.

Morphological differentiation in krill of the Euphausia genus. From Antarctica to tropical waters.

Authors: Jaime Färber Lorda, Magnolia Murcia

Presenter: **Jaime Färber Lorda**

Krill morphological differentiation is analysed using published evidence from the Antarctic krill Euphausia superba, and recent data from the oxygen minimum adapted species Euphausia distinguenda, and the

California Current key species Euphausia pacifica. Mean dry weight differences are from the Eastern tropical Pacific species ~1.8 mg, to ~350 mg for the Antarctic E. superba, and from 9 mm to 47 mm total length. Using different length and weight measurements, and the Differentiation Index (DI, Färber-Lorda, 1990), and applying principal components analysis; long-lived E. superba showed a more pronounced morphological differentiation, as measured by the DI, with two different male groups (males I and males II), males II had lower DI, higher carotenoid content and lower lipids. E. pacifica showed a greater morphological differentiation than the tropical, low-oxygen adapted, species E. distinguenda. It is hypothesized that, in general, water temperature and water density, is playing an important role in the different body proportions of the three species, from high DI for the cold water E. superba to medium for the temperate E. pacifica and small for the tropical E. distinguenda, with a decreasing Differentiation Index from cold waters to warm waters. However, the case of the males II group remains unexplained. Which is the function of these different body proportions?

Overwinter growth and condition of juvenile Atlantic cod (*Gadus morhua*) in coastal Newfoundland

Authors: Emilie A Geissinger, Robert S. Gregory, Paul V.R. Snelgrove, Benjamin J. Laurel

Presenter: **Emilie Geissinger**

Atlantic cod (*Gadus morhua*) typically experience high mortality rates during their first year of life. In subarctic Newfoundland, cod settle into coastal habitats in several recruitment pulses throughout summer and fall, resulting in a broad length-frequency distribution prior to their first winter. The first winter likely represents a critical period in cod survival, ultimately determining cohort strength. To examine the effect of fish size and food availability on overwinter growth and condition of 0-year-olds, we collected demersal 0-year-old cod from Newman Sound, Newfoundland in November 2016 and brought them to the laboratory for 114-day feeding trials at ambient overwinter sea temperatures. For our experimental trials we reared two size classes of juvenile cod, from January 2017 to April 2017, under four daily ration levels (0.0%, 0.5%, 1.0%, and 2.0% of body mass). We then evaluated fish condition using Fulton's K condition factor and hepatosomatic index to infer the interactive role of food availability and fish size on juvenile cod survival during the overwinter period. Results indicated even small amounts of food (0.5% ration) significantly improve the growth and condition of juvenile cod over starvation conditions during the winter. However, large cod survived longer on low rations compared to small cod, suggesting that early settlement and/or rapid growth in the summer may improve overwintering success in Newfoundland water. Winter duration, temperature, and food availability structure condition and growth of cod in their first year of life.

Tipping points in New Zealand coastal ecosystems

Authors: Carolyn Lundquist, Conrad Pilditch, Richard Le Heron, Kate Davies, Karen Fisher, Judi Hewitt, Simon Thrush

Presenter: **Carolyn Lundquist**

Evidence is accumulating around the world that subtle but cumulative impacts can profoundly change the nature of marine ecosystems and their functionality. These changes are often called 'tipping points' and when they occur the way ecosystems deliver valued ecosystem services are put at risk affecting the benefits we enjoy from the sea. The occurrence of thresholds profoundly limits our understanding of ecosystem

dynamics and management of cumulative effects, but we have yet to develop practical techniques to assess the threat that thresholds will be crossed. Here we discuss the Tipping Points project within New Zealand's Sustainable Seas National Science Challenge which is investigating how coastal ecosystems respond to the effects of multiple stressors and cumulative impacts to inform management of marine resources to allow for multiple and diverse uses without loss of ecosystem functions and benefits. Rapid changes in coastal ecosystems are happening around the world, but we are still in the process of learning how to assess the risk of such changes before they happen. To address this knowledge gap we are conducting the first nation-wide experiment, in estuaries, harbours and rocky reefs from Northland to Southland, to identify tipping points, risks, and how ecosystems respond to change. Here we combine social and ecological knowledge defining critical system interdependencies with a latitudinal-scale field experiment investigating the effects of two important stressors (turbidity and nutrient loading) on ecosystem function. Our approach seeks to show how the loss of positive feedbacks and changes in the architecture of ecosystem interaction networks, can provide mechanistic evidence that stressors lead to breakpoints in dynamics, which theory predicts pre-dispose a system to a critical transition. This approach provides an urgently needed technique to link theory with empirical research and demonstrates that well-designed field studies can be used to test for key breakpoints in intrinsic dynamics associated with the subtle but cumulative impact of stressors before thresholds are crossed. Through the transdisciplinary collaborations within Sustainable Seas, this ecological knowledge is integrated within a social-ecological systems context to advise on how we can better identify the risks of major change, how they relate change to the types and magnitudes of stressors, and how we can be better prepared to cope with change. The project has strong research connections to the interactions between ecosystems and society as we seek to identify effective processes for change that will help society make informed choices about how we restore, conserve and use marine ecosystems.

Network structure and information flow between fishery stakeholders: an interdisciplinary approach towards assessing communication pathways for management

Authors: Clara Obregón Lafuente, Michael Hughes, James R. Tweedley, Neil R. Loneragan.

Presenter: **Clara Obregón Lafuente**

Traditional fisheries management has typically focused on the biological and economic dimensions, leaving the impact of fisheries network structure on the management, and generally the human dimensions, largely overlooked.

The blue swimmer crab (Portunus armatus) fishery is a small-scale fishery in the estuaries and coastal embayments of southern Western Australia. Although it directly employs 10 commercial fishers and is the most popular recreational fishery in the state, its social elements are largely unknown. Despite receiving the Marine Stewardship Council certification in 2016, results from a preliminary study showed that some respondents are concerned about the status of this iconic fishery and its management. Consequently, face-to-face interviews with an open-question format were used, followed by network analysis methods, to understand information flow between the fishery network stakeholders in one of the most popular systems for crab fishing in Western Australia, the Peel-Harvey Estuary. Information flow was investigated between stakeholder groups forming the blue swimmer crab fishery network, including fishers in both fishery sectors, fishery and environmental managers, scientists, local business owners and catchment councils. Results show that information flow was more concentrated within the groups, than between the groups. This could be related to a higher frequency of interactions and greater dual-directionality of information flow between these groups. Overall, the findings showcase a lack of key links within the crab fishing network across stakeholder groups, particularly between the scientists and governmental groups and the recreational fishing groups.

Understanding the network structure of small-scale fisheries, and information flow within this network from a top-down and bottom-up perspective can contribute to a more effective management, resulting in a step towards an enhanced social and biological sustainability of the fishery.

Identification of the Increase in the Air Temperature of the North Coast of Central Java as an Indicator of Climate Change (Semarang Station Climatology Data 1970-2017)

Authors: Denny Nugroho Suagianto, Yadi Suyadi, Hartanti Sandi Wijayanti, Vivilia Niken Hastuti, Diana Nur Afifah

Presenter: **Denny Nugroho Sugianto**

Global warming has occurred since the middle of the 20th century marked by increasing global average temperatures. Global warming has triggered global climate change, which is characterized by changes in the pattern and intensity of climate elements and increased extreme climate. The Indonesian territory of extreme climate events due to Climate Change is often associated with ENSO events, namely in the form of an increase in sea surface temperature (El Nino) and a decrease in sea surface temperature (La Nina) in the southern Pacific. One area in Indonesia that is vulnerable to climate change is the coastal area. Demak Regency as a coastal area is a disaster-prone area due to climate change. The purpose of this study is to identify climate change in Demak based on the temperature parameters of the data period 1970-2017 and climate projections for the period 2021-2050 and the potential threats faced. Air temperature data was analyzed by data distribution test, linear regression test, Mann-Kendal, and descriptive analysis. While the projection data (climate and temperature) carried out distribution test analysis, correlation test, linear regression test, Mann Kendal test, and descriptive analysis then with the GCM model the scenario RCP 8.5 analyzed the changes compared to the observation climate. Demak Regency was identified as experiencing changes in air temperature from 1970-2017 with an increase of 0.02 ° C / year, especially in February, Climate projection (temperature) with RCP 8.5 scenario utilizing 5 GCM output models, addressing current temperature trends will continue to experience increase with an average increase of 0.037 ° C / year or increase by 1.11°C in 2050 with the possibility of an increase in extreme events in the category of "moderate" and "mild" based on the 95% percentage and 99% percentage.

Indigenous women of the Indigenous Regional Council of Cauca - Colombia, in the defense of water, epistemology's of Sumak Kawsay for the common good of humanity

Authors: Eduardo Erazo Acosta

Presenter: **Eduardo Erazo Acosta**

After the Paris meeting on COP23 Climate Change and recently with the genesis of "the book of rules" in Katowice-Poland 2018 (COP24), many talk about the political actors, the sea, the cities, but we need to talk about the importance of those who live in high mountains, talk about the peasant and indigenous communities that live in the midst of páaramos, frailejones, endemic species, in the wetlands, high mountain places where water is born, water that will later reach rivers and seas, places that also due to climate change are being affected by climate change.

Then we present the epistemology, ancestral knowledge on how climate change looks at the indigenous

communities of high mountain, the place where water is born in the Andes of South America, epistemologies that call for what could come, if we continue to break Respect for water, the biological chain and life on planet earth. This is the ancestral epistemology of sumak kawsay or Buen vivir - Good living

In the framework of the post-conflict call in Colombia, peace is presented at the international level as the only reality, without doubt giving rise to a myriad of mega-mining and extractive pro-development factors, affecting even more the conditions of the historically excluded, the original communities located in strategic places, because of the richness in páramos, water, biodiversity continue to be attacked in a systematic way, with threats, forced displacement, assassinations, for questioning the megadevelopment model that favors the damage to the Allpamamma and, above all, water affectations in the region of the Colombian Massif, a living source of páramos and above all of water for the Andean region, hundreds of species of flora and fauna and megaciduades of the Andean region of Colombia and Coastal region, as well as the factors of violence and exclusion in the country, not so for the mass media that serve in unison to national oligopoly interests and inte national

From the science there are several calls like the Global researcher climate changue, but from the same original communities there are processes of epistemic contribution that urgent to a new care of nature. The analysis of ecology, environmental care and climate change in Latin America is used

In the framework of the post-conflict call in Colombia, peace is presented at the international level as the only reality, without doubt giving rise to a myriad of mega-mining and extractive pro-development factors, affecting even more the conditions of the historically excluded, the original communities located in strategic places, because of the richness in páramos, water, biodiversity continue to be attacked systematically, with threats, forced displacement, assassinations, for questioning the mega-development model that favors the damage to the Allpamamma and above all increases the factors of violence and exclusion in the country, not so for the mass media that serve in unison with national and international oligopolic interests.

Trophic interactions of mesopelagic fishes in the South China Sea: illustrated by stable isotopes and fatty acids

Authors: Ying Wu, Fuqiang Wang, Zuozhi Chen, Guosen Zhang, Jun Zhang, Shan Zheng, Gerhard Kattner

Presenter: **Ying Wu**

As the most abundant fishes and the least investigated components of the open ocean ecosystem, mesopelagic fishes play an important role in biogeochemical cycles and hold potentially huge fish resources. There are major gaps in our knowledge of their biology, adaptations and trophic dynamics and even diel vertical migration (DVM). Here we present evidence of the variability of ecological behaviours (migration and predation) and trophic interactions among various species of mesopelagic fishes collected from the South China Sea indicated by isotopes (δ13C, δ15N) and biomarker tools (fatty acids (FAs) and compound-specific stable isotope analysis (CSIA)). Higher lipid contents of migrant planktivorous fishes were observed with average values of 35%, while others ranged from 22 to 29.5%. These high lipids contents limit the application of 13Cbulk (bulk–tissue 13C) as diet indicators of the mesopelagic fishes; instead 13Cextraction (the lipid extracted 13C) values were applied successfully to reflect dietary sources. The δ15N values of non-migrant planktivorous and piscivorous fishes varied in a narrow range (10 to 10.8‰). This small difference may be caused by the low temperature in deep ocean, which results in low metabolic rates of nitrogen. The piscivorous fishes had higher FA ratios of DHA (22:6n-3)/EPA (20:5n-3) than planktivorous fishes, which mirrored their potential feeding behaviour. The δ13C values of the 20:4n-6 and 20:5n-3 FAs were significantly higher in the non-migrant piscivorous fishes than the semi-migrant piscivorous fishes ($p<0.01$), which suggested these fishes had different dietary sources. The CSIA can reveal small changes of biochemical composition and distinguish possible sources of diet neglected by other methods. Mesopelagic fishes exist complex trophic interactions revealed by molecular and CSIA tools and play a vital function in marine "biological pump". This knowledge is important to comprehensively evaluate the role of mesopelagic fishes in global carbon budgets.

Influence of the Northern Yellow Sea Cold Water Mass on picoplankton distribution around the Zhangzi Island, northern Yellow Sea

Authors: LI ZHAO, ZHAO Yanchu, DONG Yi, ZHAO Yuan, ZHANG Wuchang, XU Jianhong, YU Ying, ZHANG Guangtao, XIAO Tian

Presenter: **Li Zhao**

Picoplankton distribution around the Zhangzi Island (northern Yellow Sea) was investigated by monthly observation from July 2009 to June 2010. Three picoplankton populations were discriminated by flow cytometry, namely Synechococcus, picoeukaryotes and heterotrophic prokaryotes. In summer (from July to September), the edge of the Northern northern Yellow Sea Cold Water Mass (NYSCWM) resulting from water column stratification was observed. In the NYSCWM, picoplankton (including Synechococcus, picoeukaryotes and heterotrophic prokaryotes) distributed synchronically with extremely high abundance in the thermocline (20 m) in July and August (especially in August), whereas in the bottom zone of the NYSCWM (below 30 m), picoplankton abundance was quite low. Synechococcus, picoeukaryotes and heterotrophic prokaryotes showed similar response to the NYSCWM, indicating they had similar regulating mechanism under the influence of NYSCWM. Whereas in the non-NYSCWM, Synechococcus, picoeukaryotes and heterotrophic prokaryotes exhibited different distribution patterns, suggesting they had different controlling mechanisms. Statistical analysis indicated that temperature, nutrients (NO3- and PO43-) and ciliate were important factors in regulating picoplankton distribution. The results in this study suggested that the physical event NYSCWM, had strong influence on picoplankton distribution around the Zhangzi Island in the northern Yellow Sea.

Seasonal variation of the abundance and biomass of picoplankton in the Sanggou Bay

Authors: Yanchu Zhao, Li Zhao, Wuchang Zhang, Sumei Liu, Zengjie Jiang, Jianguang Fang, Yuan Zhao, Tian Xiao

Presenter: **Yanchu Zhao**

This study aims to investigate the abundance, biomass, and distribution of picoplankton in the Sanggou Bay using flow cytometry in April 2013 (spring), July 2013 (summer), October 2013 (autumn), and January 2014 (winter) and analyze the correlations with environmental factors. The results revealed that the abundance and biomass ranged as follows: S*ynechococcus*, 0.04 x 10^3 - 408.59 x 10^3 cells/mL and 0.01-102.15 mg/m^3; picoeukaryotes, 0.21 x 10^3-99.64 x10^3 cells/mL and 0.31-149.46 mg/m^3; and heterotrophic prokaryotes, 3.34x10^5-50.16x10^5 cells/mL and 6.68-100.32 mg/m^3, respectively. The abundance and biomass of picoplankton were higher in summer than other seasons. In four seasons, the biomass of heterotrophic picoplankton, the average contribution of which accounted for 62.11%, was higher than that of autotrophic picoplankton. In autotrophic picoplankton, picoeukaryotes were the major contributor of the biomass, and their average contribution was 86.85%. Temperature, chlorophyll a, and nutrient concentrations were primary factors that affected the abundance and biomass distribution of picoplankton. This study will provides the basic data for the detection and evaluation of the ecological environment of the Sanggou Bay

Grazing Of Microzooplankton And Copepod On Microbial Food Web In Spring In Southern Yellow Sea, China

Authors: Yuan ZHAO, Li ZHAO, Shan ZHANG, Shiquan LIN, Wuchang ZHANG, Lingfeng HUANG, Tian XIAO

Presenter: **Yuan Zhao**

Assessment of the microzooplankton and copepods grazing pressure on picoplankton is a key point for resolving the microbial food web efficiency. However, only few of the current studies concurrently estimated and compared the grazing impact of microzooplankton on picoplankton, i.e. heterotrophic bacteria, Synechococcus and picoeukaryotes. Furthermore, there was no consistent enhancing or restraining effect of copepod on picoplankton in the very few existing studies. Dilution incubations and copepod addition incubations were performed during a cruise to the Yellow Sea. The bulk grazing of microzooplankton and calanoid copepod *Calanus* sinicus on Chlorophyll a, flagellates and picoplankton was estimated. Picoplankton comprised a large part of the food of microzooplankton in the central oligotrophic area while phytoplankton was the main food of microzooplankton in the coastal eutrophic area. In the central oligotrophic area, microzooplankton preferred grazing on Syn (44.4-72.4%) among the picoplankton. After copepod addition incubations, ciliate abundance decreased while Syn abundance increased, indicating strong grazing pressure of microzooplankton on Syn. In the Yellow Sea, microzooplankton could prey on microphytoplankton, nanoplankton and picoplankton at the same time, but the importance of picoplankton exceeded phytoplankton and nanoplankton. This suggests that there is a close predator/prey relationship between the picoplankton and the microzooplankton, and that microzooplankton grazing was potentially a key controlling factor for the picoplankton population. Both Chl a and Synechococcus abundances showed consistent high increase in the copepod-added bottles while flagellates abundance remained stable. There was not a strong copepod-ciliate-flagellate trophic cascade in the copepod addition incubations in the oligotrophic waters. This might indicate that ciliates were the main grazers of phytoplankton and Synechococcus. Our results suggest that Synechococcus might be a fundamental source for the carbon budget in the oligotrophic water in Yellow Sea, and its variation could affect the carrying capacity of the pelagic food webs.

Evidence of anthropogenic pressure on marine ecosystem from preserved sedimentary phytoplankton pigments

Authors: Zhuoyi Zhu, Futao Fang, Jinzhou Du, Bing Deng,

Presenter: **Zhuoyi Zhu**

Anthropogenic activities in river basin exerts strong impact on estuarine and adjacent marginal sea ecosystems. For the past decades, China has achieved an obvious progress in economy, with much of its GDP contributed from the Changjiang River Basin. Hence, the Changjiang River estuary and adjacent East China Sea has been under strong anthropogenic impact, with a clear eutrophication trend and pronounced nutrient stoichiometry changes in the past decades. In this presentation, we use preserved sedimentary phytoplankton pigments to reveal the historical marine ecosystem via reconstructed phytoplankton biomass and typical algal group trends in the past tens of years. Chlorophyll a, together with its degradation products, showed clear increasing trend in the past decades, indicating the overall phytoplankton biomass changing pattern in the past tens of years. Zeaxanthin and pheophytin a both have similar chemical stability, and its ratio decreased from over 150 years ago to nowadays, indicating the cyanobacteria contribution to total phytoplankton biomass has been decreasing. Cyanobacteria in the East China Sea tends to be more oligotrophic adapted, which is in contrast to diatoms and dinoflagellates. Hence, the decreasing proportion

of cyanobacteria indicates the marine system has been under mild eutrophication trend accordingly. Dinoflagellates and diatoms both showed increasing trend in the past tens of years, but dinoflagellates proportion, relative to diatoms, first decreased from 1970s to late 1990s, then became to increase afterwards. This dinoflagellates-diatoms relation roughly corresponds to the decreasing DSi/DIN trend in the Changjiang River nutrient discharge history, but a lag trend is also obvious, which needs further study.

Global ocean governance requires usable baseline knowledge on migratory connectivity in the ocean

Authors: Daniel C. Dunn, Corrie Curtice, Sarah DeLand, Ben Donnelly, Ei Fujioka, Autumn-Lynn Harrison, Eleanor Heywood, Connie Y. Kot, Jesse Cleary, Guillermo Ortuño Crespo, Patrick N. Halpin

Presenter: **Guillermo Ortuno Crespo**

Conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction (ABNJ) is dependent on governance that can account for the nature of the systems therein. Pelagic open-ocean ecosystems in ABNJ are characterized by their dynamism and the connectivity it generates. Many marine predators have developed migratory life cycles to efficiently utilize these heterogeneous and ephemeral environments. Due to their large geographic ranges, migratory marine mammals, seabirds, sea turtles and fish experience a variety of anthropogenic pressures over their life histories. Combined with conservation and management strategies that largely fail to consider spatial connectivity over their full life cycles, these threats have contributed to population declines worldwide. With increasing impacts being felt from pollution, resource extraction and climate change, synthesized knowledge on area-use and migratory connectivity is critical to support conservation and sustainable use of marine migratory species.
Advances in electronic tracking technology over the past 25 years have resulted in the rapid accumulation of information on migratory connectivity in the ocean. However, this information is not widely available, nor has it been effectively synthesized as actionable knowledge for baseline or planning purposes. The Migratory Connectivity in the Ocean system (MiCO; mico.eco/system) seeks to fill this gap by compiling and synthesizing data on connectivity among nodes (aggregations of areas used for a particular life cycle activity such as feeding or breeding) via corridors (aggregations of routes animals travel between nodes), through a systematic literature review and analyses of direct contributions of data or derived products. Here we present the system prototype and case studies of how contributed data have informed international marine spatial planning processes. We review the policy arenas that are interested in consuming this information and provide details on how the system will incentivize contributions by tracking and reporting their impact in those policy arenas.

Mangrove Tourism : an overview in Bagladesh

Authors: Salma Begum, Mahmood Hossain

Presenter: **Salma Begum**

Tourism activities in the Sundarbans are growing rapidly, especially since the Sundarbans was certified as a UNESCO World Heritage Centre in 1997. Among the tourist areas of the mangrove Sundabans, eg. Karamjal, Harberia, Kochikhali, Kotka, Dubla, Kolagachia and Nilkamal are the major sites that attract the largest numbers of visitors. Rapid but unplanned tourism activities have created various social and environmental

concerns. If appropriate planning measures are not derived from the consideration of the carrying capacities of these sites, tourism centers will be overloaded, tourism quality will be degraded, and therefore the benefit obtained from tourism activities will be reduced. This paper follows the methodology of Ceballos-Lascurain (1996) and Cifuentes (1999) in estimating the carrying capacity of 7 different sites in the Sundarbans. The carrying capacities of above mentioned 7 tourism sites are quantitatively evaluated as physical carrying capacity (PCC) real carrying capacity (RCC) and effective carrying capacity (ECC). Where PCC>RCC>ECC, maximum PCC was found in Karamjal (9450 visitors/day) and minimum was in Dubla (2400 visitors/day). In terms of RCC and ECC, Karamjal shows the highest (1908 visitors/day and 1146 visitors/day, respectively), and Nilkamal (Hironpoint Keora Shuti) shows the lowest (146 visitors/day, 86 visitors/day respectively). The management option could be a sectoral integration of all relevant sectors for promotion of ecotourism. Regarding this, the result of this research could be used as a preliminary benchmark for planning and future research in the Sundarbans ecosystem.

Multiple scenario analyses forecasting the impacts of sea level rise in Cape Town, South Africa

Authors: Sheveenah Taukoor

Presenter: **Sheveenah Taukoor**

Sea level rise is highly interdisciplinary and its study entails not only oceanography, but other fields such as geomatics, climatology and geology. In this study we relied on the tools from geomatics to produce sea level rise maps in order to assess the vulnerability of the coastline of Cape Town, South Africa. After generating a DEM of a spatial resolution of 2 m from LiDAR point cloud data, we made use of GIS to design 4 sea level rise scenarios based on the RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 scenarios from the IPCC. Among the findings, it was found that 2.16 – 3.09 km^2 of land would be potentially inundated by 2100. The main receptors which were identified were sandy beaches, rocky shores and built-up land. Permanent inundation would possibly change the appeal and the nature of the beaches and affect the tourism industry. Hence the coastline requires immediate attention as it is one of the most valuable assets in the tourism industry. Tidal effect and storm surge effect were also identified as additional factors which brought temporary changes to the sea level in Cape Town. These impacts were further investigated in 8 coastal suburbs (Tableview, Woodbridge Island, Paarden Eiland, Foreshore, Sea Point, Glencairn, Fish Hoek and Strand.) Suitable adaptation strategies including hard protection measures (e.g groynes, sea walls, barriers) and soft protection measures (e.g beach nourishment) were also proposed for these 8 suburbs.

Environmental occurrence of the novel PFOS alternatives (Cl-PFESAs) and their degradation potentials

Authors: Jianbo Han

Presenter: **Jianbo Han**

Global phase out of perfluorooctane sulfonic acid (PFOS) has led to increasing production of alternatives such as the chlorinated polyfluoroalkyl ether sulfonic acids (Cl-PFESAs) for which little is known on their environmental occurrence and fate. Levels of 6:2 and 8:2 Cl-PFESAs in rivers, drain outlets and receiving sea were detected in rivers and drain outlets which are directly discharged into the Bohai Sea of China. Relatively high concentrations of 6:2 Cl-PFESA were found in drain outlets, ranging from below method

limits of quantification (MLQ) to 7600 ng/L, but 8:2 Cl-PFAES detectionwas infrequent and all median concentration below MLQ. Mass discharges to the sea of 6:2 Cl-PFESA from rivers and drain outlets to the sea were estimated to be 37 and 17 kg/y, respectively. Aerobic biodegradation in a loam soil at 24 ± 0.5 °C showed negligible degradation of both Cl-PFESAs. Cl-PFESAs also remained unchanged in an unbuffered heat (50 C)-activated 42 mM persulfate oxidation treatment. Therefore, Cl-PFESAs are equally recalcitrant as PFOS in addition to being more sorptive, thus with a higher bioaccumulation potential for a similar alkyl chain length.

Is there any connection between a forest in mountain to marine fauna? The valuation of ecosystem services of the forests to the marine life

Authors: Anoop Das Karumampoyil, Jayahari

Presenter: **Anoop Das Karumampoyil**

By undertaking fifty per cent of the global primary productivity and supporting the great biodiversity resources, oceans are considered as most significant ecosystems. Collectively the marine ecosystems are assessed as holding 60% of the economic value of Biosphere. Ecosystem services are the lifeline of existence of mankind. These services are generated as a resulted of complex interactions and functioning of living and nonliving components of ecosystems.

Although a variety of ecosystem services classification systems and mapping approaches are available in the scientific and technical literature, they need to be carefully selected and adapted when applied to complex territories such as in the interface between water and land, estuary and sea. This study provides a framework for addressing ecosystem services in complex coastal regions. The roadmap comprises the definition of the exact geographic boundaries of the study area; the use of CICES (Common International Classification of Ecosystem Services) for ecosystem services identification and classification; and the definition of qualitative indicators that will serve as basis to map the ecosystem services. Due to its complexity and logistics, the Malabar coastal region was selected as case study, presenting an opportunity to explore the application of such approaches at a regional scale. The main challenges of implementing the proposed roadmap, together with its advantages are discussed in this research. Ecosystems are open systems which have energy, nutrient and other tradeoffs between each other. When understanding the economic value of the marine ecosystems, the tradeoffs between the terrestrial and marine ecosystems are poorly understood, especially the contribution of terrestrial ecosystems in the ecosystem service productivity of marine ecosystems. They Rivers are, functionally large-scale movement of nutrients, micro and macro organisms and fresh water at differential quantities which has its own significance in the functioning of coastal and deep marine ecosystems.

The linkages and tradeoffs between the terrestrial ecosystems (right from the montane forests to coastal mangroves) with the marine ecosystems are not really understood, studied and mapped. These studies and mapping will have its significance on policy initiations and development of management frameworks and practices related to marine ecosystems especially thee marine protected areas. This also will reveal the role of terrestrial ecosystems in the functioning and productivity of marine ecosystems which are important as far as the global economic growth is concerned.

The results highlight the importance of considering both the connectivity of natural systems and the complexity of the governance framework; the flexibility and robustness, but also the challenges when applying CICES at a regional scale; and the challenges regarding ecosystem services mapping.

Response of viruses to dust deposition in present and future ocean : Results from PEACETIME miniscosm experiments

Authors: Bigeard Estelle, Frédéric Gazeau, Karine Desboeufs, Cécile Guieu, and Anne-Claire Baudoux

Presenter: **Estelle Bigeard**

Viruses play a pivotal role in marine ecosystems, especially through their profound influence on the structure and the functioning of microbial communities. The ecological impact of viral infection is largely determined by the different viral life strategies. Lytic viruses, which kill their host by cell lysis, influence ocean productivity and biogeochemistry, while lysogenic viruses, which are inserted into their host genome as prophages, affect the microbial evolution and may provide the microbial host with new functional traits. Despite the global impact of viral infection in the ocean, the impact of natural forcings, such as atmospheric inputs, on viral infection dynamics and the relative share among the different infection strategies remain far from understood. Here, we evaluated the response of viral activities to dust deposition in actual and future ocean during three minicosm experiments deployed during PEACETIME Cruise (R/V Pourquoi Pas?). Results describing the dynamics of viral abundance, viral production, and the relative share between lytic and lysogenic viruses will be presented and discussed in the context of on-going environmental changes in Low Nutrient Low-Chlorophyll (LNLC) Ocean.

Trace metals and nutrients fluxes and solubility during the Mediterranean PEACETIME cruise

Authors: Franck FU, Karine Desboeufs, Sylvain Triquet, Jean-Francois Doussin, Chiara Giorio, Francois Dulac, Franck Maisonneuve, Pascal Zapf, Anais Feron, Antonio Tovar-Sánchez, Matthieu Bressac and Cécile Guieu

Presenter: **Franck Fu**

The atmospheric inputs to the Mediterranean Sea, play a significant role in marine nutrient cycles during the summer period of surface water stratification. The PEACETIME cruise on board of the R/V "Pourquoi Pas?" in May/June 2017, aimed at studying the physical, chemical and biological processes and their interactions at the air-sea interface in this Mediterranean environment, and in particular the effect of a Saharan dust deposition event. During the PEACETIME cruise, 40 filters of aerosols and 2 events of wet deposition were collected, characterized and quantified, and the solubility of trace metals is also estimated for the first time in the open sea of the Mediterranean Sea. The two collected rains corresponded to a anthropogenic deposition event and a dust deposition event. The concentrations of trace metals in the aerosols and rains are significantly lower than published values for coastal sites. Pb, Cd and Mo are the most enriched (relative to crust composition) trace metals in aerosols, and Zn is the most enriched in both rains. The average solubility of the 17 chemical elements measured was relatively higher compared to measurements during other cruises conducted in the Atlantic, due to larger anthropogenic activities around the Mediterranean Sea. Comparing with the concentrations measured by marine biogeochemists in seawater during this cruise, the concentrations of trace metals are significantly higher in rainwater than seawater, especially for Fe, Mn, Co and Zn. Taking into account the dilution of atmospheric inputs in marine surface microlayer (< 1mm), concentrations of all trace metals are 1-20 times higher in both rains than in the microlayer, except Mo. But in subsurface water (< 1m), atmospheric input by rain could create a significant increase only for Fe, Zn, Mn and Co (> 20%). For the mixing layer (15m), it appears that the metals added by rains have no effect on the marine concentrations of trace metals. This increase of trace metals concentration resulted by wet deposition could have a punctual effect on the marine ecosystem of the microlayer.

Dynamics of dissolved and particulate organic matter in the Changjiang (Yangtze River) Estuary and the adjacent East China Sea shelf

Authors: Lei Gao, Lingbin Zhao

Presenter: **Lei Gao**

Two cruises from the Changjiang freshwater, through the Changjiang Estuary and finally to the adjacent East China Sea (ECS) shelf were carried out in July 2015 and March 2016, during which concentrations of DOC (dissolved organic carbon) and POC (particulate organic carbon) were measured at the three depth layers (surface, middle, and bottom) of 99 and 89 stations, respectively. Concentrations of both DOC and POC showed overall decreasing trends from land to sea; however, their highest concentrations always occurred around the Changjiang river mouth where estuarine salinity fronts and turbidity maxima appeared. The POC/DOC molecular ratios showed values < 1 in most samples during the two cruises, suggesting that DOC contributed to a larger fraction, than POC, to the total organic matter inventories; and the exception only appeared in the inner stations during March 2016. The variations of DOC and POC were mainly controlled by salinity and suspended particulate matter concentration, respectively, suggesting that these two organic matter pools were largely decoupled. However, at the surface water during July 2015, the overlying Changjiang Diluted Water (generally regarded as waters with salinity < 31) generally showed a source effect on DOC with the ongoing seaward transport, and the algal bloom events, reflected by the high percentage values of POC in SPM, were always one of the important reasons that had supported the DOC releases. The above results, on the other hand, provided an example of the coupling between DOC and POC. This study shows the distributions and variations of DOC and POC in the Changjiang Estuary and the adjacent ECS area, and highlights the complex interaction mechanisms on the coupling and decoupling between these two organic matter pools in this important estuarine and coastal area.

Ocean Modeling Supports Management Conversations on the Impact of Local Pollution Sources on Acidification and Deoxygenation in California

Authors: Faycal Kessouri, Martha Sutula, James C McWilliams, Daniele Bianchi, Karen McLaughlin, Nina Bednarsek, Evan Howard, Richard Feely, Minna Ho, Steve Weisberg

Presenter: **Faycal Kessouri**

Global environmental changes in the oceans are shifting and intensifying natural gradients and variability related to warming, ocean acidification and deoxygenation (OAD). In California coastal waters, these stressors are potentially exacerbated the discharges of anthropogenic pollution. Of particular focus is the primary or secondary treated wastewater from a population of 30 million people in the Southern California Bight and San Francisco Coast that are discharged via ocean outfalls annually. Anthropogenic nutrient controls will cost billions of dollars, so managers need increased confidence about the causal linkage between nutrient inputs and OAD. The ability to connect these management decisions to important biological outcomes improves the clarity of the tradeoffs between the cost of pollution control and environmental benefits. This talk will present results from simulations with Regional Oceanic Modeling System (ROMS), comprising circulation, biogeochemical cycles, and lower-trophic ecosystem run at 300 m spatial resolution to investigate the impacts of local pollution inputs on OAH in the SCB. The modeling demonstrates mechanistic linkages between physical and chemical drivers of OAD and their compression on pelagic and benthic habitats. Model simulations are used in ongoing discussions with local coastal managers to support local pollution and marine vulnerability assessments.

Nutritional demands with increasing temperatures: more nutrients or more carbon in a warming world?

Authors: Cecilia Laspoumaderes, Meunier C, Balseiro E, Elser J.J, Modenutti B, Tremblay N, Wolinski L, Köring M, Boersma M

Presenter: **Cecilia Laspoumaderes**

Temperature and nutrients are key modulators of growth rates in ectotherms. However, little is known on the effect of changing temperatures on nutrient requirements of these organisms. Different hypotheses exist, predicting opposite outcomes: some of them expect higher phosphorus and nitrogen requirements at higher temperatures because of the increased growth rates, whereas others predict higher carbon requirements at higher temperatures due to a higher increase in respiration rate relative to growth and uptake. Here, using the copepod Acartia tonsa, we determine the temperature dependence of all important variables such as feeding, excretion, respiration and assimilation rates for C, N, and P, and the resulting threshold elemental ratio for phosphorus and nitrogen (TERC:N and C:P), and compare these with existing results for the freshwater cladoceran Daphnia magna. If these TER values change with temperature, the ideal diet for an ectotherm would vary with temperature, potentially explaining broad geographic patterns in species' distributions. These findings, may ultimately help predict how expected changes in temperature and nutrient inputs to ecosystems will affect communities.

Riverine and wet atmospheric inputs of nutrients into Annaba bay (SW Mediterranean)

Authors: Makhlouf Ounissi, Aicha Beya AMIRA

Presenter: **Makhlouf Ounissi**

Atmospheric deposition is a significant source of nutrients entering the Mediterranean Sea, as river discharge and nutrient fluxes have decreased due to dams retention and climate change. This study assessed for the first time the relative contributions of riverine and wet atmospheric inputs of nutrients into the Annaba area on the Algerian coast. Surface water sampling and water discharge estimates were performed weekly in 2014 at the outlets of the Mafragh River and Seybouse River that fed Annaba bay. Rainwater samples were collected jointly on a daily basis at a close meteorological station, where precipitation data were monitored. Riverine and rainwater samples were analyzed for dissolved nutrients (ammonium: NH4; nitrate: NO3; nitrite: NO_2; dissolved organic nitrogen: DON; phosphate: PO4; silicate: Si(OH)4). The rainwater from the Annaba region was characterized by high concentrations of PO4) and Si(OH)4 that are several times the average Mediterranean values and yield strong deposition fluxes. In contrast, the levels of dissolved inorganic nitrogen (DIN) and DON and associated fluxes were remarkably low, when compared to the typical Mediterranean values. The wet atmospheric deposition contributed 37%, 11.2%, 15% of the riverine inputs of DON, DIN and PO4, respectively. The dissolved nutrient fluxes from the two river catchments were low following the lowering of the river discharge. Mafragh River water had levels of dissolved N and P comparable to those of rainwater and appeared to be a nearly pristine estuary with low nutrient levels and almost balanced DIN:PO4 and Si(OH)4:DIN ratios. In contrast Seybouse River water had low Si(OH)4 levels but was highly charged with NH4 and PO4 and showed unbalanced DIN:PO4 and Si(OH)4:DIN ratios in almost all samples. More importantly, the rainwater was determined to be a relevant source of fertilizers for marine waters and agricultural land in the Annaba area and can partially balance for the loss of Si(OH)4 from rivers to the bay due to dam retention.

Response of benthic nitrogen cycle to hypoxia of the Changjiang estuary

Authors: Sumei Liu, Jing Zhang, Zhuoyi Zhu, Guiling Zhang, Marcel M. M. Kuypers, Gaute Lavik

Presenter: **Guodong Song**

Anthropogenic induced coastal hypoxia can significantly influence the benthic biogeochemistry cycles. However, we know very little about the effects of bottom water hypoxia on the benthic nitrogen cycle. The Changjiang (Yangtze River) estuary and its adjacent area, as a typical hypoxia zone affected by the huge amount of nitrogen input from human activities, provide us with an ideal place to study the interaction between the hypoxia and benthic nitrogen cycles. We synthetically investigated the effects of bottom water oxygen level on benthic oxygen uptake, sediment oxygen profile, net flux of nitrate and ammonium, anammox, denitrification DNRA, nitrification and mineralization in the Changjiang (Yangtze River) estuary and its adjacent area, by combining seasonal comparison and artificially induced three different bottom oxygen conditions. With a natural 50% decline of bottom water oxygen from ~200 µM in May to ~100 µM in August, sediment oxygen uptake and oxygen penetration depth averagely decreased 23% and 29%, respectively. NH4+ inclined to release from sediment to overlying water, while NO3- was prone to shifting from efflux to influx to sediment. Anammox contribution to total N loss (ra) significantly decreased from 20% to 7.4%, leading to anammox rate decreased by a factor of 2.5 from 0.15 to 0.06 mmol N m^{-2} d^{-1}. However, denitrification showed a slight increase causing total benthic N-loss stablized at 0.85 mmol N m^{-2} d^{-1}. DNRA showed a significant increase by a factor of 5 from 0.02 to 0.10 mmol N m^{-2} d-1. These responses were consistent with the results derived from artificially bottom water oxygen condition controlled experiments (oxic vs ambient). However, the experimental results showed significant changes under severe hypoxia conditions. With bottom water oxygen dropping 92% from normal oxic condition (~200 µM) to severe hypoxia (16 µM), sediment oxygen uptake sharply decreased 91%. NH_4^+ showed an enhanced release to overlying water from ~0 to 0.60 mmol N m^{-2} d^{-1} and NO_3^- shifted from an efflux of 0.14 mmol N m^{-2} d^{-1} to an influx of 0.79 mmol N m^{-2} d^{-1}. Denitrification and anammox showed an average decrease of 38% and 43% under severe hypoxia, leading to total benthic N-loss decline of 38% from 0.92 to 0.57 mmol N m^{-2} d^{-1}. DNRA showed an elevation by a factor of 3 although it only accounted for less than 10% of total nitrate reduction.

Summer Turbulent Nitrate Fluxes and the Contributions to Primary Production in the East China Sea

Authors: Qun Sun, Wenjin Lyu

Presenter: **Wenjin Lyu**

In the stratified condition, the turbulent nitrate fluxes are crucial nitrogen sources and play important roles in primary production of the upper ocean. The synchronous data of the nitrate concentration and turbulence dissipation rate in the East China Sea (ECS) were used to calculate the diapycnal fluxes of nitrate in summer of 2018. The turbulent nitrate fluxes in the ECS ranged from -5.98 to 14.14 mmol$m^{-2}d^{-1}$, and the maximum value appeared in the middle of the north Yellow Sea due to the enhanced turbulence mixing. There was a broad and thin high-value region of the nitrate concentrations outside the Yangtze River Estuary where the diapycnal nitrate fluxes was downward and its mean value was -1.69 mmol$m^{-2}d^{-1}$. The new productions supported by the diapycnal nitrate fluxes in the surface ocean were estimated by the carbon-to-nitrogen ratio in the ECS. Using the annual mean primary production, the contributions of diapycnal nitrate fluxes to the primary production were quantified. The average contributions to the primary production accounted for 4.08% and 2.43% in the south Yellow Sea and in the ECS shelf, respectively. The maximum value was 23.88% and appeared in the middle of north Yellow Sea, where the diapycnal nitrate supplies sustained the new production.

Applying marine science to enhance life cycle assessment: a tool for supporting environmental decision making in policy

Authors: John S. Woods, Francesca Verones

Presenter: **John Woods**

The marine environment is of great importance for supporting human society. At the same time, the integrity of the marine environment is increasingly being compromised by pressures arising from resource use and emissions generated by anthropogenic activities globally. Marine science is key to understanding the consequences of these pressures on the marine environment. However, this understanding needs to be effectively communicated, in order to support policy and decision making towards a more sustainable society. One widely used tool that enables connecting environmental impacts from anthropogenic activities with improved decision-making and the communication thereof is life cycle assessment (LCA).
LCA involves the application of a systems-thinking approach to quantify potential environmental impacts of emissions generated and resources used over the entire life cycle of products or processes. As such, LCA results can help, for example, to identify hotspots of environmental impact within a product system, and identify which, of several product options is associated with lower overall environmental impacts. LCA is considered by the European Commission to be the best currently available tool to assess and communicate potential environmental impacts of products. In addition, LCA is a good eco-design tool, allowing assessment of potential impacts of new technologies and products while still on the drawing board.
A strength of LCA as a decision-support tool is the ability to identify and communicate potential trade-offs between multiple impact types. However, LCA has traditionally focused on terrestrial and freshwater impacts. Impacts on the marine environment are currently insufficiently included in operational LCA methods. This gives potential for environmental impact trade-offs being missed, and decisions being inadequately informed. Given the current and projected growth in marine resource utilisation by human society, and the growing amount of waste and emissions accumulating in the marine environment, it is imperative to develop additional tools for quantifying potential marine impacts in LCA methods.
Developing new marine impact assessment tools for LCA , e.g. for marine plastic litter, requires knowledge of the fundamental environmental impact mechanisms involved. Hence, timely environmental and ecological research is required to provide a primary understanding of marine impact mechanisms. Furthermore, a robust application of marine science in the context of LCA relies on a mutual understanding between the constraints of the LCA framework and marine scientists that can help identify the predominant mechanisms governing the degree of ecological damage arising from specific pressures on the marine environment.
In this presentation, I discuss the decision-making support provided by LCA, highlighting: 1) the context and scale of LCA impact assessment methods, 2) how primary marine science is incorporated in LCA impact assessment models, and 3) identify areas where state-of-the-art marine science could be used to improve the robustness of LCA as a decision-support tool that provides and interface between science and policy.

SESSION 21: RESPONDING TO POLICY MAKERS: WHAT CAN WE DO, WHAT DO WE NEED? BRIDGING THE METHODOLOGICAL GAPS FOR BETTER TRANSPARENCY

Why is interdisciplinary ocean science still a challenge? A local perspective from Southeast Brazil

Authors: Natalia de Miranda Grilli, Luciana Yokoyama Xavier, Pedro Roberto Jacobi, Alexander Turra

Presenter: **Natalia de Miranda Grilli**

Global changes and the growing impacts of human use of coastal and marine ecosystems demand ocean scientists to work into an inter-transdisciplinary manner. However, integrating the social, physical and biological aspects of Oceanography is far from being an easy task. Aiming to contribute to the development of

future interdisciplinary scientific research and to improve science-policy interface in coastal zones, we conducted an analysis of a broad oceanographic research project in which an interdisciplinary and applied approach was adopted to understand the components, processes and importance of a coastal bay in Southeast Brazil. We discuss the process of scientific knowledge production and integration among the diverse research areas of Oceanography and between science and society through interviews with project researchers, a documentary analysis of the project's annual reports and a social network analysis. From that, we could visualize which areas interacted better and why, as well as we identified actions that would foster integration in future research projects, related to

developing common research goals, concepts and methods and promoting opportunities for integration and investing in publications for lay people in addition to scientific publications. Despite of having room for knowledge integration improvement, the project resulted in relevant legacies both to ocean sciences and the local community and provided subsidies to decision-making. We hope that sharing this experience, its challenges, advances and lessons learned will contribute to future interdisciplinary researches with similar approaches and conflicts.

Global warming impacts on Bay of Biscay fish communities by the arrival of southern species

Authors: LE MARCHAND Marie, Hattab Tarek; Le Loc'h François; Ben Rais Lasram Frida

Presenter: **Marie Le Marchand**

Species suitable habitats are shifting under climate change. A flourishing literature has highlighted the tropicalisation of marine communities as a consequence of the arrival of southern thermophilic species in different ecosystems throughout the world. Future assemblages will be driven by both local species movements and southern invasions. In order to evaluate the impacts of climate change on fish and cephalopod communities in the Bay of Biscay, we used a new methodological framework combining the hierarchical filters approach, generation of pseudo absences and consideration of the third dimension of depth. Results consist in future potential suitable habitats for the 163 considered species as well as in future arrivals of southern species under two IPPC scenarios (RCP2.6 and RCP8.5) for two periods (2041-2050 and 2091-2100). Results revealed that coastal areas would undergo the highest species richness loss and a variable extinction rate of Bay of Biscay species was projected, depending on their habitat (benthic, pelagic, benthopelagic or demersal). In addition, a high rate of southern species invasions is expected. Assessment

of the species spatial turnover and based on Baselga equation showed that changes in assemblage composition are driven by both replacement and nestedness. This could lead to a major reorganization of trophic networks and may alter socio-economics components.

Modelling the nexus Socio-Ecology in the governance of Marine Renewable Energies

Authors: Rhoda Fofack-Garcia, Camille Mazé-Lambrechts, Nathalie Niquil, Morgane Lejart, Georges Safi, François Le Loch

Presenter: **Rhoda Fofack-Garcia**

Since the last ten years, French policies have tackled climate change by setting a national frame to foster the development of renewable energies in the national mix of energies. Under this global scheme, Bretagne Region has partly oriented its territorial development on Marine Renewable Energies (MRE). With the support of recent technical innovations, this strategy of development emerged on a representation of the marine space as the future “Sea-licon valley” in the MRE industrial sector. To implement this vision, the regional political strategy focuses notably on offshore floating wind turbines. In this context, the decision is raised to construct a pilot offshore wind farm in the Bay of Biscay, located between Groix and Belle-Île islands. The decision of implementing this pilot offshore wind farm resulted from a process of negotiation between different actors (public and private), different scales of governance, and various economic, technologic, environmental and social stakes which can be sometimes conflicting. The purpose of this paper is to highlight the process of decision-making concerning the implementation of the offshore wind farm of Groix and Belle-Île. In a socio-ecological system-based perspective developed in the APPEAL project, the paper presents the new methodological framework which combines both sociological and ecological networks, and stakes supported by each other’s. By modelling the socio-ecological system in an integrative approach and by analyzing the decision-making stages concerning its management, the paper evaluates the weight of ecological and socio-political variables in the decision-making process, increasing the understanding of impacts of offshore wind farm in a complex socio-ecosystem.

Improving confidence in complex ecosystem models: the sensitivity analysis of an Atlantis ecosystem model

Authors: Chloe Bracis, Raphael Girardin, Morgane Travers, Sigrid Lehuta, Marie Savina Rolland

Presenter: **Chloe Bracis**

There is growing interest in using mechanistic ecosystem models for ecosystem-based management, including evaluating the effects of perturbations, climate change, or changes in fishery management on ecosystem processes and functions. These end-to-end models have the advantage of capturing both bottom-up and top-down processes as well as system interactions from food web structure, spatial constraints, and fleet dynamics. However, they have the disadvantage of requiring many parameters, many of which are unknown and must be calibrated to available data. Atlantis is one of the most comprehensive ecosystem models and has been applied to a wide range of ecosystems worldwide and to a diverse set of questions. It is a biogeochemical model that incorporates data from a number of sources including hydrodynamics, biogeography, stock assessments, surveys, and fisheries. In particular, we use the Atlantis Eastern English Channel model which covers a spatial extent of approximately 35,000 km^2 and uses 42

species groups. Sensitivity analysis is an important part of simulation model development in order to understand model uncertainty and which parameters are more or less influential, but has been relatively neglected with Atlantis models due to the large number of parameters and long simulation run time. Here we present the results of a sensitivity analysis of several hundred growth, mortality, and recruitment parameters, which are the parameters that are particularly difficult to measure and thus commonly tuned through the model calibration procedure. Our approach includes several steps taken to accommodate the number of parameters in the model, such as using functions for parameters that vary with age class to both maintain ecological realism and reduce parameter number and using a Morris screening approach, which can efficiently provide information on parameter main effects and interactions/non-linear effects with relatively few simulations. We discuss the implications of feedback loops and trophic structure of the model for its sensitivity to the chosen parameter values for the growth, mortality, and recruitment parameters.

Valuing the Coastal Ecosystem Service: A Case Study of Xiamen, china

Authors: Lan Bo Zhang, Peng Ben Rong

Presenter: **Lan Bo Zhang**

Abstract: Coastal ecosystems provide many goods and services for human beings directly and indirectly, such as air regulation, climate regulation, disturbance regulation, nutrient cycling, waste management, biological control, habitat provision, food supply, raw material supply, genetic resources, recreation and cultural services. Unfortunately, human activities are diminishing the capability of many coastal and marine ecosystems to continue providing these needed goods and services which jeopardize the coastal sustainability. There are many economic and political factors that might influence how people extract goods and services from coastal and marine ecosystems. Economic signals, which are reflected in prices and government policies, are one of the prime factors determining how the ecosystems are treated by humans. But prices often send the wrong signals due to the market failure and policy failure. In recent years, there has been growing interest in valuing and integrating values of ecosystem services into decision making to correct market failures.

This study will develop a systematic framework to estimate the value of coastal ecosystem in Xiamen Bay. The framework contains the following parts: (1) Identify types of coastal ecosystem services in different regions; (2) Quantify the services in different regions; (3) Estimate the value of different types of ecosystems in different regions, including both ecosystem value compensation and environmental cost; (4) Consider the connection between different habitats.

Assembling Impact Pathways: an interdisciplinary framework for understanding potential effects of ocean deoxygenation on people and societies

Authors: Hannah R. Bassett, Alexandra Stote, Edward H. Allison

Presenter: **Hannah Bassett**

Ocean deoxygenation is a pressing issue, yet how it will affect people and societies is relatively understudied. In a review of human outcomes from ocean deoxygenation, we found that the entire impact pathway, which we define as linking reduced ocean oxygen levels to biophysical and ecological changes to social, economic, and cultural impacts, has rarely been documented. Examples of affected fisheries were the exception, while other economic sectors and most ecosystem services have garnered little attention.

Beyond highlighting a critical research gap, our analysis illuminated the need for the logical bridging of disciplinary knowledge bases that provide insights on different pieces of the same puzzle. In many cases the biophysical effects of reduced ocean oxygen are well-understood and these resultant biophysical changes have known effects on people and societies. For example, it is well-documented that corals provide coastal protection and tourism opportunities, among other ecosystem services. On the biophysical end of the spectrum, decreased levels of dissolved oxygen have been shown to cause mortality in corals. Thus, ocean deoxygenation can be expected to cause a reduction in coastal protection and tourism via loss of coral cover. In addition, studies show that translation of ecosystem services to well-being, and translation of loss of ecosystem services to risk, is mediated by social systems and institutions. Considering these social mechanisms of change allows for a more nuanced understanding of how people faced with the same change in ecosystem service availability may experience different impacts.
While such impact pathways require further investigation, it is necessary to consider all pieces of available information without delay to inform resource use planning and management. Here we build on and connect the ecosystem services framework, the Pressure and Release model of risk, and the concepts of well-being and equity to present a system of logic for assessing the potential for people and societies to experience more or less well-being as a result of changes to the natural environment.

Conflicting Goals and Best Strategies for Reaching Good Environmental Status in the Baltic Sea

Authors: Kristina Heidrich, Christian Möllmann, Saskia Otto

Presenter: **Kristina Heidrich**

There has been growing interest in the need for a sustainable utilization of marine resources and sound ecosystem-based management, which is reflected in Europe by the establishment of various legal frameworks such as the Helsinki Convention for the Baltic Sea, the OSPAR convention in and around the North-East Atlantic or the EU Marine Strategy Framework Directive. All of these frameworks apply an integrated indicator-based approach to managing human activities based on the best available scientific knowledge about the ecosystem. However, the highly stochastic, interlinked and complex dynamics of marine ecosystems make it particularly challenging for marine managers to evaluate the best strategies for maintaining ecosystem integrity and achieving Good Environmental Status (GES) across various system components. The latest computational developments show a great deal of potential as tools for decision-support and management strategy evaluation for data certification and knowledge transfer but have not been widely used on marine indicators.
Here, we present a framework that enables the assessment of overall ecosystem status and the evaluation of potential trade-offs between objectives, introduces best strategies for achieving GES based on a suite of robust indicators and guides management actions.
This framework is designed to simplify the negotiations and discussions between scientists, managers, politicians, stakeholders and citizens. As a first step, indicator performance is evaluated, the impact of pressures and natural variability on ecosystem functioning is assessed and threshold values required by policy makers are identified. Subsequently, cumulative impact assessment and trade-offs are evaluated using Bayesian Believe Networks (BNN), which allow the combination of pre-existing knowledge and new data in a mathematically transparent way. We demonstrate the framework in the context of the Baltic Sea and show the implications of different management strategies in tackling the key problems of eutrophication and overfishing as well as potential cascading effects through the food web.
With this tool we will facilitate the influx of information that politicians and managers need to make sound decisions to achieve cost-effective improvements in environmental status, based on expert knowledge and stakeholders' opinion. All in a simple, transparent modeling process that includes stakeholders and explicitly addresses and accounts for scientific uncertainty.
This approach will provide managers with a simple decision-support tool in their mission to achieve healthy and sustainable European marine waters.

Exploring how information from maritime surveillance could contribute to MSP processes

Authors: Clément Dupont, Françoise Gourmelon, Catherine Meur-Ferec, Frédérick Herpers

Presenter: **Clément Dupont**

These last decades have been characterized by a growing political awareness on maritime issues, mainly due to environmental concerns, but also to the development of newly maritime activities (e.g. marine renewable energy). In response, Marine Spatial Planning (MSP) is now considered worldwide as an efficient management approach (Ehler and Douvere, 2009).
As it has been highlighted in most initiatives around the world, knowledge is the essential prerequisite for the definition of strategies and plans and their implementation, be it on land or at sea (Kid and Ellis, 2012). While knowledge of marine ecosystems is building up, knowledge of maritime activities was still recently considered an almost blind spot (St Martin and Hall-Arber, 2008). In particular, knowledge concerning the spatial and temporal distribution of activities at sea remains fragmentary, and sometimes subjective, as many authors have pointed out (NOAA, 2010; Le Guyader, 2012; Peuziat and Le Berre, 2015).
In recent years however, in response to growing maritime security issues, maritime situational awareness has greatly improved, along with maritime surveillance systems such as Automated Identification System (AIS) for shipping, Vessel Monitoring System (VMS) for fishing, but also spatial and aerial imagery or radar for broader spectrums (eg. Campbell et al., 2014; Claramunt et al. 2017)
These systems produce large amounts of objective and quantitative data, contributing to what was mentioned as the “Big Ocean Data” at the last Sustainable Ocean Summit held in Hong-Kong in 2018. This offers ways to fill blanks in the current knowledge of human activities at sea, particularly needed in MSP first stages of initial state definition. It indeed allows to extract information, not only about ship’s positions, but also about maritime activities of these ships and main areas of practice for instance (e.g. Halpern et al., 2008, Le Tixerant et al., 2018).
Potential contributions of these information to MSP could be diverse: assessment and management of individual and cumulative environmental impacts, definition and management of MPAs, prevention and avoidance of risks and conflicts, allocation of space for sedentary activities and compensation assessment for instance.
However, an analysis of the bibliography and policy documents allows to highlight that MSP does without most of this information at this point and relies on less precise and objective alternatives, at least in the visible part of this political iceberg. In most countries, only AIS is used for marine spatial planning, and only to map maritime transport.
To explain this situation, various potential constraints can be identified: 1) technical, such as those relating to processing capacity, 2) economic, such as those relating to processing costs, 3) legal, such as those relating to the status of surveillance data, 4) societal, such as those relating to acceptance by marine users, 5) political, such as those relating to recognition in the decision-making process.
This contribution will highlight main surveillance data characteristics, their potentialities in term of spatio-temporal information and their current uses in MSP processes at international level with a focus on the French situation.

How can ecological risk assessment inform marine resource governance? A case study for seabed mining

Authors: Laura Kaikkonen, Riikka Venesjärvi, Sakari Kuikka, Kirsi Kostamo

Presenter: **Laura Kaikkonen**

Human impacts on the marine environment are increasing worldwide, with a growing number of new industries for marine resource use. To determine whether new activities pose ecologically significant threats to marine ecosystems, the impacts and uncertainties related to the new pressures must be carefully evaluated prior to permitting them. However, most assessments for human pressures affecting ecosystem components are based on the vulnerability of the environment through semi-quantitative scoring, and as such do not fully describe the different possible outcomes following external disturbances.
Here, we examine how the emerging seabed mining activities would affect marine ecosystems using probabilistic modelling. The work consists of qualitative model building followed by a quantitative part to estimate the magnitude of the impacts. We use the Baltic Sea ecosystems as an example to illustrate the ecological consequences of mineral extraction. The first phase of the work was conducted in collaboration with experts in marine geology and ecology to define the key interactions between pressures caused by seabed mineral extraction and the affected ecosystem components. The resulting influence diagrams will be used to build a Bayesian network to provide quantitative estimates of the ecological consequences of mineral extraction to different functional groups of organisms. The results from model simulations in different scenarios of seabed disturbance may then be compared to the policy targets and parameters describing relative changes in ecosystem health. By doing this, the aim is to illustrate the current state of knowledge on the impacts with quantitative metrics. We further discuss how ecological risk assessments could be constructed to inform decision making in the context of seabed mining, while using both ecologically and policy-relevant parameters that capture also the long-term consequences of the activity.

Sustainable Strategies for Improved Implementation of Marine Living Resource Legislation

Authors: Danai Tembo

Presenter: **Danai Tembo**

South Africa's marine and coastal resources are rich, diverse national assets that represent an important interface of human activity, socio-economic influence and ecological diversity. Many aspects of social and economic development are dependent on marine and coastal ecosystems and, as such, these ecosystems come under pressure from activities such as fishing, mining, coastal development, waste water discharge and mariculture. They provide important economic and social benefits for the population through a wide range of ecosystem services. In order to maintain sustainable use of such a valuable resource, the Marine Living Resources Act was enacted in 1998. The Act is very comprehensive and aims to ensure sustainable utilisation of marine living resources in a manner that is beneficial to all citizens. However, sound legislation would come to naught without proper implementation and South Africa seems to fall short in this regard. Studies show that the country faces great legislation implementation problems that extend beyond marine living resource legislation. In order to better understand the implementation of said legislation and how that can be improved in South Africa's coastal provinces, legislation was analysed and expert interviews conducted. The study found that there is an urgent need to find better ways to bridge the gap between legislation and implementation. With increased pressure on the marine and coastal environments, many instances of poor policing, corruption and increased levels of illegal, unreported and unregulated fishing, South Africa is on the road to losing the valuable resources contained in the marine environment. Recommendations made included changes to management and administrative structures, amendments to the legislation and improvements in policing and enforcement strategies.

Session 22: Same, same, different: understanding variability and the relative roles of environment, climate, fishing and trophic dynamics in marine ecosystems

Future of nutrients, fish, and fisheries under climate change: a multi-model approach

Authors: Tyler Eddy, Riley Brady, Cheryl Harrison, Ryan Rykaczewski

Presenter: **Tyler Eddy**

There are many representations of how nutrients and energy flow through marine ecosystems and become available for fish and fisheries. To address how different approaches in earth system models contribute to variability in future fisheries projections, we use climate change projections from two model intercomparison projects (MIPs); CMIP and FishMIP. First, we examine nutrient supply to ecosystems in Earth system models (ESMs) to understand the underlying mechanisms and assumptions leading to variability in climate change projections of primary production. Secondly, we use global fisheries and marine ecosystem projections from FishMIP to describe how variability in primary production among ESMs propagates to projections of fisheries productivity. We then quantify the relative amount of variability in fisheries production that is attributable to choice of fish model. Overall, we will quantify variation in climate change projections of fish and fisheries due to: representation of nutrient flux, choice of Earth system model, choice of carbon emissions scenario, choice of fish model, and choice of fishing scenario.

Projections of climate change and impacts on Chilean pelagic fisheries

Authors: Eleuterio Yáñez, Claudio Silva, María Ángela Barbieri, Antonio Aranis, Claudio Bernal, Francisco Plaza, Felipe Sánchez, Gabriela Böhm, Luis Soto, Alejandro Parés, Jaime Letelier, Gustavo San Martín & Peter Muck

Presenter: **Eleuterio Yáñez**

One of the priorities adopted in national and global fisheries policies is the progressive implementation of an ecosystem approach for fisheries management (EAF) to ensure the sustainability of aquatic resources. Climate Change (CC) will affect fisheries development in the EAF context and it is important to consider such effects at regional and local scales. The conceptual approach of CLIPESCA project is to link historical and future scenarios of CC with external environmental (physical) and anthropogenic (fishing effort) drivers to assess the impacts on the pelagic fisheries (anchovy, sardine, common sardine, jack mackerel and swordfish) in Chile. The aim of CLIPESCA is to develop a forecast system to explore how CC will affect the future pelagic fisheries resources. The methodology used in the project execution was based on: 1) collection of historical spatial-temporal environmental and fisheries databases; 2) development of predictive models based on historical data (neural networks and generalized models); 3) dynamics (i.e. ROMS) and statistical (i.e. Delta Method) downscaling of oceanographic conditions in the study areas; and 4) forecast of pelagic fish catch and relative abundance based on the prediction models forced by environmental changes as projected by IPCC models under the SRES (i.e. A2) and RPC (i.e. RCP2.6, RCP4.5, RCP6.0 and RCP8.5) emissions scenarios for the simulation period 2015-2050. Finally, a web site contains all databases, models and projections by pelagic fisheries in the study areas (www.clipesca.cl).

Future projections of plankton stocks and carbon fluxes for different biological regimes of the Mediterranean sea

Authors: Caroline Ulses, C. Estournel, , A. Dos Santos, P. Marsaleix, F. Sevault, S. Somot

Presenter: **Caroline Ulses**

Located between temperate regions of Europe and semi-arid regions of Africa and the Middle East, the Mediterranean Sea, a semi-enclosed basin undergoing an increase in the population in coastal areas, has been identified as one of the most exposed and vulnerable regions to climate change. The Mediterranean Sea is characterized by a variety of meteorological conditions leading to the presence of a variety of biological regimes: productive coastal regimes influenced by fluvial inputs, regimes characterized by massive vertical nutrient inputs in the euphotic zone in winter and explosive phytoplanktonic growth, as well as ultra oligotrophic regimes characterized by low biological production rates.

The different recent hydrodynamic scenarios converge towards an increasing temperature trend reaching the deep layers of the whole basin by the end of the century (between 2.5 and 4 ° C at the surface), and uncertain changes in salinity and exchanges of water, heat and salt with the Atlantic Ocean. Some scenarios also indicate a reduction in winter vertical mixing, particularly in the northwestern deep convection region. To date, few studies have proposed answers to the question "How will these hydrodynamic modifications affect the functioning of the different biological regimes, phytoplankton growth and associated biogeochemical fluxes?" Such studies nevertheless make it possible to anticipate the evolution of stocks of plankton, the first level in the food chain which influence fisheries, as well as of carbon fluxes and in particular the uptake of atmospheric CO_2. Pursuing these first efforts will then make it possible to better evaluate the uncertainties of these evolutions.

In this context, 10km, coupled physical-biogeochemical simulations were performed over the transient period 1950-2100 to analyze the impact of hydrodynamic climate change, based on the RCP 2.6, 4.5 and 8.5 scenarios, on primary production and export of organic carbon, as well as plankton stocks for various Mediterranean biological regimes. We show that, in the most severe climate change scenario, RCP8.5, the increase in temperature and stratification leads, by the end of the century, to a sharp increase in metabolic rates (primary production, respiration), and a decrease in net community production. On the other hand, the decrease in winter vertical mixing along the African coast and the decline of deep convection could lead to a sharp reduction in organic carbon export in the regions affected by these changes. Finally, a slight increase of heterotrophic organisms stock and a strong increase of dissolved organic carbon inventory in the euphotic zone are obtained. Sensitivity tests are then used to assess the potential impact of modifications in nutrient concentrations in rivers and in Atlantic waters.

Coupling novel modeling techniques to predict future scenarios and alternative management options for small pelagic species in the Northwestern Mediterranean Sea

Authors: Maria Grazia Pennino, Marta Coll, John Gabriel Ramirez, Marta Albó Puigserver, Jeroen Steenbeek, Jose Maria Bellido

Presenter: **Maria Grazia Pennino**

During the last years small pelagic fish species (SPF), such as European sardine (Sardina pilchardus) and European anchovy (Engraulis encrasicolus), have experimented changes in their abundance, biomass and spatial distribution in the Northwestern Mediterranean Sea. Different hypotheses have been related to these changes, such as: (1) an increase in fishing impact, (2) changes in the environmental conditions that can directly influence annual recruitment, growth and condition of organisms; (3) the recent recovery of some pelagic predators such as Bluefin tuna (Thunnus thynnus); and (4) inter-specific competition for food between the expanding round sardinella (Sardinella aurita). We firstly tested these hypotheses in the northwestern Mediterranean Sea (in Geographical Sub-Areas GSA06, Spain, and GSA07, France) using a statistical modelling approach in order to understand which one of these factors may have mostly affected these species, and secondly we developed scenarios to predict their future biomass and distributions using a multi-modelling platform. In particular, using a spatial Redundancy Analysis (RDA) we tested the four mentioned main hypotheses as possible causes of European sardine and anchovy observed biomass declines in the area. Secondly, we modeled future environmental and management scenarios including IPCC projected environmental variables using Species Distribution Models and a food-web modeling approach (Ecopath with Ecosim -EwE).

Spatial RDAs highlighted that the variability in the distribution of sardine in Spain (GSA06) was due to a combination of effects that included environmental conditions (bathymetry, sea surface temperature, primary production and sea surface salinity), fishing factors (considering AIS and VMS intensity), the expansion of the occurrence of Bluefin tuna feeding habitat, as well as an increase of round sardinella. Similar results were found for European anchovy in this area, although fishing factors were the most important ones. The spatial RDA findings for European Sardine in France (GSA07) highlighted that its distribution variability in the area may have been mainly due to spatial and environmental factors. For European anchovy, results of the RDAs showed that this species was mostly affected by fisheries impact and the environment conditions.

Future IPCC projections for both species highlighted that they will likely undergo a reduction in their spatial distributions. Waters around the Rhone River in France and around the Ebro River in Spain were identified as potential management areas for both species due to their nature as “future climate refuges” (areas with a probability of occurrence >0.70). Scenarios developed using a spatial-temporal EwE model previously calibrated highlighted that a general reduction of fishing mortality for anchovy and sardine (to 50% the historical status quo) could contribute to a successful recovery of both species. The establishment of a Marine Protected Area in coastal waters with restrictions to fishing could partially compensate the negative historical fishing impacts for both species. Our results represent the baseline to test alternative hindcasting and forecasting spatial-temporal scenarios providing useful information for the sustainable management of SPF in the Northwestern Mediterranean Sea.

Drawing the short environmental straw? A comparison between the Newfoundland-Labrador Shelves and Barents Sea marine ecosystems

Authors: Mariano Koen-Alonso, Elena Eriksen, Aaron Adamack, Magnus Aune, Alida Bundy, Ulf Lindstrom, Nina Mikkelsen, Fran Mowbray, Hannah Murphy, Torstein Pedersen, Pierre Pepin, Raul Primicerio, Paul Renaud, Hein Rune Skjoldal, Garry Stenson, and Jamie Tam

Presenter: **Mariano Koen-Alonso**

The Newfoundland-Labrador Shelves (NL) and the Barents Sea (BS) ecosystems share many structural features. Both systems have Atlantic cod as a historically dominant component of their groundfish communities, capelin and other small pelagics are key nodes for energy transfer between lower and upper trophic levels, and sea ice and environmental variability are important regulators of primary production. These ecosystems have experienced important changes over the last three decades, but despite their structural similarities, these changes have led to very contrasting current states. After the groundfish collapse in the 1990s, NL has yet to recover, but after the important declines in the mid-1980 BS quickly rebounded and is currently experiencing an all-time high in groundfish productivity. Our findings suggest that key differences between these systems are associated to environmental conditions in the post-collapse period, and the relative magnitudes of the declines in each system. System-wide productivity seems to respond to bottom-up control at the ecosystem scale in both cases, where examples of top-down control appear localized in space or linked to specific trophic connections (e.g. capelin-herring in BS, shrimp-groundfishes in NL). While environmental and ecosystem conditions emerge as key elements for understanding the differences between NL and BS, fisheries management has also differed between ecosystems. Management in NL continues to be single species focused, while management for the BS has been more responsive and adaptive to key ecological changes, including the changes in availability of key forage species.

How do differences in primary production relate to ecosystem status? A comparison of two sub-Arctic and Arctic ecosystems.

Authors: Jamie C. Tam, Alida Bundy, Torstein Pedersen, Nina Mikkelsen

Presenter: **Jamie Tam**

The Newfoundland and Labrador (NL) Shelf and Barents Sea are sub-Arctic/Arctic ecosystems with a comparable species composition. Despite the similarity of these two ecosystems, differences in environmental pressures and human activities have produced divergent ecological response patterns. Historically, groundfish stocks crashed in the early 1990s on the NL Shelf without recovery and a building of shellfish resources that make up the current fisheries. In contrast, in the Barents Sea abundances of both shellfish and groundfish stocks are currently high. Here we compare and explore the trophic linkages and patterns of change in these two ecosystems using Ecopath models with similar model structure built for the same time period (1985) to gain a better understanding of causes of such ecosystem shifts in sub-Arctic and Arctic regions. We compare the models at the single-species level and the ecosystem-level through ecological indictors. The results indicate that bottom up drivers, including primary production, play and important role in determining ecosystem status in sub-Arctic and Arctic Ecosystems.

Comparing cod-capelin dynamics in the Newfoundland-Labrador Shelves and Barents Sea ecosystems: A minimum-realistic bioenergetic-allometric modelling perspective

Authors: Ulf Lindstrøm, Mariano Koen-Alonso

Presenter: **Ulf Lindstrøm**

The cod stocks in the Newfoundland-Labrador Shelves (NL) and Barents Sea (BS) ecosystems have shown very divergent trajectories over the last 30 years. Both stocks experienced either an important decline (BS) or an outright collapse (NL) in the mid 1980s and early 1990s respectively. After these important population reductions, the BS stock quickly rebounded and it is currently experiencing an all times high level, while the NL stock, despite showing some modest improvement since the mid 2000s, continues to be at low levels to this day. While fishing and environmental conditions are known to be important drivers of cod dynamics in both ecosystems, especially the availability of high energy prey like capelin, the question remains about how different or similar these two stocks truly are. Could, for example, the NL cod stock rebuild if presented to conditions similar to the ones experienced by BS cod? To explore this kind of question we developed a simple biomass dynamic model for cod using a bioenergetic-allometric approach. This model includes fisheries catches and capelin availability as drivers, and assumes a lognormal process error. The model was implemented for both ecosystems, and the estimated fits and parameters compared. Despite the differences in trends between ecosystems, the model produced very good fits in both ecosystems, and the estimated parameters were remarkably similar. These results indicate that cod trajectories in NL and BS can be reliably explained by considering simple bioenergetic-allometric arguments, fishery catches, and the availability of a key forage species like capelin. Furthermore, the similarities in estimated parameters suggest that the underlying vital rates driving these stocks are comparable, and hence, the NL stock would be expected to rebuild if enough capelin were available. This also indicates that capelin status and trend should be an important consideration for effective management of these cod stocks.

Harp Seals: Monitors of Change in Differing Ecosystems

Authors: Garry Stenson, Tore Haug

Presenter: **Garry Stenson**

Harp seals, Pagophilus groenlandicus, are the most abundant marine mammal in the north Atlantic. As an ice-pupping, high trophic level predator, they are uniquely situated to reflect changes in their environment, particularly during a period of climatic change. Also, harp seals are the focus of a commercial hunt which has resulted in a large historic data set that can be used to quantify any changes that may have occurred. There are three populations of harp seals: 1) the White Sea/Barents Sea, 2) Greenland Sea and 3) Northwest Atlantic. Massive mortalities of White Sea/Barents Sea harp seals occurred during the mid 1980s due to collapses in their major prey (capelin, herring, Polar cod) in the Barents Sea. More recently, pup production declined by almost 2/3 between 2004 and 2006 and has remained low. Body condition appeared to decline during the same period, suggesting that ecosystem changes may have resulted in reduce reproductive rates, possibly due to competition with Atlantic cod. In contrast, the Greenland Sea population appears to be increasing slowly during a period of reduced hunting. Some changes in reproductive rates have been observed although the data are limited. Pupping concentrations are closer to the Greenland coast due to the reduction in ice in the traditional area but ice appears to be adequate. Reduced ice extent and thickness off the coast of Atlantic Canada has resulted in major pup mortality among northwest Atlantic population. After a period of increase, the population has been relatively stable for the past decade due to hunting, increased ice mortality and reduced reproductive rates. Extremely large interannual variations in body

condition and fecundity have been shown to be influenced by variations in capelin biomass and ice conditions. Each of these populations have been impacted differently by changes in their ecosystems and hunting practices. By comparing the three populations, we can gain a better understanding of how these changes are likely to be influencing other components of their ecosystems.

Modelling uncertainty and changes in food web structure and ecosystem properties of the Barents Sea from 1985 to 2013

Authors: Torstein Pedersen, N. Mikkelsen, U. Lindstrøm, P.E. Renaud, M-A. Blanchet, I.H. Ellingsen, L.L. Jørgensen and H. Blanchet

Presenter: **Torstein Pedersen**

The recent changes in production of zooplankton, planktivorous and demersal fishes in the Barents Sea ecosystem have been linked to changes in climate and human exploitation. Aiming to assess the underlying mechanisms behind these changes, we modelled the ecosystem for the period 1985 to 2013 using a mass-balanced food-web model (Ecopath with Ecosim). The major objectives were to investigate if there were changes in; i) mass flow pathways, ii) ecosystem properties (e.g., production, consumption, system omnivory), and iii) the major sources of model and ecosystem property uncertainty. Ecopath models containing 117 groups were parametrized for the contrasting years 1985, 2000 and 2013 using carbon as mass unit. Hindcasts from a coupled hydrographic-ecological model were used as input data for primary production (PP), while input values for biomass (B), production per biomass (P/B), consumption per biomass (Q/B), gross efficiency, catches and predator-prey diet matrices were mainly extracted from literature. We assessed uncertainties in carbon flows and ecosystem properties by Monte Carlo simulation. An Ecosim model based on the 1985-Ecopath model was fitted to time-series of biomasses, average weights, catches and P/B values. Several environmental drivers (e.g. changes in exploitation, temperature and PP) were evaluated during the model fitting. We assessed the changes over time and uncertainties in major mass flow pathways to higher trophic levels by; i) phytoplankton-based pelagic production, ii) detritus-based pelagic production through the microbial food-web, and iii) benthic invertebrate-based production.

Predicting cumulative effects of climate change and fishing on the Newfoundland and Labrador Shelves ecosystem

Authors: Jamie C. Tam, Alida Bundy, Mariano Koen-Alonso

Presenter: **Jamie Tam**

Predicting the impacts of climate change on marine ecosystems is a growing challenge for marine scientists and fisheries managers. The cumulative impacts on fisheries, species interactions and ecosystem emergent properties are always difficult to assess, but particularly so in a changing environment. Here we examine historically important stocks from the Newfoundland and Labrador bioregion to understand how this system as whole might change under future climate scenarios, including the uncertainty surrounding those predictions. By adapting an ecosystem model fitted to reflect species optimum, minimum and maximum temperatures, we were able to explore the impacts of three climate scenarios through model forecasting. Including uncertainty within the model aided in understanding the variability of the future scenarios. We examined the outcomes by focusing on two different levels of ecological organization, individual stocks and the ecosystem as a whole. At the stock level we explored the impacts of trophic interactions, fishing and

climate change on commercially important species like Atlantic cod, Capelin, Northern shrimp and Snow crab. At the ecosystem level we explored ecosystem status through projections of ecological indicators. The results highlight the importance of including climate change in ecosystem approaches to fisheries management to better understand the cumulative effects and unintended consequences of multiple stressors on ecosystems.

Trophic levels estimates from stable isotopes and mass-balance models for the Barents Sea – how do they compare?

Authors: Torstein Pedersen

Presenter: **Torstein Pedersen**

Estimates of trophic level for functional groups and species are important to analyse food-web structure and trophic relationships. A food-web for the arctic Barents Sea (area ca. 1.6 mill km^2) spanning ca. 5.5 trophic levels was analysed using a mass-balance model approach (Ecopath). The mass-balance models have 117 functional groups including all trophic levels ranging from phytoplankton to polar bear and separate models were parametrized for three years (1985, 2000 and 2013). Estimates of trophic levels from the mass-balance model and from stabile isotope (delta 15N) studies were compared to test the hypothesis that they were equal. Generally, trophic levels values derived from the mass-balance models and from stable isotopes were highly correlated (Pearson r of ca. 0.80) and the average difference in trophic levels for ecological groups was small (< 0.20). It was tested if use of alternative baseline values and group- and delta 15N specific discrimination factors affected the general relationship with mass-balance model derived trophic levels. For ecological groups where the Ecopath and SI-derived trophic level values differed, it was analysed and discussed which factors could explain the deviation pattern. These factors included within Ecopath-group variability in trophic level with regard to ontogenetic changes, seasonal changes, spatial differences and yearly differences.

Impacts of environmental variability, fishing and future climate change on marine food-web dynamics and human users in the Barents Sea

Authors: Stefan Koenigstein, Hauke Reuter, Hans-Otto Pörtner, Stefan Gößling-Reisemann

Presenter: **Stefan Koenigstein**

The Barents Sea is a sub-arctic shelf sea which harbors socio-economically important fish stocks and is strongly influenced by climatic variability. In recent years, ocean warming has led to shifts in distribution and productivity of marine fish populations, and substantial management challenges are anticipated under continuing warming and ocean acidification projected for this century.

We investigated the impacts of ocean warming, acidification and fisheries exploitation scenarios on productivity and population biomass of marine fish populations and energy flow through the food-web of the Barents Sea. Experimental and observational data on organismal temperature preferences, predator-prey interactions and early life stage processes were integrated, using process-based multi-species and recruitment models. Impacts and adaptation options for human user groups such as fisheries and maritime tourism were assessed by involving local stakeholders.

Under continuing warming in the Barents Sea, gradual shifts among the major marine fish stocks are projected. The high Atlantic cod stock, and herring and mackerel stocks increasingly entering the Barents

Sea, could lead to marked food-web mediated decreases in capelin, an important forage fish. Seals and seabirds will be negatively impacted through decreased food availability. Possible recruitment failures under combined warming and acidification in the second half of this century could be ameliorated by dynamic adjustments of fisheries catches.
This work demonstrates how process-based ecological models can integrate available data and investigate the contributions of climate, fishing and food-web dynamics to fluctuations and shifts in marine ecosystems. This can help to improve understanding of marine ecosystems, identify adaptation options for fishers and other users, and develop ecosystem-based management strategies under climate change.

Satellite-derived productive fronts as a common proxy for marine ecosystem productivity across oceans: lessons learnt from a climate-dependent and fisheries-independent indicator

Authors: Jean-Noël Druon, Fromentin J.M., Gascuel D., Mannini A., Vasilakopoulos P., Coll M., Piroddi C., Pinto C., Palialexis A., Dubroca L.

Presenter: **Jean-Noël Druon**

Productive fronts that result from the resurgence of subsurface nutrient-rich waters such as on the edge of eddies or gyres were shown to attract fish and top predators (Druon et al. 2017, 2016, 2015, 2012, Panigada et al. 2017) as they are active long enough (from weeks to months) to allow the development of mesozooplankton populations (Druon et al. submitted). These productive oceanic features, which are daily detected by ocean colour satellite sensors, are used as a spatial proxy of food availability to fish populations. The satellite-derived Ocean Productivity index for Fish (OPFish) represents the potential production of high tropic level communities (fish) which results of the analysis of feeding preferences of various trophic levels such as mesozooplankton, small pelagic fish, hake recruits, tuna species, fin whale and blue shark. Typical integration time of chlorophyll-a front occurrence (at 4.5 km horizontal resolution) is of one to three days for the changing pelagic environment and predators while it is of about six to eighteen months for the more static demersal species and communities.
We present here how productive fronts are common hotspots of productivity for the marine food chains and how the derived habitat and productivity products can be used to monitor the capacity of the oceans to sustain living resources under the current effect of climate change but independently of fisheries. The interaction between fishing effort allocation and OPFish, which is seen as a proxy for potential fish distribution, will help elucidating the distribution of fishing efficiency and also hint towards potential future spatio-temporal shifts of fishing.

Long-term ecosystem dynamics on the Northeast US continental shelf with a focus on the trophic role of zooplanktivorous forage fishes

Authors: Joel Llopiz, Justin Suca

Presenter: **Joel Llopiz**

The continental shelf ecosystem off the northeast United States has long experienced human impacts from fishing, but it also undergoing rapid change associated with climate impacts—faster than most other regions of the world. However, our understanding of how such stressors cascade throughout the ecosystem is limited. Small pelagic fishes, also known as 'forage fish,' represent a critical trophic connection between planktonic production and large predators. While we know that small pelagics broadly consume zooplankton, the taxonomic resolution of their diet and the carbon pathways they represent has been limited, especially in the western North Atlantic. Similarly, we have a poor understanding of how bottom-up changes, including those related to physical properties (e.g. temperature) or zooplankton abundance and composition, alter forage fish feeding, condition, distribution, and abundance. We currently have several projects focused on the important forage fish species in the NE US shelf ecosystem, and will highlight results and future plans from three of them. Among these is a recently begun Long-Term Ecological Research (LTER) project focused on the NE US shelf and elucidating the important linkages from physics through plankton to forage fish, including how and why the trophic role of forage fish species can change. Our initial work on forage fish diets in the region reveals that there are strong consumer-specific differences as well as seasonal differences, with copepods generally dominating in the spring. Appendicularians represent a substantial portion of the diets in the spring as well, likely linking the carbon source of these fish to the microbial loop. Most species switch to a diet dominated by krill and amphipods in the fall, except Atlantic mackerel, which consume small copepod genera in both the fall and spring. Other work is centered specifically on northern sand lance—a burrowing forage fish with specific habitat requirements—and how bottom-up processes and larval dispersal variability can lead to the enormous spatial and temporal fluctuations in their abundance.

Physical regimes and energy flows through fish communities in the California Current Ecosystem

Authors: Jerome Guiet, Daniele Bianchi

Presenter: **Jerome Guiet**

Marine ecosystems emerge from the interaction of a multitude of biotic and abiotic components. Part of this complexity is lost in ecosystem models, which often adopt simplified representations of ecosystem structure and dynamics. As a consequence, models often fail to capture important aspects of the interaction between climatic drivers and human activities. Here, we present a model of the California Current Ecosystem developed to resolve these interactions. The model tracks the biomass flow from plankton to fish, for four interacting fish communities, demersal, pelagic, mesopelagic and diurnal migrants, each composed of different species, represented as separate size spectra. The model is based on the Dynamic Energy Budget theory, and species are differentiated using a single trait, their asymptotic size. We implement the model in the California Current Ecosystem, a highly variable region for which many observations of fish abundance and habitat are available, in particular scientific trawls and acoustic transects. The model reproduces the observed three-dimensional biomass distribution, and allows us to track the energy flow between different size classes, species, and communities. The model reveals how diverse physical regimes, from upwelling to oligotrophic gyres, influence the structure and variability of the fish communities they support. We use the model as a first step to quantify the relative roles of environment, climate and fishing on the biomass flow in the California Current Ecosystem, and its future change.

Operational adaption of grey mullet fishing fleet possibly influenced Climate variability in the Northwestern Pacific

Authors: Ming-An Lee, Sheng-Yuan Teng, Yi-Chen Wang

Presenter: **Ming-An Lee**

The Grey mullet (Mugil cephalus L.) is a cosmopolitan species distributing in tropical and temperate zones at latitudes 42°N–42°S (Thomson 1963). It is one of the most important commercial species of fish in the coastal fisheries of Taiwan. It migrated into the coastal waters of the southeastern Taiwan Strait (TS) around 22-25°N.for spawning in wintertime, while the feeding grounds are located in the coastal and estuarine waters of China around 25-30°N. The PDO and ENSO index play a role in affecting the migration of grey mullet, but the increase in SSTs may be the main reason for the decreased catches after 1980. Annual catches considerably dropped and continually remained at an extremely low level from 1986 to 2010. This work investigates impacts of climate variability in fishing conditions and fishing variability of mullet fishing grounds in the coastal waters of Taiwan. Due to the subsequently decreased catch, the types of the fleet with fishing methods in the coastal waters of Taiwan were changed from the purse seiner with two boats before 1986, to the drift net and trawl net as the abundance was at the low level between 1989 to 2010. Recently, the fleet with the Taiwanese purse seiner was dominant when the abundance increased since 2012. It suggested that the fishing fleet was significantly changed and autonomously adapted with the catch of grey mullet in Taiwan waters.

A life history model of giant jellyfish *Nemopilema nomurai* and its application in the Yellow Sea

Authors: Yuheng Wang, Liang Zhao

Presenter: **Yuheng Wang**

Since the bloom event of jellyfish in 2003， the accumulation of *Nemopilema nomurai* has become an increasing threaten to the Yellow Sea and East China Sea ecosystem. More and more attention is paid to the mechanism of jellyfish bloom and its relationship with climate change. A life history model forced by bottom temperature is established to simulate the asexual generation of *N. nomurai*. The model is applied in possible habitats of polyps, i.e. Changjiang estuary, Subei Shoal, and offshore of Gunsan; the interannual variations of ephyra released is counted, the results agree well with observation, especially in the regime shift before and after 2003. Comparing the three possible habitats, the simulation results of Changjiang estuary shows best consistence with observation, that supports the hypothesis that *N. nomurai* in the Yellow Sea mainly comes from Changjiang estuary. Contribution of temperature in different seasons is analyzed, short autumn and long winter seems favorable to the recruitment of ephyra. The day of temperature falling below 13℃ become notable earlier, which is verified by observation, should be a possible reason for the increase of jellyfish bloom after 2003.

Simulating marine life and change: advancing food web modelling capabilities to analyse plausible global ocean futures

Authors: Marta Coll, Jeroen Steenbeek, Joe Buszowski, Cristina Garilao, Maria Grazia Pennino, Kristin Kashner, Yannick Rousseau, Carl Walters, Reg Watson, Villy Christensen

Presenter: **Marta Coll**

There has been considerable effort to predict the impact of climate change and anthropogenic activities on the biophysical environment and marine resources at regional and global scales. To further our understanding of how changes in the environment and marine resources will affect marine ecosystems, there is a need for global integrated assessments. We improved a previously developed spatial-temporal ecosystem model of the global ocean (EcoOcean), spanning food web dynamics from primary producers to top predators, and including worldwide fisheries. We recalibrated EcoOcean and enhanced its ability to reproduce spatial-temporal ecosystem dynamics by linking species productivity and distributions to main environmental conditions in flux under climate change (e.g. primary production, sea surface temperature, salinity, ice cover), accounting for varying species compositions of functional groups in time and space. The updated modelling platform was used to model past and future scenarios of climate change and fisheries, considering intrinsic input parameter uncertainty and alternative input drivers using standardized outputs from Earth-system models (ESM) and contrasting emission scenarios (RCPs) for historical (1950-2005) and future (2006-2100) periods. Standardized ecological indicators were used to compare changes in marine structure and functioning between scenarios. Comparing results from alternative environmental and management scenarios allowed evaluating how climate-driven responses differed. The study sets the baseline to further develop global ocean analyses and contribute to the quantification of cumulative effects assessment of multiple stressors and plausible ocean-based solutions to global change.

A food web model to evaluate climate change impacts and fisheries management for a large oceanic plateau in the Southern Ocean

Authors: Roshni Subramaniam, Jessica Melbourne-Thomas, Stuart Corney, Kerrie Swadling

Presenter: **Roshni Subramaniam**

The Kerguelen Plateau is the largest volcanic plateau in the Southern Ocean, extending more than 2,200 km in a northwest-southeast direction. It is an important oceanographical feature in the sub-Antarctic Indian Ocean and the Antarctic Circumpolar Current. The plateau influences the eastward flow of the Antarctic Circumpolar Current and fertilises high nutrient low chlorophyll water with iron, enabling phytoplankton blooms. Persistent blooms on the plateau attract a wide range of prey species and their predators making the plateau a biological hotspot. The ecosystem supports commercial fisheries in the area targeting Patagonian toothfish and mackerel icefish. The Kerguelen Plateau ecosystem is understudied compared to other productive ecosystems in the Southern Ocean. Major linkages and energy pathways have not been explored, and the combined effects of fishing and a changing climate on the ecosystem are largely unknown. In this study, we attempt to bridge this gap in knowledge by developing the first time-dynamic, spatially explicit ecosystem model for the Kerguelen Plateau using Ecopath with Ecosim. We first present a static view of the ecosystem using Ecopath, showing energy flow and major linkages within the food web. We then add time series data to this model using Ecosim to identify the physical and biological drivers of the ecosystem and identify vulnerable species. Lastly, we incorporate habitat maps and species distribution using Ecospace to assess the effectiveness of marine protected areas. Identifying the drivers of the ecosystem, key energy pathways, and the ecosystem impact of the two fisheries will help to inform projections of ecological change in the Southern Ocean. This model is part of a suite of models currently under development that form part of a large comparative ecosystem study for East Antarctica.

Assessing the potential impacts of fishing and ocean acidification on the southern Benguela food web and fisheries

Authors: Kelly Ortega-Cisneros, Lynne Shannon, Kevern Cochrane, Elizabeth Fulton

Presenter: **Kelly Ortega-Cisneros**

This study aims to determine the impacts of fishing and ocean acidification on the functioning of the southern Benguela upwelling system using the Atlantis modelling framework and climate projections from the NEMO-MEDUSA 2.0 model. Acidification was assumed to affect the growth and mortality of plankton and squid only. This decision was made because of the limited number of studies evaluating the effects of acidification on invertebrate and fish species in South Africa. Meta-analyses reporting the effects of ocean acidification in different marine taxa were used to inform model simulations. The direct effects of ocean acidification were modelled on small and large phytoplankton, microzooplankton, mesozooplankton, macrozooplankton and squid.
The effects of fishing were simulated by increasing and decreasing the fishing mortality rates of all target species by 50%.The base case scenario does not include the effects of ocean acidification and maintained the current fishing mortalities documented for the period 2011-15 throughout the model runs (i.e. years 2016-2050). The average biomass values of the last 10 years of a simulation (e.g. 2041-2050), were compared to the baseline scenario to determine the individual and combined effects of fishing and ocean acidification. Five ecological and fishery indicators (total biomass, total catch, proportion of predatory fish, ratio of demersal to pelagic fish biomass and mean trophic level of catch) were also calculated to provide further insights on the effects of acidification on the ecosystem. The presentation will describe progress made to date in identifying the combined effects of acidification and fishing on the structure and functioning of the southern Benguela system.

Parsing human and biophysical drivers of coral reef regimes

Authors: Jean-Baptiste Jouffray, Lisa M. Wedding, Albert V. Norström, Mary K. Donovan, Gareth J. Williams, Larry B. Crowder, Ashley L. Erickson, Alan M. Friedlander, Nicholas A.J. Graham, Jamison M. Gove, Carrie V. Kappel, John N. Kittinger, Joey Lecky, Kirsten L

Presenter: **Jean-Baptiste Jouffray**

A key challenge for effective management is to understand how anthropogenic and biophysical conditions interact to drive distinct ecosystem configurations. Here, we focus on coral reefs and use machine learning to model the occurrence of four distinct reef regimes defined by both fish and benthic communities. Drawing on the most spatially extensive predictor dataset available across the Hawaiian archipelago – 20 anthropogenic and biophysical predictors over 620 survey sites – we show that reef regimes are distributed along a gradient of human and environmental influence, with an overwhelming importance of biophysical predictors, such as wave power, depth and structural complexity, in predicting their occurrence. However, the most degraded regime, characterised by low fish biomass, few corals and high algal cover, is primarily explained by human predictors (i.e., fishing catch and effluent discharge). Identifying what predicts different reef ecosystems is essential to help practitioners effectively anticipate and respond to coral reef change. In particular, discerning the relative influence of anthropogenic and biophysical drivers is critical to appreciate how environmental conditions may either expand or narrow the opportunity space for effective management. Our findings provide empirical evidence that dealing with ecosystem change is inherently a social-ecological issue, and that designing effective management interventions requires both focusing on prominent human drivers while accounting for the natural bounds set by the local biophysical environment. From an analytical perspective, we anticipate that our approach and use of boosted regression trees will be of high relevance to researchers involved in explanatory predictions across a wide range of ecosystems.

An uncertain future: The impact of fishing on a highly vulnerable ecosystem, the case of Juan Fernández Ridge Ecosystem.

Authors: Javier Porobic, Fulton E., Parada C., Frusher S., Ernst B., Manríquez P.

Presenter: **Javier Porobic**

The Juan Fernández Ridge (JFRE) is a vulnerable marine ecosystem (VME) located off the coast of central Chile formed by the Juan Fernández Archipelago and a group of seamounts. This ecosystem has unique biological and oceanographic features, characterized by small geographical units, high degrees of endemism and a high degree of connectivity within the system. Two fleets have historically operated in this system - a long-term coastal artisanal fishery associated with the Islands, focused mainly on lobster, and a mainland-based industrial demersal finfish fishery operating on the seamounts (which is currently considered overexploited). The management of these fisheries has been based on a classical single-species approach to determine output controls (industrial fleet) and a mixed management system with formal and informal components (artisanal fleet). There has been growing interest in increasing the exploitation of fisheries and modernization of the fishing fleet already operating in the JFRE. Under this scenario of increased levels of fishing exploitation and the high level of the interrelation of species, it might be necessary to understand the impact of these fisheries from a holistic perspective based on an ecosystem-based modeling approach. To address these challenges we developed an Atlantis end-to-end model for this ecosystem. The implemented model has a high degree of skill in representing the observed trends and fluctuations of the JFRE. The model shows that the industrial fishing has a localized impact and the artisanal fisheries have a relatively low impact on the ecosystem under current harvest levels, mainly via the lobster fishery. The model indicates that the depletion of large-sized lobster leads to an increase in the population of sea urchins. Although this increase is not sufficient, as yet, to cause substantial flow-on effects to other groups, caution is advised in case extra pressure leads the ecosystem towards a regime shift.

Ecological basis to embrace temporal assessment and spatial management of the European hake (Merluccius merluccius) in the northern Iberian Peninsula

Authors: Francisco Izquierdo, Santiago Cerviño, David Conesa, Alexandre Fernández, Maria Grazia Pennino, Francisco Velasco, Fran Saborido-Rey, Antonio Punzón and Izaskun Preciado.

Presenter: **Maria Grazia Pennino**

Spatial management of commercial resources is becoming an effective measure to be broadly implemented in the European Seas. However, it is currently unconnected from the population dynamics and the temporal assessment. Indeed, it is known that species abundance can be influenced by the environmental features of its own habitat and/or by biotic process that are spatially structured (e.g. reproduction, predation, among others). Usually, this variability is assumed to be implicitly in the abundance trends used as inputs of the stock assessment models and it is not explicitly taken into account. Within this context, in this study we propose a novel methodological approach for an effective implementation of spatial and ecological knowledge that could help to embrace species spatial management in an operational way, providing a more holistic and ecosystem-based approach. As case study we used the European hake (Merluccius merluccius) in the northern continental shelf of the Iberian Peninsula. Hake data in functional groups by size collected during the scientific survey series “DEMERSALES” by the “Instituto Español de Oceanografía” (IEO) from 1993 to 2017 were analyzed using Bayesian hierarchical spatial-temporal models (B-HSTMs), considering as environmental variables Sea Temperature, Sea Salinity, bathymetry and rugosity of the seabed. B-HSTMs link spatially information on hake abundance to environmental variables to estimate and predict where

(and how much of) this species is likely to be present in the studied area in a specific year. Indices of abundance obtained as outputs from B-HSTMs, performed with the innovative integrated nested Laplace approximation (INLA) methodology and software, are then used as inputs for the GADGET (Globally applicable Area Disaggregated General Ecosystem Toolbox) stock assessment model. Finally, a comparative analysis of the results obtained with the GADGET model using the B-HSTMs abundance indexes and the ones commonly used in stock assessment evaluations is performed. We argue that the analytical framework proposed in this study allowed to (1) assess which environmental factors influence the different size groups of the hake in the northern continental shelf of the Iberian Peninsula, (2) identify the areas in which the different functional groups are more aggregated and their spatial-temporal fluctuations, and (3) could be a decisive step to improve habitat-based standardization abundance indexes and stocks' management in European Seas.

Monitoring shifts in abundance of cephalopods in North Spain shelf ecosystems: A key in fisheries assessment

Authors: Esther Abad, Julio Valeiras, Maria Grazia Pennino, Eva Velasco, Alberto Serrano, Francisco Velasco, Graham J. Pierce

Presenter: **Maria Grazia Pennino**

Cephalopod species are an important marine resource in the fisheries of Northern Spain and in particular for the otter bottom trawl fleet. This fleet prosecutes a mixed fishery which takes place throughout the year and although targets mainly fish, several cephalopod species are also landed by this commercial fleet. These landings have been relatively poorly documented in the past. However, a standardized scientific on-board observer program is carried out monthly to collect quantitative spatio-temporal data on both catches and discards for use in stock assessment. Such data provide long time series, covering the whole year each year, and information on a large variety of cephalopod species. However, this kind of data can be biased due to constraints imposed by management and the deliberate misreporting of catches. Furthermore, another issue arises because the sampled fishing locations are often repeated and tend to be associated with high abundances of target species because fishing fleets are commercially driven. Nevertheless, in the northern shelf of the Iberian Peninsula (ICES divisions 8c and 9a north), cephalopod species data are also collected through the annual bottom trawl scientific survey IBTS-DEMERSALES, performed by the Instituto Español de Oceanografía (IEO). This type of fishery-independent dataset is considered to be of superior quality because it is independent of fisher behaviour and management measures, standardized fishing methods are used, and both sampling statistics and the biological information can be taken into consideration. The disadvantage of these surveys is that they have limited space-time coverage, as they are performed over relatively short periods of time (autumn season). Comparing and combining observations from different fishery data sources could provide a useful tool with which to bridge some gaps in our cephalopod species knowledge. In this context, the aim of this study is to characterize catches and discards of cephalopod species along the northern continental shelf of the Iberian Peninsula, taking advantage of these two different data sources and to relate distribution and abundance to environmental variables. In particular, species data were analyzed with Bayesian hierarchical spatial-temporal models considering, as environmental variables, Sea Surface Temperature, Sea Surface Salinity, bathymetry and rugosity of the seabed. Spatio-temporal patterns obtained with the two sources were then compared using similarity and prediction statistics. Results highlight that the main cephalopod species in catch biomass terms, in order of decreasing abundance, were: curled octopus (Eledone cirrhosa), broadtail shortfin squid (Illex coindetii), lesser flying squid (Todaropsis eblanae), long finned squid (Loligo forbesi), common squid (Loligo vulgaris), European flying squid (Todarodes sagittatus), pink cuttlefish (Sepia orbignyana), common cuttlefish (Sepia officinalis) and elegant cuttlefish (Sepia elegans). Spatio-temporal patterns of occurrence of each species, based on the two data-sources, obtained with Bayesian models were generally similar, although the agreement is closer for some species than others. Finally, we argue that the approach applied

in this study could help fishery managers to better define survey designs and analyses, as the obtained results help to improve understanding of patterns in the catches and discards cephalopods along the northern continental shelf of the Iberian Peninsula.

Pattern or Process: considering space, time, and the environment in species distribution models

Authors: Stephanie Brodie, Gemma Carroll, James Thorson, Ellen Willis-Norton, Steven Bograd, Elliott Hazen, Kirstin Holsman, Jameal Samhouri, Melissa Haltuch, Stan Kotwicki, Rebecca Selden

Presenter: **Stephanie Brodie**

In an era of extraordinary environmental variability and change, there is increasing need to accurately describe the patterns of species distribution and understand the processes shaping those patterns. Species distribution models (SDM) are the most common approach to describing species distributions, with a myriad of model types and parameterization options. Space and time covariates in SDMs can effectively describe species distribution patterns, but environmental covariates can better address the processes involved. Not all SDM types equally attribute environmental covariates and there is a need to explicitly explore if environmental covariates are realistically and accurately reflected in SDMs. We explored spatiotemporal dynamics and environmental attribution across a suite of species distribution models and comparatively assessed model strengths. To achieve this, we first used simulated species distribution data with known environmental preferences to build and compare three types of species distribution models of increasing complexity: a machine learning model (boosted regression tree), a semi-parametric model (generalised additive model), and an autoregressive model (vector autoregressive spatiotemporal model). Secondly, we apply the same comparative model framework to a case study with three species (arrowtooth flounder, pacific cod, and walleye pollock) in the Eastern Bering Sea, USA. Spatiotemporal covariates effectively described species distributions, with the addition of environmental covariates generally improving model fit. Species abundance estimates were more variable between model types, rather than the covariate parameterisation, indicating that model biases play a large role in estimating species abundance and distribution. In the models tested here, there was an apparent trade-off between accurately estimating species abundance and accurately estimating the environmental mechanisms influencing species distributions. This trade off between pattern and process highlights the importance of considering and identifying model purpose as a first step in the SDM process. Models used to transfer beyond the study domain (i.e. climate projection) likely need to have a focus on understanding processes, relative to models that are used to accurately describe patterns in species distribution.

Main drivers of seasonal change in commercial species distributions of the Northwestern Mediterranean Sea

Authors: Elena Lloret-Lloret, Maria Grazia Pennino, Daniel Vilas, José María Bellido, Joan Navarro, Marta Coll

Presenter: **Elena Lloret**

Despite multiple studies that focus on marine Mediterranean resources and ecosystems, there is a lack of information considering the importance of seasonality on these ecosystems. This knowledge is key to

predict and understand how ecosystems can react to climate change effects and how to improve fishing management. Here, we examined the spatial distribution of eight commercial marine species; including fish, crustaceans and cephalopods, in a highly exploited area of the Northwestern Mediterranean Sea during two different seasons (winter and summer). We hypothesised that the seasonal differences in the water column (with a marked thermocline in summer and absence of it in winter), as well as the spatial heterogeneity of oceanographic conditions, can result on a seasonal variation of species distributions, which may impact ecosystem spatial and functional traits. We employed a Bayesian hierarchical species distribution model with data from two experimental oceanographic surveys conducted during winter and summer of 2013. Our model included seven explanatory variables; depth, type of bottom substrate, water temperature (surface and bottom), sea surface salinity, primary production, and fishing effort as the drivers of species distributions during both seasons. We identified significant drivers in each season and we analysed if they were specific or common to all the studied species. Then, we investigated whether the functional relationships between the predicted and explanatory variables varied from winter to summer. Our results provide solid knowledge about ecosystem response to environmental and anthropogenic drivers, as well as the first systematic quantification of seasonal changes in commercial species distributions in the western Mediterranean Sea. These results could have important management applications and help project regional ecosystem responses to existing or new stressors in the future.

Take it to the limit: finding ecological boarders of fish distribution using quantile regression

Authors: Husson Bérengère, Husson Bérengère, Benjamin Planque and Gregoire Certain

Presenter: **Bérengère Husson**

Understanding and predicting species habitat is of critical importance for ocean resource management and ecosystem monitoring. A central issue in species distribution modelling is that of missing relevant variables (e.g. because they are hard to monitor or unknown). Lack of important variables can decrease model performance and predictive power.
One way to circumvent this problem is to identify how individual environmental factors may restrict a species potential habitat, rather than trying to best explain the average response variable (i.e. presence/ absence or abundances data). Quantile regression modelling can be used to achieve this by estimating the upper quantile of the conditional distribution of abundances data, instead of its center or its mean. Some values of an individual factors might represent limiting conditions for the species (e.g. low oxygen concentration). Several factors can limit the same response variable at different time and place, making the potential habitat easy to define and predict. Following Liebig's concept of the limiting factor, the response will be as high as the most limiting factor allows it.
Quantile regression was applied on the 30 most abundant demersal fish taxa from the Barents Sea. Biomasses sampled during the autumn ecosystem surveys between 2004 and 2017 were linked to ten environmental variables: surface and bottom temperature and salinity, ice cover, stratification, depth, slope, and type of sediment. Single species - single factors GAM models were trained on data from 2004 to 2013 and tested on the 2014-2017 period. Factors most often limiting the potential habitat include surface and bottom temperature. Some species (e.g. Polar cod) display a high variance in biomass in the Barents Sea, and their distributions appear to be constrained by environmental conditions. For other species (e.g. Gadus morhua) there is low contrast in abundances in the Barents Sea and the SDM model performance are poor. Because current environmental conditions appear to be non-limiting, it is hard to predict their future habitat, given the set of variables used.

Seabird distribution and abundance in a region of rapid environmental change

Authors: Rhian Evans, Hindell, MA, Swadling KM, Lea M-A

Presenter: **Rhian Evans**

Understanding the spatial distribution of seabirds at sea allows linkages to be formed between their behaviour and the bio-physical drivers which dictate their foraging. South-east Tasmania supports a diverse array of resident and migratory seabirds and is also a region of considerable environmental variability as a result of the intensification, and southward advection of the East Australian Current (EAC). Effects of this warming have been documented along the east coast of Tasmania, and a significant change to the community composition and abundance of the zooplankton community has been recorded at multiple sites along the coast. Changes in the lower levels of food-chains are expected to have cascading impacts to higher order predators. Here we present the results of three-years of visual seabird surveys in conjunction with an integrated biophysical study of the continental shelf region where they forage. Multivariate statistics as well as regression modelling will be used to relate the distribution and abundance of seabirds to environmental variables, which vary substantially through the study period. The findings of this study are expected to inform managers of this variable ecosystem and establish baseline information on the response of seabirds to changing environmental conditions in a region which has previously been little studied.

Understanding Cephalopods catch and discard rates from fishery-dependent and independent data in north Iberian waters.

Authors: Julio Valeiras, E. Abad, M.G. Pennino, E. Velasco, A. Punzón, F. Velasco, G. Pierce

Presenter: **Eva Velasco**

Cephalopod species are an important marine resource in the fisheries of Northern Spain and in particular for the otter bottom trawl fleet. This fleet prosecutes a mixed fishery which takes place throughout the year and although targets mainly fish, several cephalopod species are also landed by this commercial fleet. These landings have been relatively poorly documented in the past. However, a standardized scientific on-board observer program is carried out monthly to collect quantitative spatio-temporal data on both catches and discards for use in stock assessment. Such data provide long time series, covering the whole year each year, and information on a large variety of cephalopod species. However, this kind of data can be biased due to constraints imposed by management and the deliberate misreporting of catches. Furthermore, another issue arises because the sampled fishing locations are often repeated and tend to be associated with high abundances of target species because fishing fleets are commercially driven. Nevertheless, in the northern shelf of the Iberian Peninsula (ICES divisions 8c and 9a north), cephalopod species data are also collected through the annual bottom trawl scientific survey IBTS-DEMERSALES, performed by the Instituto Español de Oceanografía (IEO). This type of fishery-independent dataset is considered to be of superior quality because it is independent of fisher behaviour and management measures, standardized fishing methods are used, and both sampling statistics and the biological information can be taken into consideration. The disadvantage of these surveys is that they have limited space-time coverage, as they are performed over relatively short periods of time (autumn season). Comparing and combining observations from different fishery data sources could provide a useful tool with which to bridge some gaps in our cephalopod species knowledge. In this context, the aim of this study is to characterize catches and discards of cephalopod species along the northern continental shelf of the Iberian Peninsula, taking advantage of these two different data sources and to relate distribution and abundance to environmental variables. In particular, species data were analyzed with Bayesian hierarchical spatial-temporal models considering, as environmental variables, Sea Surface Temperature, Sea Surface Salinity, bathymetry and rugosity of the seabed. Spatio-temporal patterns obtained with the two sources were then compared using similarity and prediction statistics. Results highlight that the main cephalopod species in catch biomass terms, in order of decreasing abundance, were: curled octopus (Eledone cirrhosa), broadtail shortfin squid (Illex coindetii), lesser flying squid (Todaropsis eblanae), long finned squid (Loligo forbesi), common squid (Loligo vulgaris), European flying squid (Todarodes sagittatus), pink cuttlefish (Sepia orbignyana), common cuttlefish (Sepia officinalis) and elegant cuttlefish (Sepia elegans). Spatio-temporal patterns of occurrence of each species, based on the two data-sources, obtained with Bayesian models were generally similar, although the agreement is closer for some species than others. Finally, we argue that the approach applied in this study could help fishery managers to better define survey designs and analyses, as the obtained results help to improve understanding of patterns in the catches and discards cephalopods along the northern continental shelf of the Iberian Peninsula.

Balancing or compensating your fisheries catches? Evaluating different fishing patterns using the EcoTroph approach

Authors: Jennifer Rehren, Didier Gascuel, Hubert Du Pontavice

Presenter: **Jennifer Rehren**

Balanced harvest has been suggested as an alternative strategy to the current fisheries management in order to minimize the effects of fishing on the ecosystem structure, while simultaneously maximizing overall yield. Balanced harvest aims to achieve this goal by distributing fishing mortality across all species and size classes in proportion to their natural productivity. Such a fishing pattern is supposed to maintain the relative biomass structure of the ecosystem. However, some authors claimed that the removal of lower trophic level species might lead to the loss of food supply to higher trophic levels and thereby to an “unbalanced” effect on the biomass structure of the ecosystem.

We used the trophic-level approach EcoTroph to investigate the effect of balanced harvest (i.e. fishing mortality is fixed proportion of the production rate of each trophic level) on the biomass, production and catch trophic spectra of a virtual ecosystem. Trophic spectra were then compared to a fishing scenario based on a logistic selectivity curve, mimicking the increase of fishing selectivity from low values at low trophic levels to full selectivity at higher trophic levels. Furthermore, we explored alternative strategies for distributing fishing mortalities across trophic levels to minimize impacts on the ecosystem.

Our results show that fishing all trophic levels proportional to their productivity as proposed by balanced harvest, does not fully maintain the ecosystem structure. Cumulative effects of fishing along the food web, from preys to predators, induce an increase in biomass depletion with increasing trophic level. The balanced harvest catch was nine times higher than in the fishing scenario with selectivity, but over 70% of the catch was comprised of trophic levels below 2.5, mostly including low value species (if not non-commercial).

We developed a compensated harvest strategy in which fishing mortalities were defined according to the release of predation induced by predator’s exploitation. This “compensated harvest” scenario resulted in the same biomass structure as the virgin ecosystem, while producing a large amount of catch, including high trophic levels.

In brief, EcoTroph simulations suggest that compensated harvest outperforms balanced harvest ecologically and economically.

Temporal trends and drivers of Sardine condition in the Bay of Biscay over the last 14 years

Authors: Veron Matthieu, DUHAMEL Erwan, PAWLOWSKI Lionel, BERTIGNAC Michel, HURET Martin

Presenter: **Matthieu Veron**

Small pelagic fish such as sardines are among the most ecologically important fish species because they constitute an important biomass at mid-trophic levels. Due to their socio-economical importance, these species, characterized by large fluctuations, are highly targeting by fisheries. As a result of the critical abundance of sardine in the Iberian waters, fishing pressure on the sardine stock in the Bay of Biscay has increased since the end of the 2000s. At the same time, a significant decrease in mean body length and weight was observed and still remained unexplained. In order to develop effective assessment and management tools it is therefore important to understand life history traits under the angles of their annual cycle and interannual variations. Based on 14yrs of morphometric data from scientific survey and fisheries in the Bay of Biscay, we analyzed sardine body condition variability and its responses to environmental and anthropogenic changes. Generalized additive models were first used to identify trends in body length and condition over the study period and to test the existence of trend specific to age-class and sex. Results showed an age-sex specific decreasing trend in body length over the study period with most of the variability explained by the age-class. The strongest difference emerged between age-classes 1 and 2, supporting the fact that individual growth is strongest during this time period. Body condition was best explained by the smoothed time trend and exhibited an age-class specific decrease. Based on those results, annual cycle of sardine condition at age was inferred from 7 linear-mixed effects models including endogenous factors. Overall, sardine younger than 3yrs appeared to be more strongly affected over the study period with yearly decline in condition. Whatever the age-class, condition was maximal during the third quarter, after the spawning period and when food availability is high. The minimum of condition varied among age-class, likely reflecting life history strategies and physiological responses to environmental conditions. Individuals identified as matures and being spawning exhibited a better condition for almost every age-classes excepted sardines of 5 and 6 yrs. Annual trends in condition at age showed remarkable coherence with a significant decrease since 2007 for all age-classes suggesting that factors influencing body condition operate at the population level. Time series was analyzed to examine the effects of fishing activity, oceanographic abiotic (Sea Surface temperature, salinity, eddy kinetic energy) and biotic (chlorophyll a, net primary production, phytoplankton) factors on sardine condition. Potential synchrony in temporal changes in fish condition at age and those factors was also investigated through a breakpoint analysis in order to distinguish two continuous periods of significant different levels in a given variable.

Projecting climate change and eutrophication-induced effects on distribution of a key benthic invertebrate: <i>Saduria entomon</i> in the Baltic Se

Authors: Mayya Gogina, Michael L. Zettler, Irene Wåhlström, Helén Andersson, Hagen Radtke, Ivan Kuznetsov, Brian R. MacKenzie

Presenter: **Mayya Gogina**

Saduria entomon is a glacial relict species that plays an important role in benthic food webs, both as a prey for higher trophic level species such as cod (Gadus morhua), and as a predator of other benthic animals. To investigate how environmental perturbations under climate change might affect its distribution and food web role in a Large Marine Ecosystem (Baltic Sea), we construct habitat distribution models based on density and occurrence of this species from 1981-2010 and estimate the relative importance of different

driving variables. Next, we use two regional coupled physical-biogeochemical models to investigate the combined impacts of two future climate change and nutrient loading scenarios on spatial distribution in 2070-2100. Our results suggest that the distributional and biomass responses of S. entomon were dominated by salinity, and secondarily by temperature changes, leading to a southward expansion of range, but a loss/decline in northern areas; the impact of expected changes in near-bottom oxygen concentrations was comparatively small. Local food web links and trophic flows, including those with commercially important fish species, are likely to be affected by such changes. These findings display the necessity of considering multiple hydrographic variables when estimating climate change impacts on species living in brackish and estuarine systems.

Predation selection and diet shift of Cyanea nozakii in the northern East China Sea

Authors: PengPeng Wang, Fang Zhang, Fang Zhang, Song Sun

Presenter: **Fang Zhang**

Cyanea nozakii, as a common jellyfish in the offshore China, has a complicated trophic relationship with other zooplankton communities. Predation selection by experimental clearance rate and diet shift by analyzing stable isotope (SI) δ13C and δ15N of Cyanea nozakii in situ were carried out in the northern East China Sea. Clearance rates varied widely with prey organisms: clearance rate of gelatinous organisms were significantly higher than other preys; C. nozakii captured Artemia and fish larvae more efficiently than copepods and chaetognaths. C. nozakii size and prey size both had marked effects on clearance; Clearance linearly increased with the cross sectional area of C. nozakii, which demonstrated that predation ability on zooplankton is enhanced with the increase of C. nozakii size. Clearance decreased with prey size increase, and predation of C. nozakii on fish is mainly in the period of juvenile fish. A significant change in SI values was found during C. nozakii growth, and δ13C and δ15N increased linearly with C. nozakii diameter. Increase of the feeding proportion of high trophic zooplankton promoted the enrichment of isotope δ13C and δ15N. The MixSIAR model indicated that seston (< 160 µm) contributed a proportion of 50.87% to the diet of 1 - 20 cm and 18.98% to the diet of > 50 cm jellyfish, while zooplankton ranged from 49.13% of young medusae diet to 81.02% of large medusae diet. We hypothesized, therefore, a dietary shift during C. nozakii growth, which from a seston based diet in young medusae to a zooplankton based diet in larger medusae. Copepod meanly contributed 36.34% - 38.16% to the C. nozakii diet during its growth. Gelatinous organisms averagely comprised ranged from 16.80% of young C. nozakii diet to 35.28% of large C. nozakii, perhaps larger C. nozakii need more gelatinous preys to grow well. Mixing model output indicated a low proportion of Nemopilema nomurai in the diet of C. nozakii, and thus to a potentially lesser importance of intraguild predation among these species in the northern East China Sea.

Future climate change challenges food web stability in an exploited marine system

Authors: Susa Niiranen, Steven J. Lade, Olle Hjerne, H.E. Markus Meier, Saskia A. Otto, Maciej T. Tomczak, Johanna Yletyinen, T. Blenckner

Presenter: **Susa Niiranen**

Climate change in combination with heavy resource exploitation stresses the world's oceans in ways

previously unseen. As a consequence, an increasing number of large-scale marine ecosystem changes, including ecosystem reorganizations or regime shifts, are being reported worldwide. While changes in species composition, relative species abundances and food web structure are recorded, it is often unclear how the system's vulnerability to external perturbation, or system stability, develops together with the changing system. We explore how projected future climate change in different combinations with fishing and nutrient load scenarios can affect food web stability in the Baltic Sea, a highly exploited brackish waterbody in Northern Europe. We translate species abundances, energy flows and key population rates projected by a dynamic food web model into Jacobian matrices and use the leading eigenvalues as a proxy of food web stability. Further, we study how food web stability is related to climate variables, primary productivity and top predator biomasses (cod, Gadus morhua) across different multiple stressor scenarios. We find that climate change decreases food web stability in every scenario. The magnitude of this effect is, however, dependent on the specific nutrient loads and fishing intensity. Changes on the higher trophic levels and top-down control, via fishing, have a clear impact on food web stability under future climate, while nutrient loads resulted only in a minor effect, emphasizing the role of top predator cod as a keystone species. Importantly for ecosystem management, we show that due to the non-additive nature of multiple stressor interactions food web stability can vary unexpectedly between different management scenarios affecting both the vulnerability of the ecosystem state to external perturbation, as well as its potential for recovery. Our study provides a valuable example on how a broadly used food web modeling approach can be utilized to gain an understanding on system-specific vulnerabilities for management and restoration actions.

Variability of fishing reference points for interacting species under climate change

Authors: Morgane Travers-Trolet, Youen Vermard, Mathieu Genu, Pierre Bourdaud

Presenter: **Morgane Travers-Trolet**

In Europe, marine fish stocks are mostly managed through the assessment of their exploitation and ecological status compared to reference points such as Maximum Sustainable Yield (MSY). Efforts towards an ecosystem approach of fisheries have led to the exploration of multispecies MSY or pretty good yield concepts, but so far management is still using mono-specific reference points. In parallel, climate warming is already affecting marine ecosystems and its impacts will probably increase in the future. Climate-induced changes on the ecosystem will affect fish stock directly or indirectly, but they might also impact the optimized level of catch expected from a stock and its relative fishing pressure. Here we propose to explore the level of variability of MSY reference points for interacting species under climate change by using a multi-species model of the fish community. The individual-based OSMOSE model has been applied to the Eastern English Channel, a highly exploited semi-continental sea, by explicitly representing predation interactions between 14 species of fish, feeding also on plankton and benthic invertebrates groups. This spatial model assumes a size-based opportunistic predation between individuals and represents the entire life cycle of fish. Additionally to the simulation of the Eastern English Channel ecosystem during a recent period (2000-2009), the model has been used to assess the ecosystem state for the 2040-2050 period, using two contrasted climate change scenarios (RCP 4.5 and RCP 8.5). In a first step, simulations of ecosystem state for the recent period and under future scenarios allows identifying the main changes in food web structure and species abundances under two levels of warming, with fishing pressure kept constant. In a second step, a monospecific MSY estimation routine is performed by varying the fishing mortality applied to each species independently. Estimation of these reference points is realized for the recent period and for both future scenarios. The simulated evolution of the resulting monospecific reference points is compared across species in order to emphasize some commonalities, notably in relation to their current exploitation status. Comparison between the two contrasted RCP scenarios also shows the non-linearity of the response. Finally, total yield supported by the system is also assessed for the three sets of simulations in order to quantify how climate change may affect future yield. Using a flexible multispecies model based on predation interactions allows exploring the effects of climate change both on the ecosystem and on the fishing activities depending on it.

Marine species facing global changes in the Celtic sea and Bay of Biscay

Authors: MARIANNE ROBERT, François SIMON-BOT Lionel PAWLOWSKI

Presenter: **Marianne Robert**

Important amount of literature highlight effects of climate change on marine species, communities functioning and consequences for fisheries, which exploited them 1,2. Scenario of global warming on marine ecosystems indicate that the magnitude of effect depend on ecosystems location and status. This work studies the effect of climate change on marine species in the temperate ecosystems of the Celtic sea and Bay of Biscay, two systems intensively exploited by European fishing fleets. The scientific survey EVHOE (Evaluation of fishing resources of Western Europe) provides long-term fisheries independent and standardized data on species composition and abundance as well as associated environmental data such as temperature, salinity and depth. Spatio- temporal evolution of species distribution were analyzed by identifying North and South drifts in the minimal, maximal and gravity center of latitude of abundance indices. Temporal evolution of depth observed were also analyzed. For the species presenting spatial drifts through time, we tried to understand the relative role of abiotic (e.g temperature at both local and more global scale) and biotic conditions (e.g. abundance) as well as fishing pressure on the observed changes. The identification of underlying mechanisms involved in the observed changes in distribution is still challenging as our understanding of the ecosystems dynamics and responses to multiple stressors are still very poor.

The Celtic Sea through time and space: what drives what in the ecosystem?

Authors: Pierre-Yves Hernvann, Didier Gascuel, Marianne Robert, Dorothée Kopp, Hubert Du Pontavice, Chiara Piroddi, Jean-Noël Druon

Presenter: **Pierre-Yves Hernvann**

Both trophic structure and biomass flows within marine food webs are shaped by the environment, which is likely to be modified by climate change, and anthropogenic pressures such as fishing. The environment influences species productivity and distribution, thus spatial co-occurrence of predators and preys, while fishing modifies species abundances also affecting the food-web structure. In order to disentangle the impact of these two drivers in the Celtic Sea ecosystem, we developed a trophic model (Ecopath with Ecosim and Ecospace) over the 1985-2016 period, both temporally and spatially dynamic. This model was fed with a wide diversity of information on environmental response of all trophic levels. Satellite remote sensing was used to determine annual fluctuations in primary production (PP) and their geographical distribution. Spatial and temporal variability in habitat favorable for zooplankton was informed from a novel ecological-niche model using daily detection of productive fronts from satellite sensors and 3D-hydrodynamic models results. Functional responses of fish compartments to several environmental variables (temperature, salinity, oxygen concentration, both at the surface and the bottom) were characterized from presence-absence data issued from fisheries-independent surveys. Driven by time-series of fishing effort, PP, suitability of zooplankton habitat and environmental variables, the temporal component of the model (Ecosim) was fitted on observed data of abundance and catches. For specific years, characterized by contrasted environmental conditions, spatial versions of the model (Ecospace) were built to predict biomass distribution of all the ecosystem compartments. Our results highlight that fishing was the main driver of observed changes in the Celtic Sea ecosystem over the study-period. However, the improvement of the temporal fit after integration of environmental variability suggests that PP controls the pelagic production and temperature influences the productivity of compartments of various trophic level. Additionally, substantial changes in the spatial distribution of targeted species were stressed out. Mainly driven by temperature, such changes may significantly impact fisheries in the near future.

Spatiotemporal patterns of northern shrimp life-history traits and its relation to fishing and environmental variability

Authors: Andres Beita-Jiménez, Arnault Le Bris, Eric Pedersen

Presenter: **Andres Beita-Jimenez**

Numerous stock collapses worldwide have revealed that declines in stock productivity are often preceded or accompanied by significant changes in species life history traits such as length or age at maturity. The mechanisms of changes in life history and whether these changes are reversible remains unclear for many species. Northern shrimp (Pandalus borealis) has been one of the most economically valuable fisheries since the collapse of the northern cod. However, this stock is now experiencing a sharp decrease in productivity with important socio-economic consequences for coastal communities in the region. In this study we evaluate the variation shrimp size at sexual transition during a 20 years period encompassing both an increasing and decreasing population productivity. We evaluate if 1) variation in shrimp size at sexual transition are caused by variation in fishing intensity, population density or temperature, 2) if trends in shrimp size at sexual transition are reversible, and 3) if these trends precede or result from trends in stock productivity We use spatially explicit Generalized Additive Models (GAMs) to consider the fine-scale spatial variation when evaluating trends in shrimp in size at sexual transition . We show that shrimp size at sexual transition significantly reduced during the period of high stock density and that the current decrease in stock abundance is accompanied by an increase in size at transition. These trends are contrary to previously documented trends in size at transition of P. borealis in other regions during periods of low biomass. Ongoing work will help reveal the mechanisms governing variation in northern shrimp life history.

Quantify the potential role of environmental fluctuations and changes in the small pelagic fish status of the northwestern Mediterranean Sea

Authors: Marta Coll, Maria Grazia Pennino, Elena Fernández, Marta Albo Puigserver, Jeroen Steenbeek, Jose Maria Bellido.

Presenter: **Maria Grazia Pennino**

Small pelagic fish species are sensitive to environmental fluctuations and change, which can be amplified due to climate variability, with cascading effects up and down the food web. In the Mediterranean Sea, small pelagic fish species such as European sardine (Sardina pilchardu) and European anchovy (Engraulis encrasicolus) have been shown to be key elements in the transfer of energy from lower to higher trophic level organisms. Historically, they showed an important bulk of biomass and production and played a key ecosystem role due to a strong coupling between the pelagic and the demersal environments. Relevant declines in biomass and landings of sardine and anchovy have been observed in recent decades in the

western Mediterranean Sea (in GSA06, Spain, and GSA07, France). These changes were linked to environmental fluctuations that can directly affect annual recruitment, growth and condition of organisms. Within this context, we firstly performed a systematic review of the existing information about available studies analyzing the role of environmental changes in relationship with the status of sardine and anchovy in the NW Mediterranean using the PRISMA approach. Secondly, statistical analyses were performed crossing available datasets regarding presence/absence, abundance, biomass, and landings of anchovy and sardine with environmental parameters from 2003 to 2016. In particular, we developed two different statistical approaches: (1) to explore the effect of the environment from a time-specific temporal perspective we used Random Forests (RFs), and (2) to spatially predict the distribution of SPF species and their annual changes we used Boosted Regression Trees (BRTs) considering available environmental variables (sea surface temperature, sea surface salinity, primary production and bathymetry).
During the systematic review, more than 1300 studies were evaluated although only 50 provided quantitative information about relationships between anchovy and/or sardine and the environment in the Mediterranean Sea. Both species showed mostly a negative relationship with depth. In the case of sardine, there was mostly a positive relationship with salinity and primary productivity, while temperature showed mixed effects although a negative relationship prevailed in the literature. The relationship between anchovy variables and temperature, primary productivity and salinity was mixed depending on the study.
The RFs showed an overall negative effect between both species and primary productivity, a positive effect with temperature, and mixed effect with salinity. Predictive spatial-temporal maps obtained with BRTs showed an overall expansion of anchovy distribution in the study area, while sardine reduced its natural niche more closely to the Ebro (Spain) and Rhone (France) rivers' deltas. Our results identified some of the priority habitats for these two SPF species in the northwestern Mediterranean Sea providing essential tools, such as predictive distribution maps, with the final aim of contribute to a sustainable management and future conservation.

The CLIOTOP Regional Programme: building collaborations to develop understanding of dynamic marine ecosystems and the pathways for sustainable practices needed.

Authors: Karen Evans, Joel Llopiz, Sebastian Villasante

Presenter: **Karen Evans**

Marine ecosystems are dynamic and constantly changing through both natural and anthropogenic processes. Effective management requires sufficient understanding of such dynamic systems, including the pressures impacting them and associated risks, and the implementation of adaptive frameworks for management of those risks. At the same time, pathways for sustainable practices that meet stakeholder and public expectations and are resilient to change are also required. Delivering ocean management that addresses these key components requires multi-disciplinary approaches that incorporate physical, ecological, and socio-economic aspects. International networks such as the CLimate Impacts on TOp Predators (CLIOTOP) science programme (a regional programme of the Integrated Marine Biosphere Research (IMBeR) project), where a comparative philosophy is actively supported, provide efficient avenues for the exploration and attribution of drivers of variability in dynamic pelagic systems to support the development and implementation of adaptive management applications that consider ocean variability and change. CLIOTOP's overarching goal is to facilitate broad-scale comparisons (e.g. over time, space, and taxa) that better identify the impacts of climate and fishing on top predators and the functioning of pelagic ecosystems, with the ultimate goal of developing a predictive capability for the effects of such impacts. Several activities, including collaboration-promoting workshops, open science symposia, and dedicated task teams addressing specific topics, have yielded valuable studies and results to meet CLIOTOP's objectives and contribute to IMBeR's research goals. Moving forward, CLIOTOP—open to any interested individuals—looks to continue to expand these collaborations to facilitate large-scale comparative efforts focused on elucidating key processes involved in the interaction between climate variability and change and human uses of the ocean on the structure of pelagic ecosystems, thereby providing information, products and tools for better resource and conservation management.

The impact of environmental changes on the primary production in the Gulf of Lions and links with small pelagic fish

Authors: Feuilloley Guillaume, Fromentin Jean-Marc, Stemmann Lars, Demarcq Herve, Saraux Claire

Presenter: **Guillaume Feuilloley**

Bottom-up control is one of the most widespread ecosystem regulation and refers to a system controlled by its resources. A good knowledge of the interactions between environment and plankton productivity is then necessary to understand energy transfer across the food web. This study focuses on the Gulf of Lions shelf, where an important decrease in small pelagic fish condition and size has been observed since 2008, leading to an important fishery crisis. Although alternative hypotheses such as fishery-induced and natural top-down pressures, potential diseases or migration changes were tested, the bottom-up control seems the most probable cause for these changes. The objective of this study was then to investigate the environmental drivers of primary production, estimated by the Chla concentration, and their temporal variability. The Gulf of Lions is one of the most productive areas in the Mediterranean Sea, mainly driven by the Rhône river nutrient inputs, coastal upwellings and mesoscale oceanographic processes. Therefore, new time series of upwelling, stratification and thermal front indices were constructed and analysed together with classical variables, such as SST, Chla and Rhone river nutrient concentration and flow. Seasonal cycle and trend were investigated in order to detect possible changes using time series decomposition and breakpoints. Interestingly, the unique regime shift in Chla concentration has been detected in 2007, which matches the beginning of the decrease in small pelagic fish condition and size. Moreover, the Rhone nutrient inputs significantly decreased over time, and the Rhone flow was identified as the principal driver of the Chla, accounting for a third of the variance. In summary, the system on the shelf seems to have become less productive concomitantly with the decrease in small pelagic size and condition, mainly due to a decrease of the Rhône river inputs. How such changes in primary producers has translated in changes of the secondary production whether in terms of abundance or specific composition and ultimately on small pelagic fish populations remains to be investigated.

Modelling Chance and Necessity to explore the possible dynamics of the Barents Sea ecosystem under climate and fishing pressures

Authors: Elliot SIvel, Benjamin Planque, Ulf Lindstrøm, Nigel Gilles Yoccoz

Presenter: **Elliot Sivel**

Numerical models of ecosystem dynamics provide a useful tool to anticipate the combined effect of climate and fisheries on marine ecosystems in the future. The conventional mechanistic approach, as applied in end-to-end models, simulates the dynamics of the system by resolving an ensemble of complicated ecological processes. This often involves a large number of state variables, equations and parameters. A difficulty is that predictions may be 'precisely wrong', i.e. the model might provide precise answers but

these can be misaligned with observations because, for example, some processes are lacking, some ecological relationships may be elusive, the model can be highly sensitive to some parameter values, and so on. Here, we use an alternative modelling framework based on chance and necessity (CaN). Rather than mechanistically modelling the detailed processes at play, CaN modelling focuses on the limits to the possible configurations of the system (necessity) and explores these configurations in a stochastic fashion (chance). CaN modelling explicitly recognises irreducible uncertainty of ecological dynamics and provides a tool to explore possible ecosystem trajectories. We apply CaN modelling to the Barents Sea food-web using the Non-Deterministic Network Dynamic (NDND) model. We explore the potential future dynamics of the Barents Sea ecosystem under present climate and fisheries conditions and under scenarios of climate (temperature) and fisheries (catch).

Drivers of spatiotemporal variability in the forage base for pelagic top predators in the California Current

Authors: Barbara Muhling, Stephanie Brodie, Michael Jacox Owyn Snodgrass, Heidi Dewar, Desiree Tommasi, Chris Edwards

Presenter: **Barbara Muhling**

The California Current ecosystem (CCE) is highly productive, but characterized by strong spatial and temporal variability in environmental conditions, ecological processes, and fisheries landings. Small pelagic species such as sardine (Sardinops sagax) and anchovy (Engraulis mordax) are known to be extremely important to coastal food webs. However, it is not well understood how their characteristic fluctuations in biomass and migratory behaviors impact the foraging dynamics of the higher order predators which rely on them. Here, we use statistical models of the distribution and phenology of key forage species to show how oceanographic variability and extreme events can alter the prey assemblage available to pelagic top predators in the CCE. We combine these results with multiannual diet time series data for commercially important tuna species, to show how foraging behaviors and prey availability may influence diet composition, prey-switching, and energy flows through the system. Our findings can improve understanding of dynamic trophic interactions in the region, as well as the development and refinement of ecosystem models for the CCE. Enhanced knowledge of these processes will be particularly important for natural resource managers, as climate change continues to result in novel environmental conditions, and unforeseen species interactions.

Toward a global decrease in biomass flow in marine food webs over the 21 st century?

Authors: Hubert Du Pontavice, William W. L. Cheung, Gabriel Reygondeau, Pierre-Yves Hernvann, Jennifer Rehren, Didier Gascuel

Presenter: **Didier Gascuel**

Climate change already has very significant effects on marine life and should play a key role in the future, with notably a displacement of species toward the poles. That will have huge impacts on the structure and functioning of ecosystems, ultimately affecting the future of fisheries and beyond all services provided by the Ocean. We analyzed a key aspect of this issue, focusing on the impact of changes in biomass flow within the marine food webs and the resulting effects on biomass and productivity of the global ocean.

We used the EcoTroph approach where the ecosystem functioning is summarized as a flow of biomass. Ecosystem is fueled by primary production or detritus recycling and, biomass propagates trough the food-web from low to upper trophic levels, due to predation and ontogenic processes. Productivity and total biomass, from primary consumer to top predator, are determined by three key factors, each depending on the sea water temperature: the primary production entering the food web, the transfer efficiency describing the biomass transfer losses, and the kinetic determining the residence time of biomass at each trophic level. Here, using climate forcing of three global circulation models, we calculate biomass and production in every 1°x1° grid cell of the global ocean, under two contrasted climate change scenarios. We especially showed that unexploited consumer biomass and production are expected to decrease by 10% and 15%, respectively, by 2100 under RCP8.5 scenario. We analyzed spatial and temporal changes and quantified the relative impact of each process: changes in primary production, transfer efficiency and flow kinetics. Finally, we identified the most sensitive marine ecosystems to climate change.

Variability of the trophic structure in the Humboldt Upwelling System

Authors: Tianfei Xue, Ivy Frenger

Presenter: **Tianfei Xue**

Eastern Boundary Upwelling Systems (EBUS) host extremely high productive ecosystems and support highly diverse communities. Despite similar levels of primary production of EBUS they vary in terms of fish catch: The Humboldt Upwelling System (HUS) supports higher fisheries yields than the other three EBUS combined. It is unclear what the causes are of the extremely high fish productivity of the HUS. To better understand the bottom-up regulation of the system we assess the impact of variability of upwelling on secondary production, the trophic transfer efficiency, and the lower trophic dynamics. We carry out the analysis in a coastal band of 300 km width in the EBUS, first focusing on the HUS using a regional coupled physical-biogeochemical model (ROMS-BioEBUS). Second, we will analyze the EBUS in a global model (GFDL ESM2.6) to investigate how the HUS trophic dynamics differ from the other EBUS. With this, we aim for a better understanding of the bottom-up regulations of the HUS system and its sensitivity to variability on plankton dynamics associated climate-driven changes.

Historical changes in life-history traits of small pelagic fish in the western Mediterranean Sea along a latitudinal gradient

Authors: Marta Albo-Puigserver, Jose María Bellido, Ana I. Colmenero, Ana Giráldez, Manuel Hidalgo, Maria Grazia Pennino, John Ramírez, Pedro Torres, Marta Coll

Presenter: **Marta Albo Puigserver**

Small pelagic fishes (SPF) in the western Mediterranean Sea are key elements of the marine food web and are important in terms of biomass and catches. Significant declines in biomass, landings and changes in the age/size structure of European anchovy Engraulis encrasicolus and European sardine Sardina pilchardus have been observed in recent decades in the northwestern Mediterranean Sea (in GSA06 Northern Spain and GSA07 Gulf of Lions, France). Instead, SPF in the southwestern Mediterranean Sea (GSA01 Alboran Sea, Spain) showed different patterns without a clear trend. Fluctuations of SPF have been related to local and regional scale environmental changes, driving annual recruitment and growth, mainly by river runoff, temperature and primary production. To understand the different patterns observed in SPF populations in

the western Mediterranean Sea, we analysed seasonal and inter-annual variability of key life-history traits (size at first maturity, gonadosomatic index and body condition) collected in different fishing harbours of Spain distributed along a latitudinal gradient from Tarragona and Torrevieja, in GSA06, norther Spain, to Malaga, in GSA01, southern Spain. Results showed a clear decline in size at first maturity and body condition of sardine and anchovy since 2008 until 2017, with minimum values in 2012 and 2014 in the north of the area. On the contrary, in the south inter-annual fluctuations in body condition did not present a clear temporal trend while size at first maturity increased. However, in absolute terms, levels of energy stored and energy invested in reproduction were lower in the southern area compared with the northern populations. Maximum values of body condition of European sardine also differed between areas at seasonal scale. The decline in size at first maturity may have been translated into lower reproductive capacity in the north, since younger females have proportionally lower fecundity and shorter spawning season.
Overall, the most plausible combined causes to explain observed changes in life-history traits of small pelagic fish in the western Mediterranean Sea were (1) a combination of environmental factors affecting the body condition, (2) a phenotypic selection by fisheries for the individuals that mature earlier and (3) the disappearance of larger and older individuals due to historical overfishing. The decline in body condition and size at first maturity of both species should be taken into account when evaluating the commercial stocks since natural mortality may have increased and earlier maturation, in combination with the removal of older individuals, could highly reduce the reproductive potential of the stocks. This study highlights the importance of understanding the trade-off between the energy invested in reproduction, maintenance and growth to better predict how environmental and human pressures influence population dynamics of small pelagic fish.

SESSION 23: THE MULTIPLE PATHWAYS OF THE BIOLOGICAL CARBON PUMP: CURRENT UNDERSTANDING AND FUTURE CHALLENGES

Pelagic ecosystem functioning in the vicinity of the Kerguelen Islands (Southern Ocean): Towards and end-to-end approach

Authors: Bernard Quéguiner, Ingrid Obernosterer, Stéphane Blain, Urania Christaki, Karine Leblanc, Cédric Cotté, Alice Delegrange, Yves Cherel, Meng Zhou, Brian Hunt, Evgeny Pakhomov

Presenter: **Bernard Quéguiner**

Results acquired over more than two decades now make it possible to outline the functioning of the pelagic ecosystem off the Kerguelen Islands. Although the structuring role of natural iron fertilization has been demonstrated both in terms of productivity and the structuring of pelagic communities, recent results raise questions about the paradigm of the coupling between carbon and silicon biogeochemical cycles in naturally iron-fertilized environments of the Southern Ocean. Similarly, new, recently published results highlight the role of biological processes, e.g. the partitioning of grazing between micro- and mesozooplankton, or the life cycles of primary producers (including senescence and resting spore formation) in the operation of the biological carbon pump. At the same time, several conceptual models have been developed to better describe the functioning of pelagic ecosystems with regards to the limiting nutritional factors of the first trophic levels. The synthesis of current data lays the foundation for the current functioning of the pelagic ecosystems surrounding the Kerguelen Archipelago while new ongoing and future studies aim at achieving an in-depth understanding of the processes linking biogeochemistry and biodiversity in an end–to–end approach, i.e., from prokaryotes to apex predators.

Seasonal changes in Southern Ocean diatom community composition shed light on the link between diversity, carbon biomass and export.

Authors: Stephane Blain, Ingrid Obernosterer, Mathieu Rembauville, Olivier Crispi

Presenter: **Stephane Blain**

Diatoms are ubiquitously present in different regions of the Southern Ocean. When environmental conditions are favorable they accumulate large biomass in the surface layer followed by downward transport which contributes to carbon sequestration in the deep ocean and ultimately in the sediment. The major role of diatoms compared to other phytoplankton groups in the functioning of the biological pump of carbon has been extensively studied. However, in regions like the Southern Ocean where phytoplankton biomass can be entirely dominated by diatoms the link between phytoplankton community composition and biological carbon pump should be reexamined. Previous studies have suggested conceptual qualitative frameworks describing the changes of diatom community composition during blooms and possible consequences on export. Here we propose to make a step forward using a unique data set gathered in Southern Ocean blooms. Thanks to synchronized autosamplers deployed both in the surface layer (40 m) and at depth (300 m), we could follow the changes of the diatom community composition and of several environmental parameters from mid-October to the end of February with a temporal resolution of 11 days. The data provide a quantitative assessment of seasonal changes of diatom carbon biomass and export linked to changes in the diatom community composition. Moreover, we are able to address the so far unresolved issue of the possible influence of diversity of diatoms on carbon biomass and fluxes.

Nature of the sinking particle flux during a late summer bloom around the Kerguelen plateau (MOBYDICK)

Authors: Leblanc Karine, Quéguiner B., Lafont A., Cornet V., Legras J.

Presenter: **Karine Leblanc**

The nature of the sinking particle flux was investigated during a late summer bloom around the Kerguelen plateau in February-March 2018 during the MOBYDICK cruise. Intense diatom blooms were encountered, dominated by heavily silicified species. Distinct mortality modes were observed during the cruise, ranging from parasitic and viral infection of diatoms, to predation by larger zooplankton organisms. Interestingly, an intermediate level of small microzooplanktonic (50-80 µm) grazers (various Protocystis species) belonging to the Phaeodarian group (Rhizaria) was actively grazing on Fragilariopsis kerguelensis, otherwise known to be resistant to grazing. This resulted in the production of mini-fecal pellets, heavily packed with siliceous material. Resting spores and winter forms of various diatom species were also observed potentially leading to distinct export modes. The relative contribution of intact cells, broken cells and debris, eaten cells, infected cells, spores and fecal pellets to the sinking particulate flux was investigated through the use of a bottlenet, a device allowing to filter above 20 µm all particles within discrete depths of the mesopelagic layers. SEM images, taxonomical analyses, molecular analyses, as well as Si and C contents are used to characterize different types of particles involved in the operation of the biological pump.

Diversity and contribution of pico- and nano-phytoplankton to the carbon uptake in contrasted areas of the Austral ocean

Authors: Irion Solène, Berthelot H., Sassenhagen I., Jardillier L. & Christaki U.

Presenter: **Solene Irion**

Research on the biological carbon pump has mainly focused on large phytoplanktonic cells. Nevertheless, pico- and nanophytoplankton are major contributors to primary production outside of bloom periods and contribute to the carbon pump through consumption by larger organisms and aggregation.
This study was realized in the Southern Ocean around Kerguelen islands during the French MOBYDICK cruise in February-March 2018 (https://www.mio.univ-amu.fr/mobydick/). Two contrasted stations were repeatedly sampled, namely stations M2 located in iron fertilized waters above the Kerguelen plateau, and M4 located in HNLC waters. The aim was to investigate carbon uptake by different pico- and nanophytoplankton populations at the end of the diatom bloom. Samples were taken to determine (i) the composition of the whole eukaryotic community based on 18S rDNA metabarcoding, (ii) the composition of pico- and nanophytoplankton thanks to the MiSeq Illumina sequencing of amplicons of the V4 region of the 18S rDNA of pigmented cells sorted by flow cytometry, (iii) the daily carbon uptake of the phytoplanktonic community and the contribution of different taxa to this uptake through the use of *in situ* incubations with NaH13CO3.
Contribution of pico- and nanophytoplankton to phytoplankton biomass was similar across all stations, representing between 40% to 50% of total Chl a according to pigment composition. Metabarcoding data also evidenced *Phaeocystis antarctica* to be dominant within plankton communities smaller than 20µm at all stations. Preliminary results also indicate (i) that total carbon uptake was overall low (0,2 to 0,48 µmol of C L^{-1} d^{-1}) at the exception of the last visit at M2, where the primary production doubled, reaching 0,92 µmol of C L^{-1} d^{-1}, and (ii) that productivity is positively correlated to pico- and nanophytoplankton abundances (R2=0,92; P=0,02).
Further analyses with a combination of flow cytometry cell sorting and NanoSIMS imaging will allow to establish the relative contribution of different pico- and nanophytoplankton populations to the global carbon uptake, considering inter- and intra-group differences in the metabolic activities of single cells.

A Southern Ocean field sampling with in situ pump to study fatty acids contents and lipid production of phytoplankton and microzooplankton at the very first levels of marine food webs and their implications in Biological Carbon Pump.

Authors: Marine Remize, Frédéric Planchon, Ai Ning Loh, Philippe Soudant, Fabienne Le Grand

Presenter: **Marine Remize**

In order to know fatty acids contents and production in natural ecosystems and understand their role in the Biological Carbon Pump (BCP), we have studied four sampling sites located in the Southern Ocean (south of the Polar Front) during MOBYDICK cruise and showing contrasted production regimes. We have sampled suspended particulate organic matter (SPOM) using large volume in situ pumping systems (ISP) as well as from seawater samples filtered onboard. SPOM were fractionated according to size by using sequential filtration with different pore size filters mounted on the ISP. Three size fractions were obtained in order to separate zooplanctonic organisms (>200-300 µm) from large size phytoplankton (50-300, 20-200 µm) and from small size phytoplankton (1-50, 1-20 µm). We intend to determine in these 3 size fractions the lipid biomarker contents and their stable isotopic composition in order to (i) establish trophic position and dietary quality (= abundance of the two polyunsaturated fatty acids of interest) and (ii) better understand the trophic transfer of EPA and DHA through marine food webs. To supplement ISP data, a 13C incubation experiment conducted on board will allow to estimate the daily lipid production (24 hours incubation) and then assess the capacity of these organisms in answering a stress or environmental changes and apprehend better the fate of EPA and DHA in Southern Ocean and their availability for upper trophic levels. This should improves the knowledge of carbon processing at the very first level of the food webs by phytoplankton and/or microzooplankton.

Trophic pathways and transfer efficiency from phytoplankton to micronekton under contrasting productivity regimes in the Kerguelen Islands region (Southern Ocean).

Authors: Boris Espinasse, Brian Hunt, Alice Delegrange, Natasha Henschke, Cédric Cotté, Yves Cherel, Evgeny Pakhomov

Presenter: **Cédric Cotté**

Food web dynamics is strongly size structured. As such, shifts in the size of primary producers can play an important role in determining key food web properties, including food chain length and transfer efficiencies. Critical to this are the specific food web pathways conferred by the primary producer composition. In the HNLC Southern Ocean the addition of iron for shallow topography can significantly affect the phytoplankton composition, allowing the development of high biomass dominated by diatoms. Such bloom development is typically observed in the summer months in the vicinity of islands. The specific dynamics of food web interactions in HNLC vs Bloom regions remains poorly resolved.
The objectives of this study were to inform food web structure and function in high and low productivity zones of the Kerguelen Region, specifically 1) to determine the food chain length, 2) to detail the linkages between size structure component so the pelagic food web, and major mesozooplankton, macrozooplankton and micronekton taxa and 3) to identify the major carbon sources supporting the food webs.
A research cruise was conducted around the Kerguelen Island from February 21 to March 19 in the context of the MOBYDICK research project. During the expedition, plankton size fractions, and major taxa of the mesozooplankton, macrozooplankton and micronekton were collected at four stations for biogeochemical analyses. Stable isotope and fatty acids of plankton and micronekton were measured to determine pelagic food web properties in high and low productivity zones of the Kerguelen region. More specifically, bulk stable isotopes and community size structure were used to determine the length and transfer efficiency of the food chain in the different productivity zones sampled, while a combination of Compound Specific Isotope analysis and Fatty Acid analysis was used to identify the carbon sources supporting the food web in each productivity zone.
A preliminary overview of the data showed similarities in size structure between the 4 stations while community composition differed significantly.
These results will support ecosystem model development, and together with other studies of the MOBYDICK research project, will provide essential information for the sustainable management of these vulnerable ecosystems.

Go further in constraining C remineralization in the mesopelagic ocean: new insights into the barium tracer

Authors: Jacquet Stéphanie, Christian Tamburini, Dominique Lefèvre, Marc Garel, Aurélie Dufour, Sophie Gasco, Nagib Bhairy

Presenter: **Stéphanie Jacquet**

Ocean ecosystems play a critical role in the Earth's carbon cycle and the quantification of their impacts of both present conditions and predictions into the future remains one of the greatest challenges in oceanography. Being able to predict the role of the ocean in terms of carbon storage capacity is key to understand climate change at the global and local level. The barium (Ba) proxy is a powerful tool to estimate C remineralization fluxes in the mesopelagic layers (100-1000m) which are crucial depths in driving the C transfer efficiency. Indeed particulate barium (barite) forms in the mesopelagic zone during heterotrophic prokaryotic degradation of organic matter (remineralization). Particulate-dissolved Ba dynamics at the depth of C remineralization and the inter-connectivity of barium, oxygen dynamics and prokaryotic heterotrophic activity will be discussed through recent results obtained in the north Atlantic ocean and in the Mediterranean Sea. The results of these works will allow to reinforce assessment of C remineralisation rates from barium measurements.

The functional role of marine fish in carbon cycling and flux

Authors: Angela Martin, Esben Moland Olsen, Grace Saba

Presenter: **Angela Martin**

Understanding the functional roles of heterotrophs in ocean carbon cycling and flux is important for effective policy and conservation efforts aimed at harnessing ocean and coastal carbon sinks for climate change mitigation. One way to determine the fate of carbon transferred via ocean food webs is by quantifying the bioenergetics of heterotrophs. Field, lab and telemetry data are used to map the bioenergetics of a predatory fish, cod (Gadus morhua), in the coastal fjords of the Skagerrak, south Norway. Carbon that is held in biomass through growth and reproduction, or released via respiration and egesta, is considered, as well as fish behaviour that transfers carbon within and between ecosystems. The methods and models developed by this study can be replicated for other species and ecosystems, or used to generate estimates where direct sampling is not possible. The results help to inform an important, and currently little understood, component of the biological carbon cycle.

Respiration rates in the Southern Ocean: A day in the life of mesozooplankton and micronekton

Authors: Anna Belcher, Gabi Stowasser, Sophie Fielding, Geraint Tarling

Presenter: **Anna Belcher**

The biologically driven flux of carbon from the atmosphere to the seabed mediates atmospheric CO_2 concentrations. However, only a small fraction of the particulate organic carbon (POC) sinking out of the euphotic zone reaches the deep ocean due to heterotrophic consumption. Quantifying this rate of

attenuation with depth is key to the ability of global climate models to make accurate climate predictions, and requires detailed knowledge of heterotrophic respiration rates.
Respiration rates of the mesopelagic community, where the most rapid decline in POC is observed, are not always easy to measure due to the difficulty of bringing up live, healthy animals for incubations. It is also difficult to replicate natural conditions in an incubation, and thus assessing diel variability in respiration rates is not trivial. Here we present respiration rates based on electron transport system (ETS) activities of mesopelagic zooplankton and micronekton collected in the Scotia Sea in the Southern Ocean. Not requiring live incubation, this method allows detection of any diel variability in respiration. We examine relationships between time of day, depth and respiration rate, making assessments of the contribution of vertical migrators to the active respiratory flux of carbon. We evaluate whether any diel variability in respiration rate makes a significant difference to estimates of total respiration and remineralisation in the mesopelagic.

Threatened species drive the strength of the carbonate pump in the Scotia Sea (Southern Ocean)

Authors: Clara Manno, Giglio F., Stowasser G., Fielding S., Tarling G. A.

Presenter: **Clara Manno**

The efficiency of deep-ocean CO_2 sequestration is regulated by the relative balance between Particulate Inorganic and Organic Carbon (PIC, POC) export respectively acting through the biological carbon pump (BCP) and the carbonate counter pump (CCP). Here, we describe a 2-year-long series of particles flux, as measured by deep moored sediment traps located at two sites close to South Georgia (Northern Scotia Sea). We assess the specific contribution of each part of the plankton calcifying community (pteropods, foraminifera, coccolithphores and ostracods) in regulating the strength of the CCP in a Southern Ocean region (northern Scotia Sea) known to be a major hotspot for the drawdown of atmospheric CO_2. We found that when pteropods dominated the calcifying community, the total annual reduction of CO_2 transferred to the deep ocean was an order of magnitude higher compared to the year when foraminifera and coccolithiphores dominated. Our results show that the role of calcifying zooplankton in regulating the strength of the CCP is also a function of associated food-web processes. In particular, a combination of predation and zooplankton grazing can have a large influence on the efficiency of the CCP. Pteropods are threatened in polar regions by ocean warming and acidification. Result of this study emphasises the consequences of the potential declines in these organisms to the comparative strengths of the BCP and CCP.

Are mesopelagic microbial communities iron limited?

Authors: Joanna Ainsworth, Mark Moore, Alex Poulton

Presenter: **Joanna Ainsworth**

The biological carbon pump and trace metal cycling are intricately linked. Trace metals are required by phytoplankton for growth and cell function and contribute to bloom events and alter community composition and ecosystem structure. Trace metal remineralisation occurs due to abiotic and biotic factors, which cause decoupling of the trace metals and organic carbon with depth and affects residence times and resupply of essential nutrients to surface communities. Deeper carbon remineralisation can increase carbon sequestration at depth storing the carbon away from the atmosphere. The majority of trace metal cycle research has focused on surface waters rather than the mesopelagic. Less is known about the remineralisation of trace metals than organic carbon and macronutrients, with only limited experiments

having been performed in the mesopelagic, with the possibility for trace metal availability to influence microbial metabolism away from the surface almost completely unexplored. It is well established that phytoplankton communities in High Nutrient Low Chlorophyll regions (such as the Southern Ocean) are iron limited with the injection of iron allowing blooms to form. However, less is known about the sub surface microbial community and the potential of iron limitation affecting bacterial remineralisation of carbon and how that iron and carbon are re-cycled within the water column.
Shipboard experiments were performed as part of the Natural Environment Research Council funded COMICS (Controls over Ocean Mesopelagic Interior Carbon Storage) project in the Southern Ocean (South Georgia) to investigate iron limitation and the relative remineralisation rates of iron and carbon by the mesopelagic microbial community. Although surface phytoplankton communities were iron limited, the upper mesopelagic bacterial community were not iron limited and de-coupled remineralisation rates and subsequent remineralisation depths of the iron (transfer of adsorbed iron into the water column) and carbon (transfer of carbon via respiration into the water column) could influence the short term recycling or the longer term re-supply of these elements.

SINKING DEAD – How zooplankton carcasses affect POC flux in the subantarctic Southern Ocean before the start of the spring bloom

Authors: Svenja Halfter, Boyd P.W., Cavan E.

Presenter: **Svenja Halfter**

The role of mesozooplankton in the global carbon cycle has been largely overlooked. For example, they contribute to the vertical carbon export by producing fast-sinking faecal pellets. During a field campaign the subantarctic Southern Ocean in October 2018 two species of copepods, *Neocalanus tonsus* and *Nannocalanus* spp., were collected before the start of the spring bloom to evaluate their faecal pellet properties and production rate. After the copepods failed to produce faecal pellets in the laboratory, their carcasses were used for sinking velocity estimations, bacterial degradation experiments and carbon content measurements. Sinking and degradation behaviour of both species were compared to assess their contribution to the particulate organic carbon export flux of the subantarctic zone. Higher sinking and slower decomposition rates of *Neocalanus tonsus* carcasses highlight the importance of the species for the carbon flux in early spring. The results indicate that non-consumptive mortality of zooplankton can lead to a significant flux of carcass carbon to the deep sea, which affects the oceanic carbon sequestration and, hence, should be included in the global biogeochemical models.

From the origin of Feces - The impact of krill and salp fecal pellets on iron chemistry and iron bioavailability to Southern Ocean phytoplankton

Authors: Sebastian Böckmann, Florian Koch, Franziska Pausch, Anna Pagnone, Dorothee Wilhelms-Dick, Luis M. Laglera, Camila Sukekava, Bettina Meyer, Christel Hassler, Scarlett Trimborn

Presenter: **Sebastian Böckmann**

The Southern Ocean is considered to be a major player in the climate system of our planet while being extremely sensitive to climate change itself. The pelagic Southern Ocean is limited by the bioavailability of iron. Zooplankton has a large impact on the remineralization of iron in the water column and thereby an

important influence on primary production. Indications exist that due to increasing water temperatures in the course of climate change, vast areas of the Southern Ocean might shift from a krill to a salp-dominated community. Since the degree of iron remineralization is dependent on the taxonomic group of zooplankton, we investigated the different impacts that salp and krill fecal pellets have on iron chemistry and its bioavailability to Southern Ocean phytoplankton, during a Polarstern cruise in spring 2018. We incubated salp and krill fecal pellet material in Antarctic low-iron water without phytoplankton. In a second step, a concentrated natural phytoplankton community was added into the thusly preconditioned water and for the first time ever the iron uptake into the living cells, in respect to the fecal pellet type that acted as an iron source, was determined. Our results indicate that iron released from salp fecal pellets into the seawater was significantly more bioavailable to phytoplankton than iron from krill fecal pellets, since phytoplankton picked up 0.28 nM Fe d^{-1} from water treated with salp fecal pellets and 0.16 nM Fe d^{-1} from water treated with krill fecal pellets. These results demonstrate that salps might actually play a role in stimulating phytoplankton growth in the Southern Ocean, thusly influencing the biological carbon pump.

Jellyfish and Marine Snow: A First Glance

Authors: Nicolas Djeghri, Sandra Valette, Jordan Toullec, Philippe Pondaven, Brivaëla Moriceau

Presenter: **Nicolas Djeghri**

Zooplankton is known to play a role in the biological carbon pump through chemical and mechanical modification of the seston. Historically, research efforts have mainly focused on copepods and appendicularians but other zooplanktonic groups might affect the export of carbon such as jellyfish (i. e. pelagic cnidarians and ctenophores). Jellyfish can attain large biomass, and are important component of deep ocean communities. However, little is known on how they could affect the biological pump. More particularly, how jellyfish impact the formation and the fate of marine snow stays an open question. In an attempt to gain some firsts insights on these processes, we present a suite of experiments in which we assess how jellyfish could affect marine snow. In these experiments, we incubate the cosmopolitan jellyfish genus Aurelia in presence of phytoplankton or artificial marine snow in roller tanks. The aggregations dynamics, the size spectrum, sinking speed and abundances of aggregates will be compared in the presence or absence of jellyfishes. The results of these experiments will allow us to provide hypotheses on how jellyfish might affect marine snow in the ocean providing a first framework for future studies.

Trophic interactions between filter-feeding mesozooplankton and the *Emiliania huxleyi* virus

Authors: Kyle Mayers, Janice Lawrence, Joachim Töpper, Katrine Sandnes Skaar, Elzbieta Petelenz-Kurdziel, Aud Larsen, Gunnar Bratbak, Daniella Schatz, Assaf Vardi and Jessica Louise Ray

Presenter: **Kyle Mayers**

Marine viruses are the most abundant entity in the oceans, regulating microbial populations and biogeochemical cycles through infection and lysis of cells. There is a paucity of information, however, about factors that regulate the abundance and diversity of viral populations. One group of planktonic marine tunicates, appendicularians, live inside filtering structures ("houses") that can efficiently trap and concentrate food particles as small as 0.2 µm (Bedo et al., 1993). Our group has previously demonstrated

that the globally distributed appendicularian *Oikopleura dioic*a is able to remove the *Emiliania huxleyi* virus (EhV) from seawater (Lawrence et al., 2018). Furthermore, we detected EhV DNA in O. dioica houses, gut and faecal pellets. These results suggest an important, yet under-explored, loss mechanism for viruses from the upper water column. However, they also raise questions regarding the net impact of *O. dioica* feeding on the abundance and diversity of marine virus assemblages, and the ultimate fate of captured viruses.
To address these questions, we conducted feeding experiments by incubating O. dioica in seawater collected from a mesocosm experiment in which a bloom of the coccolithophore *E. huxleyi* was induced by nutrient manipulation. Phytoplankton assemblages were near *E. huxleyi* bloom peak when water was collected for *O. dioica* incubations, although Prasinophytes (*Micromonas* sp.) and other Haptophytes (*Phaeocystis* spp.) were also observed, increasing the likelihood of rich marine virus diversity. Incubation water was filtered to remove all potential host cells but to retain viruses. Cell-free mesocosm virus assemblages were incubated in triplicate in the presence or absence of mature (Day 5 at 15°C incubation) *O. dioica* (20 animals L^{-1}) for 8 hours as described previously (Lawrence et al. 2018). Water samples were collected hourly for flow cytometric enumeration of bacteria and viruses. At the beginning and end of incubations, 50-ml water samples from all incubations were pelleted by ultracentrifugation, and pellet DNA was quantified using droplet digital PCR targeting the major capsid protein (mcp) gene of EhV, to determine net differences in EhV genome equivalents after 8h incubations in the presence or absence of *O. dioica*. In order to assess the potential of O. dioica faecal pellets to disperse infectious viruses, we also incubated individual faecal pellets from both treatments in *E. huxleyi* 374 cultures to determine if infectious particles are shed from pellets.
Clearance rates by *O. dioica* for an EhV-like virus population varied from approximately 20 – 75 mL individual^{-1} d^{-1}. Flow cytometry results are compared with droplet digital PCR quantification of EhV in the same samples. Results from virulence assays demonstrate unequivocally that faecal pellets from *O. dioica* incubated in the presence of EhV contain and shed infectious particles, causing lysis of *E. huxleyi*. This raises speculation about the importance of this interaction as a loss mechanism for EhV from the water column, but also about the impact of this on the fate of virus particles in the marine environment. Alterations in virus-host dynamics will influence the virus-mediated turnover of carbon within the pelagic realm.

Biological Pumps of Carbon, Nitrogen and Phosphorus in a Large Tropical Marginal Sea

Authors: J.-J. Hung, Z.-Y. Lin, C.-H. Tung, S.-H. Peng

Presenter: **Jia-Jang Hung**

This study aims to understand the biological pumps of carbon (C), nitrogen (N) and phosphorus (P) in the tropical northern South China Sea (NSCS) in response to seasonal and oceanographic changes. The biological pumps of CNP are defined as sums of active and passive fluxes of CNP and regarded as the central part of marine carbon cycle. In addition to spatial and seasonal variability, the effects of eddy and internal waves on biological pumps of CNP were also explored. The passive fluxes of C, N and P in the NSCS were respectively estimated to be 66.8±1.29 mg C m^{-2} d^{-1}, 12.8±0.38 mg N m^{-2} d^{-1} and 0.99±0.07 mg P m^{-2} d^{-1} in the spring season, about 64.3±1.47 mg C m^{-2} d^{-1}, 12.1±0.47 mg N m^{-2} d^{-1} and 0.93±0.04 mg P m^{-2} d^{-1} in the summer season, and about 183±17 mg C m^{-2} d^{-1} in a winter period enhanced by anticyclonic eddy. The fluxes were apparently elevated to be 155±15.9 mg C m^{-2} d^{-1}, 21.2±1.68 mg N m^{-2} d^{-1} and 1.79±0.19 mg P m^{-2} d^{-1} in an internal-waves induced event. The averaged active fluxes of C, N and P through 200 m were about 25.6 mg C m^{-2} d^{-1}, 2.68 mg N m^{-2} d^{-1} and 0.37 mg P m^{-2} d^{-1}, respectively, corresponding well to the variations of passive fluxes. Positive correlations were significant between the chlorophyll inventory and DIN inventory, and also significant between passive and active fluxes of CNP and DIN inventory in the euphotic zone. The active and passive fluxes of CNP were apparently driven by primary production which was controlled by the availability of nutrients. The passive fluxes accounted for the highest proportion of the biological pumps of CNP, ranging from 62.1 to 65.5% for C, from 73.5 to 76.6% for N, and from 64.7 to

75.2% for P in the NSCS. The proportions of DOM fluxes were insignificant in CNP biological pumps. The biological pumps of CNP were significantly higher in this tropical marginal sea than in the open oceans, but they were strongly various in spaces and seasons and apparently enhanced by extreme conditions in the marginal sea.

Heterotrophic prokaryotic activity and structure in the water column vs fast sinking particles

Authors: Marc Garel, Fabrice Armougom, Virginie Riou, Sophie Guasco, Nagib Bhairy, Chiara Santinelli, Anna Belcher, Richard Lampitt, Frédéric A.C. Le Moigne and Christian Tamburini

Presenter: **Marc Garel**

The biological carbon pump of oceans dominated by the sinking of organic marine snow from the surface ocean to its interior is a component controlling the marine carbon cycle. While marine snow is produced by plankton networks in the sunlight layer of the ocean, its fate and microbial transformation deeper in the dark ocean remains poorly unknown. For example, the heterotrophic biological processes that convert this downward flux of organic matter back into CO_2 are poorly constrained, both quantitatively and mechanistically. It is generally admitted that the amount of sinking OM is not sufficient to meet the energy required by prokaryotes to perform observed remineralization rate in the dark ocean, in other words, in the dark ocean, we face a discrepancy between the estimation of biological carbon demand and carbon supply (particles flux). In this study, microbials activities (prokaryotic heterotrophic production and ectoenzymatic activities) and amplicon sequencing of 16S rRNA gene revealed distinct prokaryotic communities associated with the different fraction of particles (slow sinking – SS, suspended – SUSP, fast sinking – FS – particles). These results compared to Niskin sampling (NIS) revealed a clear differentiation with the FS fraction.

Drivers of carbon export efficiency in the global ocean

Authors: Stephanie Henson, Fred Le Moigne, Sari Giering

Presenter: **Stephanie Henson**

The export of organic carbon from the surface ocean forms the basis of the biological carbon pump, an important planetary carbon flux. Typically, only a small fraction of primary production (PP) is exported (quantified as the export ratio: export/PP). Here we assemble a global data synthesis to reveal that very high export ratios can occasionally occur. These events drive an inverse relationship between PP and export ratio, which is opposite to that typically used in empirical or mechanistic models. We find that high export ratio, low PP (or HELP) regimes tend to occur early in the phytoplankton growing season when macrozooplankton and bacterial abundance are low. This implies that a decoupling between PP and upper ocean remineralisation processes can result in a large fraction of PP being exported, likely as intact cells or phytoplankton-based aggregates. As the system becomes recoupled, the proportion of PP being exported declines as macrozooplankton and bacterial abundances rise. High export ratio, high PP regimes can also occur post-bloom, possibly associated with non-biologically mediated export of particles. A similar analysis at a biome scale reveals that the factors affecting export ratio may be different at regional and global scales. Our results imply that the whole ecosystem structure, rather than just the phytoplankton community, is

important in setting export efficiency. Further, the existence of HELP regimes imply that current models that parameterise export ratio as increasing with PP may underestimate export flux during decoupled periods, such as at the start of the spring bloom.

Upper mesopelagic bacterial remineralization, an *in situ* perspective across ocean provinces

Authors: M. Bressac, E.C. Laurenceau-Cornec, A. Santoro, N. Briggs, K.O. Buesseler, F. Carvalho, A. Dufour, C.A. Durkin, M.L. Estapa, M. Garel, S.L.C. Giering, S.A. Henson, S.H.M. Jacquet, D. Lefèvre, P. Masqué, M.M. Omand, V. Puigcorbé, R.J. Sanders, C. Tamburini

Presenter: **Matthieu Bressac**

Bacterial remineralization within the mesopelagic is a key particle-transformation process controlling the transfer efficiency of organic carbon into the deep ocean. Despite its importance, this mesopelagic process is one of the most poorly understood aspects of the biological carbon pump due to technical issues involved in studying this zone. Estimates of bacterial rates of particle remineralization in the mesopelagic zone are still very few, and based on in vitro laboratory assessments rather than in situ incubations. Changes in pressure and temperature, when transferring samples from the mesopelagic zone to the laboratory, likely introduced a range of unknown biases to remineralization measurements. A novel approach recently developed, called RESPIRE (REspiration of Sinking Particles In the subsuRface ocean), provides rates of particle remineralization (mainly by particle-attached bacteria) under in situ temperature and pressure conditions. In recent years, this dual particle interceptor/incubator has been deployed within the upper mesopelagic (100-250 m) of contrasting oceanic areas, such as the Southern Ocean, the South Atlantic, the Mediterranean Sea and the low iron North Pacific. These areas, characterized by contrasting surface ecosystem structures, differing subsurface temperature and oxygen regimes offer a wide range of downward flux magnitude and composition, allowing us to investigate how these flux characteristics and particle remineralization rates are related. Here, we present a synthesis of these fluxes and discuss the observed particle remineralization rates in the context of other measurements (e.g. particle flux magnitude and composition, temperature) and proxies (e.g. thorium disequilibria, barium).

Global drivers of variability in carbon flux

Authors: Nathan Briggs, Stephanie Henson, Filipa Carvalho, Hervé Claustre

Presenter: **Nathan Briggs**

The “biological carbon pump”, which transfers organic carbon to the deep ocean, is a major sink of atmospheric CO_2 and the foundation of deep ocean food webs. If ongoing global changes in ocean temperature, circulation, and ecosystems are affecting the biological pump, appropriate response will strongly depend on our ability to monitor the pump at global scale. For this reason, there would be great value in finding quantitative (and ideally mechanistic) relationships between deep carbon flux and surface properties that are measurable at global scale. Here we compare a multi-ocean, multi-year dataset of autonomous measurements of subsurface spikes in optical backscattering (a crude proxy for carbon flux) with corresponding surface estimates of chlorophyll, backscattering, and mean particle size. We find the product of mean particle size and concentration in the upper 50 m alone to be a fairly strong predictor of our proxy for 200 m export flux (r2 = 0.69) and a moderate predictor of 700 m “sequestration” flux (r2 =

0.59). However, these first-order correlations still leave a factor of 2 unexplained variability in particle flux. We therefore also highlight the times and places that we find deviations from this global relationship and explore potential explanations.

Global particle sinking velocity distribution: from the Arctic to the Southern Ocean

Authors: M. Villa-Alfageme, E. Ceballos Romero, S.L. Giering, F. de Soto

Presenter: **Maria Villa-Alfageme**

A key driver of carbon transport and sequestration to the deep-sea is the speed at which particles sink. Unfortunately, it is technically very challenging to measure in situ particle sinking velocities and we therefore lack understanding of how sinking velocities relate to export and vary with depth, location or season. Here, we start to fill this knowledge gap using a relatively novel method based on the radioactive disequilibrium between 210Po and 210Pb. Average sinking velocities (ASVs) were estimated in biogeochemically contrasting sites including high latitude, temperate and oligotrophic sites (across the Atlantic Ocean, in the Arctic and in the Southern Ocean) and for different bloom stages.
ASV at 150 m correlated to carbon export efficiency (i.e. the amount of carbon exported from the surface ocean relative to primary production) during the pre-bloom and bloom periods. Highest export efficiencies were measured during bloom periods and were, in all cases, associated with high sinking velocities. However, during non-bloom periods, export efficiency was generally not correlated with ASV. This observation supports previous suggestions that the composition of exported particles strongly changes temporally in regions that experience strong seasonality.
We observe a systematic increase of ASVs in most of the locations below 150 m. The rate of ASV increase with depth was inversely correlated to carbon flux attenuation, suggesting that increases in ASV with depths are linked to remineralization processes at depth.
In subtropical latitudes, low export efficiencies were coupled to low ASVs (20 m d^{-1} at 150 m) and sinking velocities usually increased (to 100 m d^{-1} at 400 m). This observation suggests efficient recycling of carbon in surface waters most likely because of high respiration rates in warm waters. In contrast, low export efficiencies were coupled to relatively high ASVs (80 to 250 m d^{-1} at 150 m) in much colder North Atlantic High Latitude regions approximately two weeks after the bloom peak. And in this case, sinking velocities decreased with depth We suggest that this pattern was caused by zooplankton activity: in surface waters zooplankton produce fast-sinking faecal pellets, whilst zooplankton in the mesopelagic intercept large sinking particles and fragment these into smaller ones.
Overall, we here present one of the first in-situ data sets showing the variability in sinking speeds and how they are affected by ecosystem processes.

Active flux by zooplankton and micronekton: A gap in our knowledge of the biological pump

Authors: Santiago Hernández-León

Presenter: **Santiago Hernández-León**

Zooplankton and micronekton have a significant role in the downward carbon export to the mesopelagic layer. These organisms export carbon through their respiration, excretion, mortality, molting, and egestion

during their daytime residence at depth after diel vertical migration. Zooplankton active flux was the goal of different studies during the last two decades and their role is now relatively known. However, micronekton active flux was less studied because sampling these organisms requires the deployment of large nets or trawls. These ship operations are time-consuming and they are not a standard in oceanographic cruises. Thus, the study of these migrants becomes a rather arduous labor to obtain a complete picture of the biological pump. Because of this, there is only a handful of studies dealing with the estimation of this flux by both communities. In this sense, modeling the biological pump is still a challenge due to limited knowledge of downward transport in different areas of the ocean, and the almost nescience about the role of micronektonic organisms in this transport. Here, I review the results of zooplankton and micronekton active flux obtained in different areas of the ocean, covering from the oligotrophic to the meso- and eutrophic areas of the oceans. Most of the existing data are estimations of respiratory flux, mostly based on the measurement of the the enzymatic activity of the electron transfer system (ETS), or the use of empirical relationships between body mass and temperature of organisms at depth. Results showed a close relationship between migrant biomass and respiratory flux in zooplankton and micronekton as it should be expected. This flux was quite similar for both communities although the lack of reliable capture efficiencies for trawls used to sample micronekton promotes the most important uncertainty in active flux assessment. Conservative estimations of active flux by both communities showed a high variability in relation to the passive flux measured using sediment traps. Active flux accounted for less than 30% of total flux (active plus passive) in oligotrophic zones. The opposite, however, was observed in meso- and eutrophic environments, showing that assessments only based on sediment traps could severely underestimate the importance and functioning of the biological pump in the ocean.

Is active transport of carbon a significant component of the carbon pump in the eastern south ocean?

Authors: Pritha Tutasi, Ruben Escribano

Presenter: **Pritha Tutasi**

The eastern South Pacific Ocean is recognized as one of the most productive systems of the world, and plays a key role in the carbon cycle involving the atmosphere-ocean dynamics. The biological pump can indeed vertically transport carbon (C) into the ocean. It is also known that zooplankton play an important role in this processes affecting C flux in a variety of ways. (1) The passive flux, and (2) and the active flux. The latter is the transport of C by diel vertical migration (DVM). Studies on active transport of C due to DVM are scarce and critical for C flux models and biogeochemical estimates. Therefore, understanding the mechanisms involved in the active flux is needed to elucidate the fate of organic matter produced in the eastern boundary systems.
The vertical distribution of biomass and indices of feeding of mesozooplankton were investigated across a zonal section in northern Chile off Iquique (20ºS), an area subjected to important coastal upwelling throughout the year. The oceanographic information and zooplankton samples were collected during the two LowPhox cruises performed in October 2015 and February 2015 onboard the R/V Cabo de Hornos. The Zooplankton hauls were done in five depth strata from 800 m depth to the surface, during day and night condition using a Hydro-Bios Multinet, with a 0.25 m^2 opening area and equipped with 200 um mesh-size nets. The samples were digitized with a ZooScan digital imaging system and then identified and automatically classified in taxonomic categories.

Results are presented for the major taxonomic groups of mesozooplankton: Copepods (83%); Eggs Fish (3%); Nauplius Larvae (1%); Appendicularia (5%) and Salps (3%). Migrant biomass showed distinctive features associated with oxygen minimum zone (OMZ). The highest biomass occurred in a narrow band within the oxycline. The higher values were at night in the upper 150 m layer as expected from the effect of the DVM. The vertical distribution of zooplankton was modal with a slight peak in the Lower OMZ and it was

characterized by: 1) non-migrant groups, such as Salpidae and Siphonophora which showed limited nictemeral movements, probably because of the chemical barrier imposed by the OMZ; and 2) migrant groups with a greater range of vertical distribution such as the case of the Ecalanidae, Annelids, Briozoos, Euphausids, Gastropods and Foraminifera, which even showed intrusions into the OMZ during the night. Most groups are able to perform DVM in the upwelling zone, contributing with large amounts of biomass being transported below the thermocline, despite presence of an intense OMZ. However, we found a strong interaction between DVM and OMZ, such that the migration behavior may be disrupted, or exhibit reversed patterns depending on vertical distribution of OMZ and on the taxonomic group being considered. Our results, including estimates of metabolisms at depth (depending on size structure), suggest that the importance of DVM for C sink has been underestimated for these highly productive systems, and that such process can play a major role for rapidly transport freshly produced organic C to the deep sea.

Variability in C and N flow at lower trophic levels in the eastern south Pacific: the role of environmental zonation

Authors: Katty Donoso, Ruben Escribano

Presenter: **Katty Donoso**

The vast eastern south Pacific is one the most under-sampled regions of the world ocean in terms of trophic structure and C transfer in the pelagic food web. Here, using isotopes composition of C and N, we assessed variation in the trophic structure of the zooplankton community linked to variable environmental conditions determined by distinct habitats, defined as: the upwelling zone, the oligotrophic oceanic area, and the seamount area associated with two major ocean ridges off the Chilean coast. Samples for isotopes analyzes and zooplankton composition were obtained during the MOPEX and CIMAR-22 cruises conducted in September and November 2016, respectively. Zooplankton community structure was assessed by ZooScan analysis and δ13C and δ15N revealed significant changes in trophic structure and composition of the zooplankton community, both of which appeared to be linked to environmental zonation as defined above. The linkage of trophic and community structure with variable habitats is suggested to be modulated by different biogeochemical processes taking place in these zones, which can influence the sources and utilization of C and N being then transferred to the trophic web. Our findings indicate that a changing environment can have a strong effect on the C and N flow in the pelagic food web of this region upon a very complex and highly sensitive trophic structure.

Microbial degradation of black carbon particles in Halong Bay (Vietnam)

Authors: Mar Benavides, Xavier Mari, Chu Van Thuoc

Presenter: **Mar Benavides**

The combustion of fossil fuels and biomass produces black carbon particles (BC), which are emitted in large quantities in Asia. BC particles are porous and highly surface-active, sorbing nutrients and dissolved organic matter (DOM). They spread throughout the atmosphere as aerosols and its global deposition rate is estimated at 12 Tg C y^{-1}. Despite the magnitude of this flux, its fate in marine ecosystems and its role in the oceanic carbon pump are largely unknown. DOM sorption onto BC particles attracts marine microbes, potentially promoting their remineralization and hence contributing to the carbon pump. Here we explore the adsorption of isotopically labelled dissolved organic matter (DOM) onto BC particles and their subsequent colonization by marine bacteria in a time-course experiment over 48 h in the coastal waters of

Halong Bay (northern Vietnam, a highly BC-impacted region) by nanoscale secondary ion mass spectroscopy (nanoSIMS). Our results highlight the role of marine bacteria in modulating the impact of BC in the coastal ocean, a process with unknown effects on the marine carbon pump.

The reversibility of anthropogenically-forced change in biogeochemical drivers and deep carbon export in the North Atlantic.

Authors: Leonardo Bertini, Jerry Tjiputra

Presenter: **Leonardo Bertini**

With the advancement of Earth System Models (ESMs) and a better understanding of the intricacy of the ocean carbon cycle, it is possible to simulate how biogeochemical drivers would respond to different mitigation scenarios on global scales, thus making the future of our oceans become less opaque, helping tailor decisive policies to safeguard resources and our well-being.
This study's approach is based on analyzing the projected outputs from one of the Coupled Model Intercomparison Project Phase 5 (CMIP5) models, the Norwegian Earth System Model (NorESM), which performs an idealized scenario of increasing atmospheric CO_2 (1% yr^{-1}) from pre-industrial levels for 140 years followed by another 140 yr of a reversing atmospheric CO_2 trend (decreasing at 1% yr^{-1}) returning to the preindustrial level. The model continued to run for another 200 years so that long-term responses could also develop and be studied. The annual rates of increase and decrease in CO_2atm follow the standard protocol of the Carbon Dioxide Removal Model Intercomparison Project (CDR-MIP). Prior to this run, the model was spun-up by 900 years, reaching a near-equilibrium state with a mean CO_2atm of 284.7 ppm.
Our analyses assess the biogeochemical responses simulated by this rapid warming and cooling climate change scenario, focusing on determining their time-scales as well as the persistence of the anthropogenic signals and the extent of projected reversibility. The overall goal is to look at how these projected changes would affect the ocean carbon cycle at particular domains of the North Atlantic (NAtl) and how this would ultimately affect ecosystem services and deep ocean life, which is particularly sensitive to changes in pH, dissolved oxygen, vertical export of particulate organic carbon, carbon compensation depth, and aragonite saturation states.
The preliminary results for the NAtl pH Time of Departure (ToD), which can be defined as the moment the time series departures from intrinsic pre-industrial fluctuations (i.e. those driven by non-anthropogenic forcing) have shown that the mesopelagic interior (depth= 500 m) is expected to experience the effects of ocean acidification in ToD=13±4 yr, reaching its lowest pH in Tlowest=151±7 yr after the start of the ramp up (decreasing from pH=8.14 to 7.61). An increase in pH levels again (Tlag) is only seen 11±7 yr after the start of the mitigation phase. A recovery (Trcvr) in the mesopelagic NAtl is expected 476±46 yr after the start of the ramp up, when stabilized pH levels are predicted to be, on average, 0.17% lower than the mean pre-industrial pH. On the other hand, the base of the epipelagic zone (depth= 200 m) is expected to experience the effects of ocean acidification even sooner (ToD=6±1 yr) reaching its lowest pH 155±10 yr after the start of the ramp up, decreasing from pH=8.15 to 7.56. Our focus is now on determining how the particulate organic carbon flux to the NAtl deep ocean is affected by this mitigation scenario, analyzing changes in its magnitude, timescales, and reversibility trends.

Particulate organic matter composition and distribution in the Twilight Zone

Authors: Calum Preece, George Wolff, Kostas Kiriakoulakis, Sabena Blackbird

Presenter: **Calum Preece**

The efficiency of the biological pump in transferring CO_2 from the atmosphere to the deep ocean strongly depends on the degree of processing of particulate organic matter (POM) in the water column during sinking, particularly in the mesopelagic or “Twilight Zone” (100-1000m). However, the processes which control the efficiency of carbon storage in are not well known. Our study presents results from lipid biomarker, bulk nitrogen and carbon stable isotopes, and elemental analyses of sinking and suspended material sampled from South Georgia and the Benguela Upwelling Region. Particles were collected from the surface to 500m water depth using stand-alone pump systems (SAPs) fitted with glass fibre filters, snow catchers, and drifting sediment traps (Pelagras).
POM concentrations decrease rapidly with depth, significantly more so in the Benguela Upwelling region than at South Georgia. The OC/TN ratios of the fine particles decrease with depth from values of ~5 to ~3.5 in South Georgia and ~5.5 to ~4 in the Benguela Upwelling Region, implying that C is remineralized more rapidly than N at both locations. Total lipid concentrations decrease with depth in both regions, however, their composition remains similar, being dominated by the labile phytoplankton-derived polyunsaturated fatty acids eicosapentenoic acid (EPA) and docosahexenoic acid (DHA). This implies that while turnover of POM is rapid, there is nonetheless labile material available for respiration at 500 m water depth.
Keywords: biological pump, twilight zone, lipid biomarkers, suspended organic matter, stable isotopes, carbon flux

Neutrally buoyant sediment traps collect particles from further away than previously considered.

Authors: Benoit Espinola, Sarah L.C. Giering, Chelsey C.A. Baker, Corrine Pebody, Richard Lampit, Kevin Saw, Hannah East

Presenter: **Benoit Espinola**

The ocean’s biological carbon pump plays a major role in controlling atmospheric carbon dioxide (CO_2) concentrations. The biological carbon pump is a collection of biological processes that produce particulate organic material that sinks to the interior ocean. As it sinks, material is consumed and respired by deep-sea organisms, which releases CO_2 and decreases particle flux with depth. The deeper this remineralization happens, the longer the CO_2 stays away from the atmosphere. The statistical fit to the depth profile of flux material (‘Martin curve’) is characterised by a flux attenuation coefficient, the ‘b-value’. A small change in the b-value can represent a major change in atmospheric pCO_2. An important tool in measuring particle flux and obtaining b-values are drifting, neutrally buoyant sediment traps. Drifting sediment traps follow the surrounding water mass and therefore reduce the meridional and zonal relative velocities of sinking particles, which leads to a quasi-vertical trajectory for incoming particles into the sediment trap. These sediment traps are therefore often considered the ‘gold standard’ of particle flux measurements, with the resulting b-value being considered a true representation of the flux. Here I investigate whether drifting sediment traps indeed sample a quasi-vertical flux profile.
Drifting sediment traps (type PELAGRA) were deployed during the COMICS 1 cruise, during the Austral spring bloom, in November-December 2017 near South Georgia (52.7ºS 40.3ºW). The possible source area for particle flux was estimated using a backtracking model, which uses surface currents and assumed bulk particle sinking speeds (15, 20, 50, 100, and 200 m d^{-1}) coupled with a statistical uncertainty analysis (Monte-Carlo simulation).

My simulations suggest that slow sinking particles might be of a concern when collecting flux data. Particles with a sinking speed below 50 m d^{-1} carry a great level of uncertainty with respect to their origin, sampling areas well beyond the expected sampling site. Additionally, uncertainties of the particle origin increase the deeper a sediment trap is deployed. In regions that are associated with high fluxes of slow-sinking particles, as has been shown for my study site, particles collected at 500 m depth may originate >200 km from the particles collected in shallower traps. My work suggests drifting sediment traps likely do not collect a quasi-vertical flux profile in environments dominated by slow-sinking particles and with strong lateral advection, making it problematic to fit a Martin curve to obtain a b-value.

"Lithogenic carbon pump": toward a quantification to its contribution to particulate organic carbon export in the ocean?

Authors: Cécile Guieu, Olivier Aumont, Fredéric Gazeau, Justine Louis, Matthieu Bressac

Presenter: **Cécile Guieu**

Recently, several sediment traps data, in situ and laboratory experiments have provided evidence that dust deposition not only provokes particulate organic carbon (POC) export through enhanced biological production due to fertilization but also through aggregation processes between dissolved organic matter (DOM) present at the time of the deposition and dust. This "lithogenic carbon pump" has been quantified during several laboratory experiments in which Saharan dust has been sprayed over 300 liters tanks filled with 0.2 µm filtered seawater. These experiments were reproduced with the same dust analog but with unfiltered seawater having different DOM composition. Three similar experiments were performed during a cruise on board the "Pourquoi Pas?" in May/June 2017 in the frame of the Peacetime project (Process studies at the air-sea interface after dust deposition in the Mediterranean Sea). Here we present a synthesis of those experiments, all using water collected in various regions of the Mediterranean Sea. Results show a strong coherence and we were able to derive a parameterization of the 'lithogenic POC' caused by the dust deposition. Such parameterization can be introduced in a biogeochemical model to carefully assess this lithogenic component of the carbon pump that is so far neglected in models. Outputs from PISCES model (global scale) will be shown and discussed.

Late summer bloom community structure around the Kerguelen plateau (MOBYDICK)

Authors: Augustin Lafond, Leblanc K., Quéguiner B., Cornet V., Legras J.

Presenter: **Augustin Lafond**

Following up on two previous programs (KEOPS I & II) carried out in the same region of the Southern Ocean, in the naturally Fe-fertilized region of the Kerguelen plateau, the late diatom summer bloom was investigated in February-March 2018. We aim at describing the seasonal succession of diatom species as well as quantify C contents associated to key species in surface waters. Here, we present the first results of biogenic silica concentrations associated with siliceous plankton community structure, which was dominated by diatoms, but also revealed the development of a diverse Rhizarian community. Compared to early spring communities (KEOPS II), maximum diatom cell abundances were much lower (10 x 104 cell.L^{-1} vs 293 x 104 cell.L^{-1}), while maximum integrated biogenic silica standing stocks were in the same order of magnitude (458 mmol.L^{-1} vs 744 mmol.L^{-1}), which could indicate a higher degree of silicification at the end of the bloom in late summer. Interestingly, the highest abundances and BSi standing stocks were measured at station M4, located in an area considered until now as a High Nutrient Low Chlorophyll area. Specific cell activities were also investigated using the following three fluorescent dyes : PDMPO (newly polymerised biogenic silica stain), Nile red (intracellular lipid droplets stain), and Sytox Green (viability stain). Together, those data will help to better understand the role played by diatoms in the biological carbon pump around the Kerguelen plateau.

Deep Ocean Carbon Sequestration in the Iceland Basin: is mesoscale spatial variability important?

Authors: Chelsey Baker, S. A. Henson, A. Hickman, P. Martin, R. Lampitt

Presenter: **Chelsey Baker**

Organic carbon sequestration in the deep ocean is driven by the biological carbon pump, which fluxes organic rich biomass and detritus to below 2000 m, storing carbon on climatically significant timescales. Records of deep ocean particle flux are usually limited to one location and vast areas of the ocean remain unobserved. For example, the Subpolar North Atlantic is an important area for deep water formation but is understudied in relation to carbon sequestration. This study aims to quantify deep ocean carbon flux in the Iceland Basin for the first time and investigate the effects of mesoscale spatial variability in the magnitude of flux. Four sediment traps were deployed at 2000 m for two deployments during 2006 – 2008 and samples were analysed for mass and particulate organic carbon (POC) fluxes. The mean annual POC flux to 2000 m in the Iceland Basin was 102.5 (± 9.08) mmol C m^{-2} yr^{-1} which is lower than the global average of 120 mmol C m^{-2} yr^{-1}. This corresponds to a mean transfer efficiency, based on satellite derived export estimates of 7.8 %, again lower than the North Atlantic average of 10 %. Cook's distance and the threshold of expected spatial variability (35 – 69 % (lower – upper limit) of the mean POC flux) were used to identify periods of mesoscale variability between the traps. Mesoscale spatial variability was observed but decreased in importance with longer temporal scales. This study highlights the importance of considering local spatial variability when investigating particle fluxes at given locations, or using individual traps, especially for timescales less than one year. Overall, however, mesoscale spatial processes likely do not impact deep ocean carbon budgets when using long term time series.

The three-dimensional biological pump of Eastern Boundary Upwelling Systems: modelling studies of the California and Canary Upwelling Systems

Authors: Elisa Lovecchio, Martin Frischknecht, Nicolas Gruber, Matthias Münnich, Zouhair Lachkar

Presenter: **Matthias Münnich**

Eastern Boundary Upwelling Systems (EBUS) are extremely productive coastal regions located at the eastern edge of the oligotrophic subtropical gyres. The resulting gradient in production and organic carbon concentration, combined with an intense mean and turbulent offshore flow, gives rise to a substantial lateral redistribution of organic carbon from the coast. Here we quantify the total offshore transport of organic carbon (Corg) from the euphotic layer of the California (CalUS) and Canary Upwelling System (CanUS) to the open Ocean. To this end we use basin-scale setups of the Regional Oceanic Modeling System (ROMS) combined with a biogeochemical ecosystem module on telescopic grids with high

resolution of up to 5km in the EBUS nearshore. The models show that overall at least 30% (CalUS 36%, CanUS 30%) of the Corg produced within the first 100 km are transported offshore.
For the CanUS the central subregion constitutes an example of a fully 3D Corg cycle, combining substantial alongshore and offshore tracer redistribution and fueling extra deep respiration up to 2000 km into the adjacent gyre. Using eddy and filament detection algorithms, we are able to quantify their contribution to the total offshore carbon flux. Filaments dominate the offshore transport in the nearshore, representing 80% of the total flux at 100 km from the coast and constituting the primary lateral input of organic carbon up to 1000 km from the coast. The slower but farther-reaching eddies that originate in coastal waters contribute 30% to Corg in the euphotic layer of the open ocean, representing an important organic carbon reservoir for the open ocean. For the CalUS both Eulerian and Lagrangian analyses reveal that prior to coastal production, inorganic nutrients get transported laterally over thousands of kilometers toward central California. More than 80% of the nutrients originate from central offshore or southern alongshore locations. About half of it is supplied by the California Undercurrent alone, underscoring its importance in sustaining the high coastal productivity. Even though most of the inorganic nutrients get quickly transformed into organic matter once upwelled to the euphotic layer along the coast, a substantial fraction remains unused and is transported offshore. Overall, our results highlight the three-dimensional nature of the biological pump in EBUS and their strong influence on the adjacent open-ocean ecosystems.

The SNOWMAN: a new experimental device to improve our understanding of the Biological Carbon Pump through quantitative studies of aggregation kinetics and export time lag.

Authors: Emmanuel Laurenceau-Cornec, Alan Henderson, Chris Young, Brivaela Moriceau, Matthieu Bressac, Emma Cavan, Robert Strzepek, Svenja Halfter, Jordan Toullec, Frédéric Planchon, Philip W. Boyd.

Presenter: **Emmanuel Laurenceau-Cornec**

Our difficulties to fully comprehend the in situ processes driving the efficiency of the Biological Carbon Pump (BCP) lie in part in our inability to simulate it experimentally in controlled conditions. Phytoplankton aggregation and its subsequent sinking from the surface ocean governs the strength of the BCP by regulating the fraction of the biomass produced in the euphotic zone that will be efficiently exported to the mesopelagic. Despite its importance, no experimental tools allow to mimic adequately phytoplankton aggregation forbidding to study in particular how phytoplankton community variations affect the kinetics of their coagulation, aggregate physico-chemical properties and related export timing. Available coagulation instruments such as cylindrical tanks placed on a rolling table or Couette devices (using respectively differential settling and shear as coagulation kernels) have been used for decades in marine sciences to easily provide aggregated material for various studies. But the confined nature of these incubators limit their use to non-quantitative studies because of the impossibility for the large negatively buoyant particles to be exported downward as it would occur in the water column and instead keep participating to the coagulation processes until no particles remain in suspension.
The SNOWMAN or Simulator of Non-finite Open-Wheeled Marine Aggregation and siNking has been developed to address these limitations and open new perspectives to explore quantitatively in an experimental setting the links between community structure, aggregation kinetics and export timing (i.e. production/export time lag). The design of the SNOWMAN — refined with Computational Fluid Dynamics simulations and partly built with 3-D printing technology— consists in an innovative apparatus allowing traditional marine particle aggregation by differential settling but also permits the continuous export and collection of the largest sinking particles. We present here for the first time quantitative experimental data of the influence of phytoplankton community variations on aggregation kinetics and export timing and more specifically provide new insights into the relationship between community structure and export time

lag. Furthermore, we show the large panel of applications aimed with this new device and demonstrate how it can significantly improve our understanding of the complex lever that ecosystem structure exerts on the spatio-temporal variations of the BCP.

Anticyclonic Eddy Edge Effects on Phytoplankton Communities and Particle Export in the Northern South China Sea

Authors: Lei Wang, Bangqin Huang, Edward A. Laws, Kuanbo Zhou, Xin Liu, Yuyuan Xie, Minhan Dai

Presenter: **Lei Wang**

We examined response of phytoplankton total chlorophyll a (TChl a) and community composition to three coherent anticyclonic eddies (ACEs) observed during a cruise to the northern South China Sea on 28 July to 7 August 2007. Photosynthetic pigments were measured to estimate the contribution of nine phytoplankton groups to TChl a. Although the water column-integrated TChl a inventory in the upper 100 m was very similar among the three ACEs (17.6–18.9 mg/m^2) we observed during the cruise, there were remarkable enhancements in biomasses at the eddy edges. TChl a inventory was 20.8 ± 3.0 mg/m^2 at the edge, which was 33% or 60% higher than at the center and reference. The greatest enhancement of the TChl a at edge was attributed to haptophyte-8, which was 1.6 and 2.2 times the analogous concentrations at the center and reference sites. The Prochlorococcus Chl a was ~50% greater at the edge relative to the reference and was intermediate at the center. Diatom Chl a at the edge was ~2.5 times the concentrations at the center and reference sites. The positive correlation between particulate organic carbon flux and haptophyte-8 Chl a at the edge implied an important role of haptophyte-8 in particle export productivity. It is interesting to note that there occurred higher fluxes of biogenic Si at the center of the ACEs due likely to lateral transport of diatoms from the edge. The phenomenon of higher TChl a at the edge but higher export at the center may have been the combined result of vertical convection and lateral transport within the eddies.

Refractory dissolved organic matter along the conveyor belt, sources, sinks and implications for carbon sequestration

Authors: Gabriel Dulaquais, Kévin Crampond, Marie Boyé, Pierre-Marie Sarradin, Ricardo Riso

Presenter: **Gabriel Dulaquais**

Marine dissolved organic matter (DOM) is a key parameter of the biological carbon pump. Rivers are a major of DOM to the Ocean, but chemical biomarker and stable isotopic data indicate that most of the oceanic DOM comes from the recycling of carbon fixed by primary producers. This large reservoir (662Pg) of non-living organic matter has a spectrum of reactivity ranging from labile DOM (subject to biodegradation/assimilation) to recalcitrant DOM (poorly or not biodegradable). The latter accumulates in the deep ocean and sequesters carbon. The intensity of this biological carbon pump is subject to debate as to its importance in relation to the export of carbon on sinking particles. The size reactivity continuum and microbial carbon pump models both have been widely used to provide conceptual frameworks to better understand the processes governing the deep ocean cycle of the recalcitrant DOM. However, they are faced to fluorescence data that show an increase in humic fluorescence with the ageing of water masses, suggesting a production of these compounds along the conveyor belt. Humic substances are widely

recognized as recalcitrant DOM of high molecular weight, so models and observations transform a DOM paradigm into a humic paradox.
We will present new quantitative data of humic substances in seawater acquired by chromatography coupled with carbon, nitrogen and UV detection. We analyzed full depths profile in the two main ocean basins (Atlantic and Pacific) and monitored the fate of humic substances along the thermohaline circulation from the young surface waters of the North Atlantic to the old deep waters of the North Pacific Ocean. We will show that humic substances are enriched in surface waters and depleted in deep waters, with a profile very similar to that observed for dissolved organic carbon. Our results suggest that humic substances are produced at the surface and slowly respired by heterotrophic bacteria in the mesopelagic zone (200- 1000 m) throughout the global circulation. The variability of surface concentrations of marine humic substances indicates that the intensity of their production depends on biogeochemical domains and therefore on the community of primary producers. Estimations of the production-degradation balance, their residence time and thus of the time scale on which the sequestration of carbon by humic substances in the deep ocean induces carbon sequestration will be presented and discussed. Our results challenge our understanding of the oceanic cycle of humic substances but resolve the humic paradox by providing evidence of changes in their structure during their microbial respiration.

Nutrient limitations during diatom growth Influence the copepod grazing and the carbon export

Authors: Jordan Toullec, Dorothée Vincent, Nicolas Djeghri, Laura Frohn, Philippe Miner, Manon LEe Goff, Jérémy Devesa, Brivaëla Moriceau

Presenter: **Jordan Toullec**

Within the marine realm, diatoms play a major role in carbon export mainly when they aggregate. Another efficient export pathway is zooplankton faecal pellets emission in the surface mixed layer or after vertical migration in the mesopelagic layers. When diatoms are grazed by large copepods their frustule may ballast the resulting faecal pellets and increase their sinking rates.
Change in the water column stratification induced by global warming should increase the nutrient limitations in the surface ocean. Previous studies have shown that when diatoms grow under such limitations they change their silicification, but the influence this may have on grazing is yet unknown. We present here the first results on copepods grazing on limited diatoms. Two diatom monospecific cultures (Chaetoceros neogracile and Skeletonema marinoi) were grown under nitrogen and silicon limitations. Limitations led to a quick modulation of the diatom Si/C ratios and cell chain length of S. marinoi. Grazing incubation with both diatoms and three species of copepods (*Acartia clausi*, *Calanus helgolandicus* and *Euterpina acutifrons*) have been performed. Changes in Si/C ratios and cell chain length influenced the ingestion rates of all copepods, also modifying the emission of faecal pellets and their composition. The physiological answer of diatoms to nutrient limitations is species specific and modulate the copepod contribution to the export flux of particles. Our results suggest that limitations need to be taken into account to predict change in the biological carbon pump in the future ocean.

The imprint of the Amazon River on the phytoplankton community structure and carbon export in the Tropical Atlantic Ocean

Authors: Domitille Louchard, Nicolas Gruber, Matthias Münnich

Presenter: **Domitille Louchard**

In the Western Tropical Atlantic Ocean, anomalously low pCO_2 values are observed within the extensive plume of the Amazon River. As a result, these river influenced waters tend to act as a sink of atmospheric CO_2, quite in contrast to the surrounding waters that release CO_2 to the atmosphere. To unravel the complex interplay between physical and biogeochemical processes that leads to this unique effect of the Amazon, we use a telescopic configuration of the Regional Oceanic Modeling System for the entire Atlantic ocean, covering the mouth of the Amazon at a resolution of a few kilometers. This physical model incorporates a full-biogeochemical/ecological module that explicitly considers four phytoplankton functional types, i.e., small phytoplankton, free-living diatoms, a symbiotic assemblage of diatom-diazotrophs (DDA), and free-living diazotrophs. As expected, the large input of riverine nutrients leads to a substantial enhancement of the phytoplankton production in the otherwise oligotrophic tropical waters, providing new pathways for carbon sequestration. Our results show that the strength of this biological pump is highly dependent on the phytoplankton community structure that shifts along the plume continuum. We find that the stoichiometry of nutrient supply is the main factor shaping the emerging ecological niches. In mesohaline waters (between salinity of 30 and 35), the excess supply of phosphate and silicate over nitrate favor the DDAs, while further downstream, the progressive scarcity of silicate gives an advantage to the free-living diazotrophs and small phytoplankton. These floristic shifts and the associated changes in nutrient biogeochemistry and carbon export cause then also substantial changes in surface ocean pCO_2. The importance of the Amazon river input in driving the biogeochemistry of the tropical Atlantic is well illustrated when the stiochiometry of the riverine nutrients is altered or when this input is turned off. Our simulation suggests that this leads to a 20 to 80% reduction of the annual carbon export of the plume waters.

Contribution of siliceous Rhizaria (Polycystine radiolarian and Phaeodaria) to the ocean silica and carbon cycles

Authors: Natalia Llopis Monferrer, Aude Leynaert, Fabrice Not and Paul Tréguer

Presenter: **Natalia Llopis Monferrer**

Polycystinean radiolarians and phaeodarians are open-ocean planktonic protists typified by complex siliceous skeletons. Previous studies have emphasized their global distribution and significance in surface and mesopelagic layers of the oceans, yet their contribution to the carbon and silica cycles remain poorly constrained.

Recently, the combination of genomic and in situ imaging data showed evidence that biomass of these organisms might have been largely underestimated, representing approximately 33% of large zooplankton (>600 µm) biomass in the upper water column and ca. 5% of oceanic carbon standing stock (Biard et al. 2016). Rhizaria thus appear to be very relevant for carbon and silica export.

In order to improve our understanding of the role of these organisms in both the carbon and silica cycles, we collected siliceous Rhizaria during oceanographic expeditions (MOOSE-Mediterranean Ocean Observing System for the environment and the Atlantic Meridional Transect, in 2017 and 2018 respectively) During these research cruises we performed measurements of biogenic silica, carbon and nitrogen content of various taxonomic groups belonging to Rhizaria. Here we discuss the potential contribution of these organisms to the carbon and silica cycles.

Quantifying the ocean-to-atmosphere feedback of the biological carbon pump on IPCC timescales

Authors: Wolfgang Koeve, Paul Kähler, Andreas Oschlies

Presenter: **Wolfgang Koeve**

The biological carbon pump, i.e. the production of organic matter in the surface ocean, its export to and degradation in the ocean interior, contributes significantly to the surface-to-deep marine inorganic carbon gradient and hence provides an important control on atmospheric CO_2 and climate for any given steady ocean circulation and on millennial time scales. It is less clear though, how changes of the biological carbon pump can best be quantified and eventually monitored in the presence of a changing ocean circulation, e.g. on IPCC-relevant timescales. One widely-held conception is that the biological carbon pump, and its changes, can be equated with the export of organic matter out of the euphotic zone (export production). Using an ensemble of global ocean-atmosphere model experiments representing a wide range of potential responses of the biological carbon pump to climate change, we show that the change in export production is a poor measure of the biological pump's feedback to the atmosphere. We measure this feedback by quantifying the biogenic component of global air-sea oxygen flux. On the other hand, we find that the change in global true oxygen utilization (TOU), an integrative measure of the imprint of the biological carbon pump on marine oxygen is in very good agreement with the net change in the biogenic air-sea flux of oxygen. In our experiments, changes in TOU correlate very well with changes in apparent oxygen utilization (AOU), a property, which has been widely used as a measure of the biological carbon pump strength. We propose, that measuring the change of AOU by means of data from the global BIO-ARGO float program provides an opportunity to monitor the potential feedback of the biological pump to the atmosphere on transient time scales.

Modeled changes in the particulate carbon export efficiency in the North Atlantic due to diel zooplankton vertical migration.

Authors: Thomas Gorgues, Olivier Aumont, Laurent Memery

Presenter: **Thomas Gorgues**

In the ocean, zooplankton exhibits a behavior characterized by its migration at depth, in darker water masses, most probably to avoid visual predation during daytime. This Diel Vertical Migration (DVM) has been commonly observed in various locations and has been hypothesized to influence the biological pump by releasing nutrients and carbon at depth. Large uncertainties regarding the magnitude, spatial occurrence and variability of this "active transport" remain. Furthermore, its impact on the ocean biogeochemistry is still largely unknown. To tackle these questions, a simple cost-effective parameterization of the DVM is included into a regional biogeochemical model simulating the North Atlantic. In addition to a reference simulation in which no DVM is simulated, two relative biomasses of migrating zooplankton (30% and 60%) have been tested. Even if we only consider the lower end of the migrating zooplankton biomasses, an increase of 5% of the carbon export at 1000m has been estimated despite a concomitant decrease of the primary production. Therefore, our study advocates that active transport by migrating zooplankton is a contribution to the biological pump (increased efficiency) relevant enough to be rapidly included in contemporary biogeochemical models for present and future climate projections.

Microplastics Disrupting the Biological Pump?

Authors: Alina Madita Wieczorek, Peter L. Croot, Fabien Lombard, Jerome N. Sheahan, Thomas K. Doyle

Presenter: **Alina Madita Wieczorek**

Microplastics have been described to interact with a variety of marine organisms, some of which, such as copepods, mesopelagic fish and larvaceans are key players of the biological pump. More recently it has been shown that the sinking velocity of aggregates and copepod faecal pellets decreased when microplastics were incorporated. However, determining the precise interactions of microplastics in the biological pump has been limited as most studies used virgin microplastics at unrealistic environmental concentrations. Here, we used salps as a model organism to study the effect of low- density microplastic ingestion onto the sinking velocity of their high-density faecal pellets. Salps readily ingest particles from 2-1000 µm and are known to be one of the most important drivers for the downward flux of carbon and other key elements such as calcium, magnesium, aluminium, copper and manganese to the ocean floor. Using mesocosm experiments, we exposed Salpa fusiformis to fractured and UV exposed polystyrene and polyethylene microplastics possessing a biofilm, at concentrations observed in the Mediterranean, the South Pacific Gyre as well as potential future concentrations (10x and 100x that of the South Pacific Gyre). We found that microplastics significantly altered the size, density and sinking rates of salp faecal pellets (p-value in each instance <0.01). Sinking rates decreased by 1.35-fold for faecal pellets with polyethylene microplastics and 1.47-fold for polystyrene. However, the percentage of salp faecal pellets with microplastics present was minimal for exposure experiments using environmentally relevant concentrations. Nevertheless, these findings are of concern as salps may encounter much higher microplastics abundances in areas such as convergent zones or under predicted future scenarios of increased microplastic concentrations. In fact, one of the future scenarios chosen for these experiments (10 x that of the South Pacific Gyre) is considerably close to currently reported maximum abundances of microplastics within sea surface waters. In conclusion, where salps and microplastics overlap in high concentrations, microplastics may disrupt the biological pump. Further we recommend that future models estimating surface carbon export should consider the potential decrease in particulate organic matter sinking rates caused by the incorporation of microplastics.

Dissolved organic carbon release due to viral lysis in an ultra-oligotrophic basin (Levantine, Eastern Mediterranean)

Authors: Anastasia Tsiola, Ioulia Santi, Stella Psarra, Paraskevi Pitta

Presenter: **Anastasia Tsiola**

In May 2016, a large sampling expedition was carried out on-board the R/V Aegaeo in the NW Levantine Sea (Eastern Mediterranean), one of the most underexplored marine ecosystems throughout the Oceans. The aim of the study presented here was to assess the unique role of viruses as lytic and lysogenic agents and compare it with other systems; in other words, the interplaying roles of viruses in 1) killing their hosts, 2) replenishing the adjacent system with vital nutrients and organic matter, 3) modifying the non-infected community composition and 4) transferring ecologically-important genes through lysogeny were disentangled. We aimed to give an insight into the carbon-export potential due to complex viral actions in an ultra-oligotrophic system, considering spatial variability. To do so, samples were collected from four stations covering an offshore longitudinal transect in the Levantine and four depths (2, 50, deep chlorophyll maximum; DCM and 1000 m, where DCM was determined by CTD profiles). We conducted on-board viral production experiments to estimate the frequency of lysis, as a means of carbon, nitrogen and phosphorus

releases that altogether influence oceanic ecosystems sustainability. We also estimated the frequency of lysogeny (using the mitomycin-c protocol); a strategy that "protects" the hosts from lysis and reduces carbon export. For the accurate estimation of lysis and lysogeny, we determined the burst size (i.e. the number of intracellular viruses) using transmission electron microscopy. To supplement the above-mentioned viral reduction approach, we analyzed the viral genome through high-throughput sequencing and traced viral auxiliary metabolic genes (AMGs) involved in critical steps of carbon metabolism that, upon their expression, "help" their hosts to survive under harsh conditions (e.g. starvation or light inhibition).
Mean lytic viral production (VP-lytic) averaged 0.225 (± 0.121) x106 viruses mL^{-1}, with consistent subsurface maxima (50 m) and minima (DCM) observed in all stations. The VP-lytic rates were positively correlated with the bacterial production and abundance, as seen in other oceanic systems too. The frequency of lysogenic cells (35 ±15 %) varied little between stations and depths and exhibited minimum levels when bacterial abundance was also minimum, confirming that lysogeny prevails when ambient conditions for the hosts are not favorable. Viral abundance averaged 3.3 (± 1.4) x106 virus-like particles mL^{-1} and decreased with depth, as expected, and the content of AMGs differed significantly between the different depths. In this study, the lysis – lysogeny balance was determined with conventional ecological and molecular tools, while the dissolved organic matter that will not be ultimately transferred to higher trophic levels but will rather be re-processed within the microbial loop was estimated. Overall, our findings uncovered the important functional potential of viruses and their microbial hosts in the Eastern Mediterranean, a vulnerable-to-future-changes ecosystem. The new information from this ultra-oligotrophic basin is dually used; to predict future responses in a CO_2-increase scenario as well as to fuel carbon-export modeling approaches that usually disregard the criticial release of organic matter due to viral lysis.

Effect of jellyfish-associated nitrifying archaea on f-ratio measurements

Authors: Nathan Hubot, Sarah Giering, Cathy Lucas, Jessika Fuessel, Julie Robidart

Presenter: **Nathan Hubot**

Nitrogen often represents the limiting element for primary production in the surface ocean and its availability is therefore closely linked to the biological carbon pump. New production is often estimated indirectly by measuring nitrate assimilation based on the assumption that nitrate is solely supplied to the surface by vertical transport from nitrate rich, deep waters, while ammonia assimilation in turn represents uptake of recycled nutrients and is used as an estimate for regenerated production. In steady-state systems, new production balances the export of organic matter allowing it to be a proxy for the assessment of the efficiency of the biological carbon pump. Jellyfish excrete inorganic nitrogen mainly in the form of ammonium, the most reduced and usually preferentially assimilated form of inorganic nitrogen. Nitrification, the stepwise oxidation of ammonia via nitrite to nitrate, within the surface ocean however has been shown to unlink the connection between "new production" and nitrate assimilation. Here we demonstrate the potential of jellyfish-associated microbiomes for nitrification. Incubations in artificial seawater of three species of jellyfish (*Chrysaora fulgida*, *Chrysaora hysoscella* and *Aurelia aurita*) show substantial rates of nitrification associated with all three species, the produced forms of inorganic nitrogen however differ. Accumulation of nitrite in incubations with *C. fulgida* (1.03 ± 0.02 nmol gWW^{-1} h^{-1}) indicate the presence of ammonia oxidizing mircoorganisms, but the absence of nitrite oxidizing bacteria. A. aurita in contrast appears to harbour both types of nitrifiers, indicated by the accumulation of nitrate in these experiments (5.43 ± 0.48 nmol gWW^{-1} h^{-1}), while *C. hysoscella* induces accumulation of both nitrite and nitrate (2.66 ± 0.47 and 10.73 ± 4.28 nmol gWW^{-1} h^{-1}), suggesting uncoupling of the two steps. Fluorescence in situ hybridization (FISH) on different jellyfish body tissues confirms the presence of ammonia oxidizing archaea on all species. Our results suggest that ammonia-oxidizing archaea are commonly associated with jellyfish, which reinforces the importance of including nitrification when calculating new production based on nitrate concentrations. Jellyfish biomass during jellyfish blooms can be extensive, suggesting they could have a significant effect on the ratio of inorganic nitrogen species in

surface waters.

Session 24: The Second International Indian Ocean Expedition (IIOE-2): Motivating New Exploration in a Poorly Understood Basin

Impact of the Mesoscale on Carbon Chemistry in the Arabian Sea

Authors: Alain de Verneil, Zouhair Lachkar, Shafer Smith, Marina Lévy

Presenter: **Alain de Verneil**

The biogeochemical carbon budget of the Arabian Sea (AS) is impacted by myriad processes requiring the coupling of physical, chemical, and biological mechanisms. Monsoon-driven coastal upwelling produces intense biological production, fixing inorganic carbon at the surface into organic carbon and carbonate shells that are brought to depth through the biological pump. At depth, carbon is released through respiration or dissolution into inorganic carbon, where it is redistributed through circulation patterns that either export this carbon to other regions or bring it back to the surface.
As the physical-biological coupling of these dynamics move carbon around, the concentration of various carbon species alters in situ ocean water chemistry, impacting consequential parameters such as pCO_2 and pH. The difficulties of amassing ground-truthing measurements of the carbon system, along with computational constraints in resolving smaller-scale dynamical features in global Earth system models (e.g. eddies), have to date prohibited exhaustive investigation of the role of the AS in larger-scale carbon budgets. Here we attempt to address this through a modeling approach using the Regional Oceanic Modeling System (ROMS) coupled to a nitrogen-based nutrient-phytoplankton-zooplankton-detritus (NPZD) ecosystem model with an implemented carbon chemistry module. With an average horizontal resolution of 5km, we focus our analysis on how better resolution of mesoscale physical features impacts the overall carbon budget, along with identifying the relevant spatiotemporal scales that impact for future sampling strategies in the AS.

Major impact of atmospheric iron on the productivity of the Arabian Sea

Authors: Cécile Guieu, Al Azhar Muchamad, Aumont Olivier, Mahowald Natalie, Levy Marina, Lachkar Zouhair

Presenter: **Cécile Guieu**

In the Arabian Sea (AS), spatial and temporal nutrient limitation of the mixed layer ecosystem and the possible role of new nutrients from the atmosphere are still not well understood. Such a link, in the absence of sufficient in situ measurements informing both on spatial and temporal variability, can be approached through the modeling tool. In this study, we use a state of the art circulation and biogeochemistry model that considers the atmosphere as a source of nutrients (soluble iron, phosphate and reactive nitrogen) to assess the seasonal impact of atmospheric deposition on chlorophyll, new production (NPP) and N2 fixation. We show that the high N- high P –low Fe waters upwelled from shallow and steep upwelling along the coast of Oman are fertilized by atmospheric iron from dust. The iron from the dust deposition is responsible for one third of the NPP during the summer monsoon over the whole Arabian Sea but up to 80% in large region of the western Arabian Sea. There is thus a potential iron limitation linked to dust deposition occurrence. All year round, atmospheric iron also support most of the N2 fixation over the whole AS. On average over the AS, nitrogen fixation remains only a very small fraction (<1%) of the NPP, meaning that other phytoplankton species rather that diazotrophs are also favorably impacted by atmospheric iron. Although nitrogen deposition is high all year round and represent the main source of new nitrogen entering the surface waters of the AS, in particular due to emissions from India, these inputs do not significantly change the patterns of the ecosystems.

Current-topography interaction at three shallow seamounts in the South-West Indian Ocean: impact on ecosystem productivity

Authors: Jean-François Ternon, Steven Herbette, Mike Roberts, Patrick Vianello, Margaux Noyon, Francis Marsac

Presenter: **Jean-François Ternon**

Shallow seamounts ecosystems are known to be potentially productive due to physical processes resulting from current-topography interactions. Such processes are linked to the shape of the seamounts, to the speed and variability of the currents, to the water column stratification and to the latitude – through the Coriolis effect. Under favorable conditions, theoretical considerations suggest the generation and maintenance of circulation cells (the Taylor column or cone), the generation of upwelling along seamount slope, mixing due to internal tide/wave generation or enhancement, or rectification of tidal current. In turn, such processes potentially boost nutrients within the euphotic layer and sustain primary productivity. From that point, trophic pathways may – or may not – develop up to top predators. Seamount ecology is thus an issue for food security as well as a matter of concern for biological conservation as several seamounts are geographically isolated and such ecosystems generally show rather low resilience.

Seamounts are ubiquitous, a large number of them being located in the IO, especially in the South West Indian Ocean, along the South West Indian Ridge, the Madagascar Ridge and on the Mozambique Plateau. Few of them have previously received scientific attention, mostly the six seamounts surveyed during a Fridtjof Nansen cruise in 2009. In 2016-2017, IRD scientists – together with colleagues from France, La Réunion, South Africa and Madagascar – have undertaken an ecosystem survey of 3 shallow seamounts, namely the La Pérouse seamount (north-west of La Réunion, at 19°30'S – 54°E), an unnamed seamount north of the Madagascar Ridge (hereafter MAD-Ridge, at 27°340'S – 46°15'E) and the Walters Shoal at the southern end of the Madagascar Ridge (at 33°15'S – 44°E). The cruises were part of the WIOURI (West Indian Ocean Upwelling Research Initiative) project of IIOE-2.

All three seamounts are shallow (64m, 230m and 20m respectively), they all show evidence of enhanced biological productivity (spot for pelagic and demersal fishery, seabird feeding areas, etc.) while being located within oligotrophic biomes. The dynamical context of the 3 sites, however, is much contrasted, the MAD-Ridge area being highly impacted by mesoscale (and submesoscale) turbulence. Also, the MAD-Ridge area is just about hundred miles south of the active Fort Dauphin upwelling which can impact the seamount productivity through entrainment of coastal water by the eddy boundary currents.

A comparison of the dynamical, hydrological and biogeochemical context described from the set of observations and measurements achieved during the three surveys will be presented. S- and L-ADCP current measurements, CTD profiles of the main hydrological descriptors (temperature, salinity, oxygen, and fluorescence), nutrients and phytoplankton pigments data will be used to characterize the circulation, the water masses and the potential enrichment processes evidenced at the three seamounts. Due to their specific shape, to the local hydrology and circulation and to remote influences, all three seamounts appear to have different biological production potential, which has been confirmed by the higher trophic levels surveys achieved during the cruises.

Seawater oxygen isotopes as geochemical tracers of water mass exchange between the Red Sea and the Indian Ocean

Authors: Benjamin Kuerten, Nikolaos D Zarokanellos, Ulrich Struck, Burton H Jones

Presenter: **Benjamin Kürten**

The Red Sea is a semi-enclosed marginal sea that exchanges water masses with the Indian Ocean through the receiving basin of the Gulf of Aden. Unique geologic and ecohydrographic characteristics set the Red Sea apart as an ideal ocean for studies of past, present, and future climate in sub-/tropical oceans and the influence of the Indian Ocean. The only natural connection of the Red Sea with world oceans is at the south end of the basin through the shallow strait of Bab-al-Mandab where the inflow of relative low salinity and warm water from the Gulf of Aden occurs. Conversely, Red Sea Deep Water (RSDW) forms in the northern part of the basin, and spreads at intermediate depths throughout the Indian Ocean and along the African continental slope toward the Agulhas system. Limited by the shallow strait depth (~137 m), the inflow is reduced during glacial sea level low-stands, and modulates the circulation as well as primary production and plankton biodiversity in the Red Sea. As the magnitude of the exchange flow is sensitive to global climate and sea level changes, it has been subject to substantial paleoceanographic research. Although, seawater oxygen isotope (δ18OSW) data is key to improve our understanding of paleotemperature and paleoproductivity, δ18OSW data from the Red Sea were limited to few observations. We present a substantial set of δ18OSW and salinity (S) observations obtained during a series of surveys from 2014−2017 in the Red Sea and the Gulf of Aqaba. We demonstrate that δ18OSW is a convenient and conservative tracer of the inflow of water from the Gulf of Aden in the Red Sea. First, we show that Gulf of Aden Intermediate Water (GAIW) transports nutrients toward the central Red Sea. Second, we show how Gulf of Aden Surface Water (GASW), which is characterized by its higher temperature, lower salinity and relatively low δ18OSW, interacts with mesoscale eddies in the central Red Sea. We conclude that upon formation in the northern Red Sea, RSDW can be identifiable in the Indian Ocean based on its high salinity, low dissolved oxygen, and high δ18OSW.

Physical controls of Arabian Sea oxygen and primary productivity interannual variability and change

Authors: Parvathi, Vallivattathillam, I. Suresh, M. Lengaigne, C. Ethé, J. Vialard, M. Lévy, S. Neetu, O. Aumont, L. Resplandy, H. Naik and S.W.A. Naqvi

Presenter: **Jérôme Vialard**

The Arabian Sea is the most productive region of the Indian Ocean, and hosts a very prominent oxygen minimum zone. In this talk, we will discuss physical controls of the interannual and long-term changes in the Arabian Sea biogeochemistry. We will first show that the episodic anoxic events on the west coast of India, with deleterious influences on ecosystems and fisheries, can partly be linked with the Indian Ocean Dipole (IOD), one of the leading modes of year to year climate variations in the Indian Ocean. We will then examine long-term projections from climate models for the Arabian Sea, and discuss possible mechanisms for the long-term changes in primary productivity and oxygen.

The case for iron limitation in the Indian Ocean

Authors: Jerry Wiggert

Presenter: **Jerry Wiggert**

There is mounting evidence that parts of the Indian Ocean are prone to iron limitation, even within the northern Arabian Sea that is heavily impacted by atmospheric dust deposition. Given that heavy dust deposition, with associated aeolian iron contribution to its surface waters, the Arabian Sea has historically been identified as “Mother Nature’s Iron Experiment”. This presentation will review the various lines of evidence, drawn from ocean models, remote sensing observations, and ship-based measurements, to examine areas where phytoplankton appear to be prone to iron stress and to characterize the spatial and seasonal patterns that are indicated.

SESSION 26: TRANSBOUNDARY FISHERIES MANAGEMENT IN CHANGING NORTH ATLANTIC AND PACIFIC OCEANS: TAKING STOCK, FUTURE SCENARIOS

Combining automated optical approaches for building an integrated platform for marine phytoplankton observation

Authors: Luis Felipe Artigas, Claquin P.2, Créach V3, de Blok R.4, Debusschere E.5, Deneudt K. 5, Grégori G6, Hébert P.-A.7, Karlson B.8, Kromkamp J.9, Lahbib S.6, Lefebvre A.10, Lizon F.1, Louchart A.1, Möller, K.O. 11, Poisson-Caillault E., Rijkeboer M., Tybergh

Presenter: **Luis Felipe Artigas**

Regular monitoring of marine waters is of upmost importance for understanding physical, biogeochemical and biological fundamental processes as well as for addressing changes that could be driven by anthropogenic pressure and/or global change. Phytoplankton micro-organisms, which are at the base of most food webs, mediate biogeochemical cycles and can be responsible for harmful events impacting ecosystem goods and services as well as human health. They display changes in their community’s growth rate, size structure, taxonomic and/or pigmentary composition, at high rates, evidencing rapid changes in environmental conditions. Most of the dedicated monitoring programmes are based on discrete sampling and reference laboratory methods such as microscopic identification and counts, as well as pigment analysis. However, sampling frequency/spatial coverage of these long-term series (discrete stations sampled monthly or fortnightly) or extended spatial (short duration dedicated cruises) series of observations might not be sufficient to fully understand and evidence of phytoplankton dynamics in the highly variable marine waters. In order to address phytoplankton temporal changes and spatial distribution at fine resolution, automated in vivo and in situ approaches are being deployed during the last decade. Whether being less precise in identifying different phytoplankton taxa or pigmentary groups than in vitro laboratory techniques (including molecular methods), these innovative approaches provide new insights into phytoplankton dynamics and thus allow gathering useful complementary information for research on phytoplankton ecology and biodiversity and moreover they help calibrating remote sensing algorithms retrieving phytoplankton functional types, as well as eco-hydrodynamical models. When implemented in automated environmental monitoring platforms (fixed stations, moorings, research vessels and/or ships of opportunity), can represent early-warning systems of phytoplankton changes, as the occurrence of blooms and, in particular, of harmful algal blooms (HAB), of special interest in areas of fishing, aquaculture and tourism. Within international projects as the Joint European Research Infrastructure network for Coastal Observatories – Novel European EXperTise for coastal observatories (JERICO-NEXT- H2020, 2015-2019), scientists are applying a combination of phytoplankton automated observation approaches, based on single cell/particle or bulk optical characteristics, in several coastal systems ranging from oligotrophic (West Mediterranean) to mesotrophic and eutrophic marine waters (Channel, North Sea & Baltic Sea). Three main techniques, image in-flow acquisition and analysis, pulse shape-recording flow cytometry, as well as multispectral and variable fluorometry, are being critically explored. Their operability and limits in addressing phytoplankton diversity (at taxonomical and/or functional levels) and productivity are defined, together with development of new methodologies and automation tools for signal analysis and definition of common ways of integrating international databases. Results on new information gathered on phytoplankton dynamics in coastal and marine waters are presented and remaining challenges are discussed in the frame of fundamental and operational oceanography and environmental policy requirements.

Temporal and Spatial distribution of marine nanoflagellates' diversity and community structure in East China Sea

Authors: Xin Guo, Lingfeng Huang

Presenter: **Xin Guo**

Although marine nano-flagellate (NF) is a class of highly heterogeneous group in global marine ecosystem, with high biodiversity, multiple trophic modes and a wide range of distribution, their temporal and spatial distribution of diversity and community structure are still poorly characterized. Here we analyzed the taxonomic diversity and community structure of NF (size, 2 to 20μm) from surface (0m) and bottom samples collected in coastal and shelf habitats of East China Sea in three seasons in 2013, using high throughput sequencing of 18S V4 region amplified from rRNA gene. The diversity and community structure of NF displayed different distribution among seasons, habitats and depths, which were assessed in relation to in situ environmental conditions. Seasonal variation was more obvious than spatial variation. Communities in summer and autumn, shelf area and bottom were more diverse than in spring, coastal area and surface of the water. Alveolates were dominant in all samples throughout the year, with average percentage of 76.55%, mostly composed of Dinophyceae and MALVs. Photosynthetic stramenopiles Chrysophyseae, Dictyochophyceae, Bicosoecida, and a Chloroplastida Chlamydomonas was relatively abundant mostly in spring, whereas heterotrophs and mixotrophs, such as MASTs, Picozoa, Chryptophyta, Pirsonia, Choanoflagellates, displayed higher relative abundance in summer and autumn. Beta diversity analysis split the protist communities into several main clusters based on seasons, habitats and depths: communities from the coastal area were clustered into different seasons, whereas communities from the shelf area were more likely to separate based on depth than seasons. Our extensive and systematic sequencing of temporally and geographically separated samples provides comprehensive understanding of NF's diversity and community structures in East China Sea.

Monitoring of fish communities and benthic habitats from unbaited underwater video techniques: lessons from a decade's experience

Authors: Dominique Pelletier, Marc Bouchoucha, David Roos

Presenter: **Dominique Pelletier**

In coastal areas, anthropogenic pressures are intense and spatially organized, and benthic habitats are

heterogeneous, both locally and at larger scales. Monitoring-based assessment of fish communities and biotic habitats in such areas generally suffers from a poor spatial replication, which makes the area-wide assessment of key biological components, such as fish communities and benthic habitat, quite challenging. This paper presents the data obtained from video-based observation techniques developed from 2007. These panoramic and unbaited techniques were consolidated, standardized and implemented in various ecosystems, both coral reef and temperate, and are now fully operational. We describe the two techniques developed and the observations collected in the Pacific, the Indian Ocean and the Mediterranean, amounting to ca. 4500 concurrent observations of both fish (and marine turtles) and biotic and abiotic benthic cover. We present the standardized methodology for field work, for analysing footages and for assessment. A large number of observations could be collected because of an easy and fast field implementation in diverse habitats, and because no diving nor scientific expertise was required on the field, so that rangers and local communities may be involved.
I present several outcomes of this work, including knowledge production and dissemination, community involvement, and education. Finally, the implications of developing new monitoring methodologies and transferring them to stakeholders are discussed.

Towards a global in situ monitoring of plankton using imaging systems: lessons learnt from the past 10 years of observation in Europe

Authors: Lars Stemmann, Romagnan Jean Baptiste, Alain Lefebvre, Gérald Grégori, Jean Olivier Irisson, Bengt Karlson, Jukka Seppala, Kaisa Kraft, Guidi Lionel, Luis Felipe Artigas, Dodji Soviadan, Guillaume Wacquet, Klas Ove Möller, Klaas Deneudt, Simon Claus, Fabi

Presenter: **Lars Stemmann**

Plankton plays a key role in the biological pump and has a big impact on marine living resources. However, plankton is difficult to observe in a consistent manner across its extended size range and by the multiple observers that uses protocols that are not inter calibrated. Imaging sensors have the potential to provide key “ecosystem essential ocean variables” eEOVs (plankton biodiversity, morphological traits) that complement other sensors such as optical ones. Lab and in-situ imaging sensors have been deployed the 10 last years to provide insights into local dynamics in the frame of time series programs (from daily to decadal scales) and during oceanographic surveys across ocean basins. Combining observations from the different programmes has sometimes allowed to detect concomitant changes in different areas or provide a better spatial distribution of plankton communities. For example, such efforts were supported by the European FP7 JERICO, H2020 JERICO-NEXT, BRIDGES, EURO-BASIN programs. Most of the observation efforts were performed independently and hundreds of millions of images have been collected (and billions to come as sensors are getting more available). All those sparsely distributed images are usually not available for the users because of limited development in software solutions for identification, archiving and distribution, which are in a current improving process. Several attempts for developing web based services for image recognition, distribution and archiving have been performed (ecotaxa.obs-vlfr.fr) but only a fraction of the existing and future data can be treated by them. Based on the past ten years of effort, we will present a synthesis of successful developments in using imaging systems to provide information on plankton community at local, regional and ultimately global scales. These examples will show how relevant they are for ecosystem monitoring (e.g. detection of ecosystem changes and regime-shifts) and services (e.g. aquaculture, fisheries, biological carbon pump). We will then build on these examples to discuss future developments with the aim of, better observing, harmonizing practices and developing state of the art marine data and information management in order to increase the connection with the relevant stakeholders and community of users among researchers, conservation managers and private companies.

Addressing high frequency phytoplankton dynamics from by automated flow cytometry and multi-spectral fluorometry in the Eastern Channel – Southern North Sea.

Authors: Arnaud Louchart, Reinhoud de Blok, Elisabeth Debusschere, Emilie Houliez, Fernando Gómez, Alain Lefebvre, Fabrice Lizon, Jonas Mortelmans, Machteld Rijkeboer, Klaas Deneudt, Arnold Veen, François G. Schmitt, Luis Felipe Artigas

Presenter: **Arnaud Louchart**

The eastern Channel and southern North Sea are shallow well-mixed marine systems of high tidal range under influence of Atlantic waters and freshwater's inputs. Flows from Northern French estuaries (as Seine and Somme) are driven from the Channel to the North Sea by the residual Atlantic current creating a "coastal flow" in the French side, whereas the Thames, Scheldt and Rhine ROFIs of variable extension into the southern bay of the North Sea. Therefore, brackish waters of high nutrient concentrations spread offshore the Channel and North Sea waters, mostly characterised by high nutrient concentrations. During spring, the increase of temperature and light quality and day-length induce the occurrence of massive blooms of Diatoms and Phaeocysits globosa along French, Belgian and Dutchcoasts, Dinoflagellates in the Thames ROFI. These blooms alternate with picophytoplankton and form irregular patches at sub-mesoscale. Most studies and surveys were carried out by reference approaches (discrete stations sampled sporadically or at low frequency), focusing on pigments and/or on part of the whole size range of phytoplankton. However, considering the fast dynamics of some phytoplankton species, current monitoring strategies are not well suited to highlight spatial and temporal patterns in phytoplankton communities' successions and outbursts. Innovative techniques provide useful information for the whole size range of phytoplankton and increase the sampling frequency which leads to a better spatio-temporal resolution. In that way, we applied automated pulse shape-recording flow cytometry (PSFCM) and multi-spectral fluorometry from the eastern Channel to the southern North Sea. These techniques provide rapid estimates of abundance and/or red fluorescence content (proxy of chlorophyll a) for the whole phytoplankton community, at single-cell (PSFCM) or bulk (Fluoroprobe) level from small picoeukaryotes up to large colonies of microphytoplankton. Within the frame of a local monitoring programme (CPER MARCO) as well as the European JERICO-NEXT H2020 project, we carried out a series of 3 following cruises in 2017 starting after the onset of the spring blooms in the eastern Channel and followed their development through the Dover Strait towards the southern North Sea. We were able to discriminate up to 11 cytometric groups showing small spatial and/or temporal dynamic with patchiness and sharp variations in abundance and fluorescences per group. We were able to identify different phytoplankton communities following the hydrology of the area (North Sea vs English Channel, offshore waters vs estuarine plumes but also between estuaries). High biomass was found in brackish waters which were more dominated by nanophytoplankton communities whereas offshore waters and Thames estuary were dominated by picophytoplankton communities associated with low biomass and higher diversity of functional groups. Ecological niche concept explained picophytoplankton had small niche breadth whereas nanophytoplankton had the bigger niche breadth. Finally, the coupling of both innovative and reference techniques gave relevant and significant results from micro- to sub-mesoscale distribution of phytoplankton and dynamics and there is an interest to develop further the use of automated devices to monitor phytoplankton dynamics.

Science support to fisheries or fisheries support to science? Proactive design of virtuous cycles for ecosystem essential ocean variables collection and analysis

Authors: Maria A. Gasalla

Presenter: **Maria Gasalla**

There is a lack of common agreement on the inclusion of fisheries data in the so-called ecosystem essential ocean variables debate, beyond catch and landing-related information. However, there has been widespread argumentation in ocean research proposals for considering marine living resources as essential to the nutritional, recreational, and health needs of human beings, beyond marine creatures. Building on recent multidisciplinary research in SE Brazil undertaken with emphasis on both industrial and small-scale fisheries, a synthetic model for the collection and analysis of ecosystem ocean variables will be presented and discussed. Overall, our analysis indicates paths for a self-conscious marine science community which may extend across different disciplines and sectors in order to better understand biodiversity and societies that link with it. It will explore how virtuous circles where the interplay between different disciplines and scientific issues promotes constant development and innovation, especially in data-poor systems, should promote knowledge integration rather than tunnel visions consolidation. Moreover, a proactive observation protocol design where each discipline cross-propagates advantageous specific needs in which a successful scientific answer leads to more of a desired result generating still more desired results in a chain is what we need to organize and promote if sustainable development goals are a truly goal to be achieved.

Monitoring Marine Ecosystems Via Biogeochemical Profiling Float Arrays

Authors: Gael Forget, Stephanie Dutkiewicz, Oliver Jahn, Mick Follows

Presenter: **Gael Forget**

Autonomous platforms will provide a wealth of new biogeochemical and ecological information in coming decades. Here we assess how the planned biogeochemical-Argo array of profiling floats may perform in terms of monitoring marine ecosystems. We simulate measurement of 6 key oceanic biogeochemical variables, as planned, by global profiling float arrays from a state of the art model simulation of marine biogeochemistry and ecosystems over two decades. The model solution, from the CBIOMES project, is a global ocean state estimate that is based on Forget et al 2015 for ocean physics, constrained by core-Argo and satellite data, and on Dutkiewicz et al 2015 for marine biogeochemistry and ecosystems. The model's detailed representation of ecosystems, with 35 phytoplankton types and 16 zooplankton types, inherent optical properties, and radiative transfer components make it ideal for simulating bio-chemical and bio-optical data. The main observing system simulation experiment samples the ocean exactly like the core-Argo program did for temperature and salinity over the past fifteen years. Additional experiments are performed where the floats sampling frequency, depth coverage, and list of measured variables are modified. As a first step, the simulated data sets are used to map out each observed variable, individually, in space and time via standard averaging and interpolation techniques. This allows a first assessment of expected observing system performances. Then we train neural networks to predict the biomass of major plankton groups from observed variables. This, in turn, allows us to assess the planned biogeochemical-Argo array as a means to monitor biogeography and biodiversity over the global ocean.

Defining the observing system for the world's ocean – from microbes to whales

Authors: Patricia Miloslavich, Nic Bax, Daniel Dunn

Presenter: **Frank Muller-Karger**

A globally coordinated and sustained ocean observing system is urgently needed to systematically assess the status of the ocean's biodiversity and ecosystems and how these are responding to increasing resource use, including coastal development under long-term climate change scenarios. Based on a set of measurable biological characteristics or biological essential ocean variables (EOVs) derived from the requirements of 24 multilateral environmental agreements, existing monitoring capabilities and scientific and societal impact, a PEGASuS Ocean Sustainability Working Group aims to design a monitoring network to answer specific scientific questions on high priority global phenomena in response to calls for guidance from policy makers and managers. Mapping the current spatial extent of observations for these essential variables, from microbes to whales and coastal ecosystems to the deep sea, will help capitalize on what is already being achieved and what remains to be done to develop a globally coordinated, fit for purpose, and sustained ocean observing system. These EOVs will form the backbone of a sustained global ocean observing system driven by societal needs and complement existing physical EOVs which have greatly influenced national management, international understanding and direct policy uptake through the IPCC. Another goal is to develop a roadmap to ensure that products maximally support monitoring progress against the Convention on Biological Diversity 2050 Vision, Agenda 2030 and other critical international agreements including scientific platforms related to climate change, biodiversity, and ecosystem services as well as the UN Decade of Ocean Science for Sustainability. The roadmap will include where current indicators can be updated to make better use of scientific information and impact the future development of scientific priorities.

One of the first tasks will be to identify and prioritize the ocean phenomena that need to be monitored to understand trends and respond to future impacts and change - essentially what are the big scientific questions that require sustained observation before they can be answered. These will be guided to the high-level phenomena developed by the Global Ocean Observing System (GOOS) of IOC/UNESCO which refer to: (1) What are the changes in production - including oceanic, shallow water and coastal primary production and the quality and extent of marine habitats?, (2) What are the changes in biological communities - including community shifts, regime shifts and persistent changes in species composition, trophic structure, species range and phenology?, (3) What are the impacts of these changes - such as population loss, mass mortalities and bleaching due to diseases, heat stress, acidification, deoxygenation, pollution, etc.?, and (4) What is the potential for populations and ecosystems to recover – how can we measure resilience and recovery of populations and of ecosystems, especially degraded ones?

The working group will also build on the essential monitoring questions developed at the Convention on Biological Diversity (CBD) workshops, while aligned with the UN Decade of Ocean Science for Sustainability by contributing to assess governance and policy for ocean sustainability and with Future's Earth mission of accelerating transformations to global sustainability through research and innovation.

Fishery resource assessment in the Bohai Sea using water column image data from multibeam echo sonar

Authors: Cheng TANG, Yanfang LI, Bin LIU, Dong LI, Xin LIU

Presenter: **Cheng Tang**

Multibeam echosounder systems(MBES) has the quantitative capability to provide data for a number of fisheries and environmental related issues with high temporal and spatial resolution. Water column image data (WCDI) is the acoustic scattering returns in the water column in athwartship plane from MBES. It can form a volumetric image by combing a series of pings along the ship track, which makes it particularly attractive for fisheries applications where the target is either elusive or non-stationary over the survey time. Around 1 T data of WCDI produced by R2Sonic 2024 operating in 400 kHz were collected during 2 scientific cruises in the Chinese Bohai Sea in 2017 summer and 2018 winter, the individual fish and fish school information was post-processed using image pattern recognition algorithm with OpenCV package. An index for regional fishery resource assessment was set up using fish number counted divided by the total ping numbers during the survey period of each site. Compared with the historical record of regional fishery resource investigation using the trawling net, the result from WCDI-MBES shows similar pattern of fish distribution except the southern Bohai Sea shows fishery vacancy in the summer survey, which may be caused by the re-open fish catching policy. The method shows a convenient and promising way for quickly assess the regional fishery resource in the shallow waters.

Towards the sustainability through understanding benthic community productivity of the Sundarbans mangrove ecosystem, Bangladesh

Authors: Salma Begum, Ratul Islam, Rupa Biswas, Jerin Sultana

Presenter: **Salma Begum**

Aquatic biotic community becomes more plentiful with benthic invertebrates which are playing several ecological roles in wetland ecosystem functions. They play significant roles in the energy pathway and nutrient cycling and they also constitute an important link in the aquatic food chain as food resource for fishes and other animals. Secondary production is the quantitative base of energy flow and of trophic interactions between heterotrophs and thus constitutes a key parameter of ecosystem functioning For understanding and comparing coastal or marine ecosystems from different areas of the world, it may be informative to examine how energy flow is channeled from the phytoplankton through pelagic and benthic components. How energy flow is channeled through different taxonomic pathways is not understood in the vulnerable Sundarbans ecosystems of Bangladesh. The ultimate goal of this proposed research is to manage the coastal ecosystems in a sustainable manner in terms of ecosystem energy flow. Therefore to understand the benthic community energy flow, the proposed research will measure the macrobenthic biomass production and productivity of the Sundarbans ecosystem, Bangladesh based on the sampling from the sediment sample. The proposed research will be an attempt to explore and identify the community parameters their distribution among major taxonomic groups in the Sundarbans ecosystem. Most productive and dominated taxa will be determined. To estimate the community energy flow, the proposed research will determine mean biomass (B) annual production (P) and productivity (P/B) of the coastal communities of the Sundarbans ecosystem, Bangladesh. Analysis will be performed multivariate approach.

Building a Marine Biodiversity Observation Network (MBON)

Authors: Frank Muller-Karger, Gabrielle Canonico, Mark Costello, Isabel Sousa-Pinto, Emmett Duffy, Maria Kavanaugh, Enrique Montes

Presenter: **Frank Muller-Karger**

National and international marine management and conservation groups and agencies need improved understanding on which key organisms are in a marine ecosystem, how they relate to each other, and how

they have been changing under different forcing, be it natural or related to human pressures.
In the last few years, several projects have been established around the world focused on collecting biodiversity and biogeographic information. These programs should be linked to coordinate the methods required to identify and collect essential variables, to define and implement data archival standards, and to conduct the joint analyses required for regional and global biodiversity assessments.
The Marine Biodiversity Observation Network (MBON) grows out of the Group on Earth Observations (GEO) Biodiversity Observation Network (BON). MBON incorporates the biodiversity priorities of various GEO initiatives. This includes 1) Integrating and synthesizing biological and other information from ongoing monitoring programs through the Global Ocean Observing System (GOOS); 2) Refining details for practical marine Essential Biodiversity Variables (EBVs) and Essential Ocean Variables (EOVs); 3) Integrating biodiversity measurements in a relational database, particularly the Ocean Biogeographic Information System (OBIS); 4) Establish a protocol to dynamically update indicators for ecological assessments, and identifying methods and tools for an ocean best practices repository at the Intergovernmental Oceanographic Commission (IOC; https://www.oceanbestpractices.net/) (this is a contribution to the BON in a Box of GEO BON); 5) support and coordinate with international programs (GEO BON, Blue Planet, IMBeR, the IOC, and others); and 6) Understand the linkages between marine biodiversity and the social-economic context of a region.
The MBON offers many benefits, including:

- Expand our knowledge of biodiversity and its services with the purpose of improving management of human activities that impact these services.
- Coordinate separate individual monitoring and science programs to optimize productivity.
- Provide mechanisms to share data, experiences, knowledge, and protocols to understand species and the status and trends of ecosystem services.
- Increase understanding of physical and biological connectivity, including distributions and movements of migratory species across jurisdictions.
- Refine and adjust methods to collect information to properly document resources and to share innovative technologies and methods (e.g. remote sensing and genetic methods).
- Amplify the effect of national investments in living marine resource surveys to a regional and global scale, maintaining the identity of local groups.
- Minimize the high costs of data management and of improving access to information.
- Provide the framework for a country to establish the baselines needed to evaluate status and critical trends in future biodiversity and living marine resource assessments. In turn, improve the capacity to detect and discriminate between changes caused by natural and/or anthropogenic factors and effectively respond to them.

GEO BON MBON is developing a “Pole-to-Pole MBON in the Americas” pilot. Similar regional efforts should be initiated and coordinated. We will work with GEO BON, GOOS and OBIS to identify programs in other continents that can be joined into a network.
The Thematic MBON community invites participation to enable this global biodiversity observation facility.

Science for the future: the use of citizen science in marine research and conservation

Authors: Hannah Earp, Arianna Liconti

Presenter: **Arianna Liconti**

Over the last decade, significant advances in citizen science have occurred, extending in scope from the ocean floor to the Milky Way and covering almost everything in between. These projects have provided cost-effective means to collect and analyse extensive data sets covering vast spatio-temporal scales that can be used in scientific research, to develop conservation policy and to promote environmental awareness. Although not as prevalent as its terrestrial counterpart, marine citizen science has recently emerged as a

powerful research tool to discover, innovate and address global marine challenges for which data is significantly lacking. This review explored the current status of marine citizen science by examining 117 marine citizen science projects. Trends in geographic locations, focal taxa, volunteer demographics, methodologies and data directionality were highlighted, and the challenges and benefits of citizen science to marine research and conservation were reviewed. Overall, marine citizen science was found to lie at a crossroads of unresolved challenges, demonstrated successes, and unrealised potential, in particular concerning biodiversity monitoring. However, should the challenges be addressed, the unique capacity of citizen science to broaden the scope of investigation maybe the key to the future of marine research and conservation in times of global change.

High-frequency monitoring of phytoplankton by automated flow cytometry: diel variability and spatial distribution at high resolution

Authors: Epinoux A., van Dijk M., Artigas L. F., Bernadi-Aubry F., Casotti R.

Presenter: **Alexandre Epinoux**

As phytoplankton ecology remains elusive at the finest scales (hourly to daily variations), due to technical limitations, our understanding of its dynamics is limited to broad spatio-temporal definitions. Quasi-continuous sampling of phytoplankton along the track of a ship, or on a fixed platform has become a possibility with the advent of automated pulse-shape recording flow cytometers, such as the CytoSense (Cytobuoy B.V., the Netherlands). This instrument is specialized for the study of phytoplankton cells and its large dynamical size range (1 µm to 1 mm), opens to the possibility of describing phytoplankton dynamics at an unprecedented resolution. Here are presented two high-frequency phytoplankton datasets (1 µm to 1 mm in size) generated with a CytoSense, identifying several optically-defined phytoplankton groups and sub-groups. The first dataset has been generated during a 2-days long sampling every 10 minutes from an oceanographic platform located in the Adriatic Sea. A significant variability is observed depending on the light field and the vertical movements of the water masses, also dependent upon the tide. The second dataset has been generated during an oceanographic cruise from the Azores to Sicily, sampling every 20 minutes while the ship was cruising through different water masses. Evident phytoplankton patchiness was observed and differences in phytoplankton communities, probably dependent on the physico-chemical characteristics of the water masses crossed during the track. High-frequency sampling helps to understand phytoplankton ecology at a finer scale than before, highlighting changes occurring at different time and space scales in terms of physiology (fluorescence, size of cells) and population dynamics. The large datasets generated will need powerful statistical analyses to appreciate the large optical diversity present in phytoplankton and to relate it to physiological parameters and their ecological meaning.

SESSION 26: TRANSBOUNDARY FISHERIES MANAGEMENT IN CHANGING NORTH ATLANTIC AND PACIFIC OCEANS: TAKING STOCK, FUTURE SCENARIOS

Matching the Time of Emergence of Transboundary Fish Stocks to Lead Time for Policy Response Under Climate Change

Authors: William W. L. Cheung, Juliano Palacios Abrantes, Thomas Frölicher, Rashid Sumaila, David VanderZwaag

Presenter: **TBD**

Theories and empirical evidence suggest that fisheries targeting fish stocks straddling between two or more political or governance jurisdictions are particularly prone to over-exploitation. Climate-induced species distribution shifts result in changes in the sharing between existing shared stocks or creation of new shared stocks, adding uncertainties to the sustainability of these fisheries. To reduce risk of over-exploitation, national and international fisheries management policies need to adapt to these climate-induced shifts in shared stocks. However, the lead time for adjustment of fisheries policies ranges from years to decades. Here, we hypothesize that the 'time of emergence' of changes in transboundary fish stocks at country's EEZ scale is earlier than the lead time for changing most international fisheries policies. We test this hypothesis using the North American region (U.S.A, Canada and Mexico) as a case study. Time of emergence (ToE) of climate risk of transboundary fisheries is defined here as the time (year) at which the change in maximum catch potential of a transboundary fish stock is larger than its background variability. To quantify ToE of transboundary fish stocks, we use the Dynamic Bioclimate Envelope Model (DBEM, a mechanistic species distribution model) to project changes in species distribution driven by ocean changes simulated from 30 different ensemble members of the Geophysical Fluid Dynamic Laboratory Earth System Model 2M (GFDL ESM 2M) from 1950 to 2100 under the Representative Concentration Pathway (RCP 2.6, 'strong mitigation') and RCP 8.5 ('business-as-usual'). The variance of the projected changes in maximum catch potential from simulations using ESM ensemble members represents the background noise from interannual variability of the climatic system. We calculate the year when changes in maximum catch potential of current or future shared stocks jumps out of the range of long term interannual variability. We compare the ToE of changes in transboundary fish stocks with expected lead time for adjustment of international policy. Our results suggest that fisheries policies for some fish stocks and their fisheries in the North American region may need to reduce their lead time for revision. This study highlights the opportunities and risks of climate change on sustainable management of transboundary fisheries, and the urgency for adapting fisheries governance for climate change.

The International Law and Policy Seascape for Managing Shifting Species and Ecosystems

Authors: Phillip Saunders, Cecilia Engler

Presenter: **Cecilia Engler**

The impacts of climate change and ocean acidification on major transboundary fishery resources are projected to be significant, including, for example the following: redistribution of species, spread of invasive species and alteration in disease vectors, changes in fishery productivity, expansion of oxygen-minimum and anoxic dead zones and acidification impacts on local habitats and species. Redistribution of species and other factors will challenge the effectiveness and relevance of current Regional Fishery Management

Organization (RFMO) boundaries. In addition, the current international and legal structures governing transboundary fisheries, as set out in the 1982 UN Convention on the Law of the Sea and the 1995 Fish Stocks Agreement, are rooted in the application of outdated "predictive" management approaches based on Total Allowable Catch and Maximum Sustainable Yield, with little support for the introduction of more adaptive principles such as the precautionary and ecosystem approaches. The example of the ecosystem approach (EA) and the extent of its adoption in international legal instruments, including the Law of the Sea Convention and the Fish Stocks Agreement, is considered and assessed in more detail. The presentation describes the particular barriers to EA implementation to the management of transboundary fisheries in changing oceans, which to a significant extent are the result of fundamental principles of international law and international law of the sea, as well as historical practices of RFMOs. Additionally, the presentation provides an overview and assessment of instruments and mechanisms that are used, or could be used, to address these challenges in the context of climate anomalies and regime shifts.

Are Transboundary Fisheries Management Arrangements in the North Atlantic Seaworthy in a Changing Ocean?

Authors: David VanderZwaag

Presenter: **David VanderZwaag**

This presentation will assess how four transboundary fisheries management arrangements in the North Atlantic are addressing shifting species and ecosystems in the face of climate change. Arrangements to be critiqued in terms of how they are putting into practice key principles, such as precautionary and ecosystem approaches, include the Northwest Atlantic Fisheries Organization (NAFO), the International Commission for the Conservation of Atlantic Tunas (ICCAT), the North Atlantic Salmon Conservation Organization (NASCO) and Canada-U.S. bilateral cooperation in managing shared groundfish on Georges Bank. Common management challenges will be discussed, in particular: continuing scientific uncertainties; ignoring or overriding scientific advice because of political and socio-economic pressures; ongoing reliance by managers on single fish stock assessments; and the still rather nascent state of ecosystem modelling and its translation into decision-making. The presentation will conclude by summarizing some of the main promises in moving forward towards more dynamic and adaptive management, for example, the adoption by NAFO of a Roadmap for the Development of an Ecosystem Approach to Fisheries and NAFO's establishment of a joint Commission and Scientific Council Working Group on the Ecosystem Approach Framework to Fisheries Management.

Are Transboundary Fisheries Management Arrangements in the North Pacific Seaworthy in Changing Oceans?

Authors: Olga Koubrak

Presenter: **Olga Koubrak**

This presentation will describe how key transboundary fisheries management arrangements in the North Pacific are addressing shifting species and ecosystems in the face of climate change. Four Pacific arrangements will be reviewed regarding their initiatives to understand and respond to shifting marine ecosystems. Canada-U.S. management approaches in two bilateral arrangements, the Pacific Salmon Commission and the International Pacific Halibut Commission will be described, followed by a summary of

how two regional fisheries management organizations, the North Pacific Fisheries Commission (NPFC) and the Western and Central Pacific Fisheries Commission (WCPFC), have fared in implementing the ecosystem approach. The presentation will conclude by identifying common challenges in transboundary fisheries governance in the North Pacific and suggesting possible ways to make future management more dynamic and adaptable.

Challenges to Transboundary Fisheries Management in North America Under Climate Change

Authors: Juliano Palacios-Abrantes, Rashid Sumaila, William W.L. Cheung

Presenter: **Juliano Palacios-Abrantes**

Climate change is shifting the distribution of fish stocks that straddle between Exclusive Economic Zones (EEZ), challenging transboundary fisheries management. Canada and United States (US) share numerous economically and culturally important transboundary fisheries in the Atlantic and Pacific coasts, with some of them managed by Regional Fisheries Management Organizations. In this paper, we examine the projected sharing of jointly managed transboundary fish stocks between the EEZs of Canada and US. We hypothesize that ocean warming will alter the sharing of fish stocks between the two countries, and that such changes will intensify under a high carbon emission scenario. Specifically, the parts of the EEZs closer to the pole are expected get an increasing share of transboundary fish stocks because of climate-induced species range shifts. Firstly, we projected changes in potential catch of 34 transboundary stocks of North America in the 21st century based on multiple Earth system models' simulations and species distribution models, under two climate change scenarios. Results show that, even under a low emission scenario, most transboundary fish stocks sharing ratios, i.e., the proportion of the total catch of a fish stock taken by a given country, will change by 2050 relative to 1950 - 2000 in the direction as expected from the effects of ocean warming. Some Atlantic species like capelin (*Mallotus villosus*) are expected to increase catch potential by 60% in Canada while decreasing by 30% in the US by 2050, under a high emission scenario. Results for the Pacific also show a poleward trend with some species in Alaska increasing catch potential by 16% while species in the contiguous states decreasing by an average of 11%. For Canada, projections suggest no obvious change in catch potential (-1% ∽3%), probably due to a transition zone between the two US regions. We then look at the specific cases of the International Pacific Halibut Commission (IPHC) that manages pacific halibut (*Hippoglossus stenolepis*) and sablefish (*Anoplopoma fimbria*), and a resource sharing agreement in the Gulf of Main for cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and yellowtail flounder (*Limanda ferruginea*). Our results suggest that by 2050 climate change will generate changes in stock-share between both EEZs of Canada and US, as well as regulatory areas. Under a high emission scenario, catch potential of IPHC species will increase by 13% in some regulatory areas off Alaska while decreasing by 3 and 8% in areas off Canada and US contiguous states, respectively. In the Gulf of Maine, the overall reduction in catch potential, in addition to the changes in stock-share will further exacerbate trade-offs between changes in species catch potential. Such trade-offs in the Atlantic and Pacific regions will be amplified if a high emission scenario is followed, relative to a low carbon emission scenario. Our paper highlights the challenges that transboundary fisheries management will face as species shift their current distribution under a changing climate.

40 years of Norwegian experience in management of transboundary fish stocks: lessons learned and how will climate change interact

Authors: Peter Gullestad, Peter Gullestad, Svein Sundby and Olav Sigurd Kjesbu

Presenter: **Olav Sigurd Kjesbu**

The introduction of 200-n.m. economic zones in 1977 urged the need for increased collaboration among neighboring coastal states to manage transboundary fish stocks. Such collaboration was particularly important for Norway where its expanded economic zone not only called for intensified monitoring, control and surveillance but also for well-functioning international agreements; 90% of the value of Norwegian landings comes from shared stocks. Several of these stocks are among the most productive in the world and thereby highly important economically. The agreements developed ranges from bilateral (e.g. between Russia and Norway for five stocks in the Barents Sea and between EU and Norway for five stocks in the North Sea) to multilateral between several coastal states, including a high seas component, for three pelagic stocks in the Norwegian Sea. Although different in form the agreements may cover, not only the allocation of quotas and possible access to waters, but also important issues of joint research, reporting and sharing of data from fisheries, harvest control rules, technical regulations and fisheries control activities. The Law of the Sea Convention does not deliver an answer to how quotas of transboundary stocks should be allocated between relevant Parties. The Norwegian experience is a development where input from science on stock distribution gradually has played a more important role as the starting point for negotiations and political agreements. In this context possible shifts in distribution must be considered. Since the late 1970s the regional ocean temperature of the North Atlantic has increased substantially. The big-picture response has caused a poleward shift in species distribution from plankton to fish, however, not in a uniform way across species. We here select some species that have changed their life cycles and distributions during this warming period. These are the Northeast Atlantic mackerel–Norwegian spring-spawning herring–blue whiting complex, the northern European hake and North Sea cod. This new era of environmental change might influence management principles, but at the same time it should be realized that no general model is to be expected due to well-developed differences in many respects between fish stocks, ecosystems and management traditions.

SESSION 27: WORKING IN THE SCIENCE-INDUSTRY INTERFACE: STRATEGIES FOR EFFECTIVE COLLABORATION AND PATHWAYS TO POSITIVE ENVIRONMENTAL CHANGE

Working in the Science-Industry Interface: Modes of Collaboration and Pathways to Positive Environmental Change

Authors: Prue Addison, Christopher Cvitanovic

Presenter: **Prue Addison**

Environmental scientists are increasingly encouraged to work within the science-policy-practice interface to conduct research that has real world impact, addressing pressing environmental and sustainability issues. Whilst our understanding of what makes for successful and effective science-policy collaborations has deepened through research into the process of knowledge exchange and research impact across the science-policy interface; what makes for successful and effective science-industry collaborations has received less attention. We outline preliminary research, exploring and contrasting science-policy and science-industry collaboration in addressing ocean sustainability challenges, including: knowledge exchange contexts (e.g., environmental and sustainability issues addressed; the drivers and enabling conditions for forming partnerships); modes of collaboration (e.g., the type partnerships formed, and the role of scientists, KE practitioners and external partners); risks and opportunities that are unique to collaborators and their institutions undertaking science-industry collaborations.

To science change – a curious dance between experimental ecologists and senior executives

Authors: Henrik Österblom

Presenter: **Henrik Österblom**

Can scientists stimulate change in society? Is this something they should engage in, or should they rather be content with passive observations of the world, using their disciplinary constrained perceptions of reality? Existing descriptions of the emerging field of sustainability science argues that such science is in fact defined by the multiple perspectives and disciplines used in framing problems and their solutions, and that the science is also defined by its engagement with actors outside of academia. This study describes a long-term investment in transdisciplinarity, through a co-designed process of collaborative learning with "Keystone Actors" in global seafood. A process of identifying industry actors with disproportionate ability to influence change, led to a series of bilateral conversations with CEOs, a number of global science-business dialogues and the eventual formulation and institutionalization of the Seafood Business for Ocean Stewardship (SeaBOS) initiative. SeaBOS is staffed and funded by the world's largest seafood corporations, and is supported by independently funded scientists, who perceive the initiative as part of a large-scale experiment designed to test scientific hypothesis about systemic and transformative change associate to keystone actors. The study investigates the institutional and individual capacities that has been instrumental for progress to date, explores risks and ways of mitigating them, and reflects on scientific identity and the role of scientists in society. Change does not magically happen In an era where transformative change is perceived as necessary, we conclude that science-based processes of change with industry has unexplored capacity to contribute to sustain

Linking marine science to action: the role and utility of Outcome Mapping

Authors: Sierra Ison, Christopher Cvitanovic, Ingrid van Putten, Alistair Hobday, Gretta Pecl

Presenter: **Sierra Ison**

The field of conservation science is quickly emerging as an action-orientated discipline through which biodiversity knowledge is converted into conservation action. However, conservation occurs within a time-continuum and often does not have a clear beginning, middle or end. As funding agencies, including government, non-governmental organizations (NGOs) and industry, are under pressure to demonstrate project success via tangible and real-world impacts, it is imperative to not only demonstrate changes in the state, but also how these changes are facilitated by the stakeholders involved. To enable demonstration of change throughout the duration of a project and to enhance conservation action, we adapt the Outcome Mapping (OM) framework. OM is a program development framework that changes the focus from evaluating projects on the basis of economic criteria or by policy relevance, to focus on people: their behaviors, relationships, networks, actions, and activities. Specifically, those individuals, groups, and organisations with whom the program interacts directly and with whom the program can anticipate opportunities for influence. We outline the six key stages of the OM framework in a conservation context that address the innately non-linear complexities. This includes, for instance, formal and informal power relations and the difficulties of monitoring environmental impact to bring about social change. We aim to use the OM framework to identify behavioral indicators, such as collaboration and conflict mediation across user groups and within decision-making institutions. These indicators will assist in identifying societal changes that support environmental improvements. We hope that this is a first step towards considering the use of OM in addressing global environmental challenges and conservation initiatives. By identifying the changes in behavior that will facilitate desired environmental and social improvement, OM can further support long-term environmental change and stakeholder engagement. In the pursuit of action-orientated conservation science, OM can help resolve the problem of not having a clear ending by focusing on incremental and subtle changes rather than a singular impact.

“We collaborate, for sustaining happiness of rural community residents”: Some empirical evidence on the factors enhancing the participation of “Associated Population” into rural re-energize activities in Japan

Authors: Aoi Sugimoto, Hiroaki Sugino, Kanako Funasaka, Shoko Ueda, Shun Uehara, Takayuki Mamabe

Presenter: **Aoi Sugimoto**

In some developed countries, aging and depopulation issue is increasingly recognized as one hindrance for the effective management of public goods e.g., natural resources. There has usually been a tension between the people who argue the necessity of outsiders’ contributions (e.g., immigrant workers) for the effective public goods management and who argue the ‘risk’ of introduction of outsiders, particularly in developed countries. The question to be answered here is, who should be (un)welcomed by the local community, for the sake of managing public goods including natural, cultural and other resources which support the well-being of local residents.
Hida city, Gifu prefecture, Japan is one typical city which has been struggling with aging and depopulation problems since 2000 (MIAC Japan 2015). Essential functions of the community, such as local economic activities, tradition, and natural resource management has been degrading because of aging and depopulation since then. At the same time, however, there are growing number of people who are repeatedly visiting there and willing to contribute to the management of some public goods in Hida.

Recently Japanese Government defined such people as "Associated Population" to shed light on the possibility of those people in order to sustain rural communities. Given this circumstance, our research team, consisting of Hida city office, academic institutions (JFRA and University of Tokyo), and private ICT company (Rakuten, Inc.) has started collaboration to explore the factors of successful Associated Population growth.
Our results of structured online interview indicate the demographic factors predicting the tendency for contributing to certain local public goods management activities, as well as the types of contributions which local residents expect for outsiders. In addition, we discuss how the collaboration among local government, academics and private companies could influence both local community and Associated Population to better interact each other.
Our experience will be shared with participants of the session, and the following discussion will be highly encouraged, particularly with regard to the factors for the successful Associated Population growth for sustaining the public goods management of local communities.

Combining ecological science and industry innovation to cut back on bycatch

Authors: Sara Mynott, Martin Stevens, Jon Blount, Dan Watson

Presenter: **Sara Mynott**

Globally, some 8-25% of the total fisheries catch is discarded. These discards cost an estimated $1 billion annually and are responsible for substantial losses to marine ecosystems around the world. To tackle this waste, the EU have placed a ban on discards, preventing some 1.7 million tonnes of fish and other marine life being discarded at sea. While the landing obligation helps reduce waste, it also constrains the ability of fishers to respond to consumer demand, as not all species caught are of commercial value. This project seeks to tackle the problem at source; working with industry to develop tools to reduce bycatch and allow fishers to better meet market needs by customising their catch. The last decade has seen a substantial increase in the range of bycatch mitigation measures used. However, there is substantial scope to improve these approaches and tailor systems to attract or deter particular groups. With an understanding of the visual systems of different species, we can adapt mitigation systems to make them more visible to the species of interest. For example, escape routes could be tailored to be better seen by choke species, or those that have little commercial value. Similarly, lures could be adapted to suit the visual sensitivity of the target species, while reducing their visibility to those often caught as bycatch. This project combines sensory ecology with industry experience and technology to help make fishing more sustainable. Here we present the first results from this project, showing how visual ecology can be used to make fishing more targeted, reducing bycatch for sustainable seas.

Working with industry in the Sustainable Seas national Science Challenge in New Zealand

Authors: Julie Hall, Carolyn Lindquist, Judi Hewitt, Linda Faulkner, Conrad Pilditch, Chris Cornelisen

Presenter: **Julie Hall**

The Sustainable Seas National Science Challenge in New Zealand is undertaking research needed to support New Zealand in moving to a holistic approach to sustainable marine management with a focus on Ecosystem

Based Management (see the Challenge website at www.sustainableseaschallenge.co.nz). The transdisciplinary research is being undertaken in 38 projects by 220 researchers from 36 different organisations and includes biophysical, social science, legal and policy researchers as well as researchers with expertise in mātauranga Māori and kaupapa approaches to research. A very important component of the research is the involvement of marine industry representatives, policy makers, marine managers and community representatives, as a change in marine management will impact all these groups and they need to be involved in the journey. Marine industry representatives are involved at a variety of levels within the programme. Starting at governance level, we have industry representatives on the governance board of the Challenge. This is the group that provides strategy and financial oversight of the Challenge programme. The involvement of industry at this level is important in terms of a real-world perspective and in supporting and encouraging industry involvement at other levels in the programme. We have a stakeholder panel which provides advice to both the governance board and the leadership team of the Challenge and undertakes reviews of research proposals, provides input into strategic development, i.e. our strategic plan for the next 5 years, and provides links with their wider industry sectors. This panel has representation from both central and regional government community groups and all the major marine industries in New Zealand including fisheries, aquaculture, marine mining, tourism, an innovation hub and the oil and gas industry. At the project level some projects have industry involvement either directly with the research or in the provision of in-kind support, for example, provision of data or use of a mussel farm and associated infrastructure to support a project investigating ways of offsetting ocean acidification around shellfish aquaculture farms.
We are about to embark on a co-development of research projects for phase II (the next 5 years of research) for the Challenge. This will directly involve representatives from industry and regional and central government in a series of workshops and in the development of research proposals.
The presentation will report on the successes and difficulties we have encountered with the approaches we have taken to involving industry in our research programme, and on the lessons we have learned regarding the co-development of our new research projects over the next 4 months.

WKIRISH: Harnessing Fisher Knowledge. an Example of Positive Collaborative Research

Authors: Dave Reid, Debbi Pedreschi, Paul Bouch, Jacob Bentley, Francis O'Donnell, Robert Thorpe, Steven Beggs, Pia Schuchert and Sheila J.J. Heymans

Presenter: **Dave Reid**

Within the Irish Sea, fisheries have transitioned from a cod, whiting and herring dominated fishery in the 1960s to one that more dominated by Nephrops and other shellfish stocks today. Despite effort reductions of 40-80%, among other recovery measures, stock response has generally been slow, with others failing to respond to management measures. This led to a call from the industry for a scientific review to improve understanding and provide answers for the lack of ‘results’.”
WKIRISH is the first ICES Integrated Benchmark Assessment to include standard single species stock assessment and ecosystem modelling. The series of workshops faced multiple challenges in working to integrate ecosystem drivers into the evaluation and analytical assessment of commercially important species. The workshops progressed through scoping issues and data evaluation, to improving single species assessments, and further on to using previously untapped fisher industry and ecological knowledge to fill knowledge gaps. WKIRISH4 focussed on ecosystem integration and incorporating stakeholder knowledge. This will be vital for the development of fishery ecosystem management plans (which should involve all relevant stakeholders), through facilitating information exchange between management stakeholder groups (fishermen, scientists, regulators and other interested parties).
Here we present the experience of working with stakeholders to ‘crowd-source’ food-webs, and identify the relevant information to parametrise the models (EcoPath with EcoSim (EwE)), and a Le Mans ensemble model). Stakeholders helped supply historic information to reconstruct effort trends by gear for years in

which such data is not available (model base year = 1973, while most quantitative effort data started after 2003), using memory and historic events (e.g. changes in regulations) to anchor changes in trajectory hind-cast from the "known" position from 2003 on. This data was then used to inform the effort trends for EwE and the Le Mans model, and after a modification in amplitude, improved the fit of the model, furthering ecosystem understanding. We will present the process of working with the stakeholders and some of the results from the EwE analysis. In particular, we will focus on where we found that the best model fits were achieved when we included both "scientific" data, and the information from the stakeholders.
Fishermen, industry representatives and eNGOs also assessed the 'Fishing' components of an ODEMM integrated ecosystem assessment, improving the understanding and nuance of the ecosystem impacts of different gears.
Overall the experience was extremely useful and rewarding, with participant's eager to continue the work. The workshop has helped to identify ways in which ecosystem information can potentially be incorporated into the machinery of the stock assessment process, providing a bridge from science, to policy and practice. Furthermore, it provides an example of successful science-industry collaboration and knowledge exchange contributing effectively to improve sustainable fisheries management

Developing long-term collaborative relationships with the multiple fishing industry sectors in Atlantic Canada to achieve common objective of sustainable fisheries

Authors: Arnault Le Bris

Presenter: **Arnault Le Bris**

The roles and opinions of fishery scientists and industry stakeholders have long been considered in conflict, which has impeded effective science-industry collaborations. However, there is a growing recognition that effective collaborations between fishery scientists, managers and harvesters is the preferential path towards the common goal of sustainable fisheries. Numerous science-industry collaborative research programs are thus emerging and increasingly required by funding agencies. In this talk, I used several examples of my past and present collaborative research with various sectors of the fishing industry in Atlantic Canada to highlight key elements necessary to conduct effective science-industry collaborations. These elements include common definition of research objectives, early involvement of both science and industry in proposal writing and budget definition, recognition of the strength of the various collaborators, and communication of the research results back to industry members. I also present some challenges that need to be addressed, such as different timeline between academic research and industry needs and the ownership of intellectual property created in research programs.

Developing innovative financial mechanisms for Pacific islands conservation: opportunities and challenges

Authors: Raphaël Billé , Jean-Baptiste Marre

Presenter: **Raphaël Billé**

The well-known "funding gap", or low level of public funding currently allocated to island conservation relative to needs, calls for trialing new or under-utilized economic and financial mechanisms such as payments for ecosystem services, biodiversity offsets, marine conservation agreements, user fees etc., some of these involving strong collaboration with the private sector. That is the logic behind the RESCCUE (Restauration of ecosystem Services and adaptation to climate change) project, which is designed to increase Pacific island societies and ecosystems' resilience to climate change by implementing integrated coastal management. In addition to its tangible and practical actions at various pilot sites, this project, implemented by the Pacific Community (SPC), also targets a regional learning process grounded in real-life experiments with economic and financial mechanisms. Based on project results from Fiji, French Polynesia, New Caledonia and Vanuatu, this presentation will showcase results of collaboration with several local industries, and share Pacific Island-specific lessons learnt. It will assess challenges with setting up innovative financial mechanisms: complexity of marine, watershed and land-sea ecological processes; lack of data to assess ecosystem functions, services and values; often low population densities combined with subsistence economies; legal obstacles; customary land and marine resources tenure and the cohabitation of customary and common law; transaction costs against financial benefits. The presentation will also review opportunities such as the overall good status of coastal and marine ecosystems; the importance of a tourism industry which heavily depends on ecosystem services; climate change funding.

Working in the science-industry interface: understanding the private sector

Authors: Jan Bebbington

Presenter: **Jan Bebbington**

It is entirely natural that scientists would wish to engage with the private sector (from big corporations to small and medium enterprises) to influence social and environmental outcomes in the marine environment. In order to achieve this outcome, nuance is required to understand: (1) the relatively freedom corporations have to follow novel operational paths given their innate structure and design; (2) how pressures for change emerge for companies in strict legal terms; and (3) what other possibilities for change exist for corporations (primarily around norm producing processes). While corporations can be and are important partners in whole system transformations, the particular way they can be mobilised and supported in these processes is complex and requires some knowledge of organizational science. As an organizational social scientist who has systematically engaged with corporations for 25 years (individually and through broader norm processes) I will synthesis and bring insights from this experience to share with natural scientists.
In brief, and responding to the three aspects above:

(1) Corporations are designed to achieve economic outcomes and (depending on their ownership structure) are tightly constrained with respect to the level of financial performance expected of them. For a large, for-profit company that is listed on a stock exchange the room to manoeuvre is relatively small (but not zero). For other companies there is more leeway to undertake pro-environmental behaviours that might require financial investment. This general point, however, can and is modified by the nature of the industry in which a firm operates and the network of relationships they have with their funders, owners, customers and other stakeholders. A contingency model of which corporations might be more able to respond to calls for ocean sustainability (and when) will be presented as a synthesis from this theme.

(2) Much of what we might want companies to do in the ocean environment is hard to achieve, especially given that many instances activities may take place beyond the clear jurisdiction of national laws. This second theme will take the issue of forced labour (sometimes described as 'modern slavery') in wild capture fisheries to demonstrate the complexity of making sure that internationally agreed performance standards are met on the ground across the globe.

(3)The final theme builds on the extent to which non-legal initiatives offer promise for encouraging and supporting industry transformation.

Taken together, this contribution seeks to highlight the complexity of working alongside companies who often facing constraints in terms of what they can do. This is not to argue, however, that business cannot be a partner with science for ocean stewardship … but it is the case that more knowledge of the world from which companies emerge is important to ensure that science and industry collaborations work well.

Science-fishing industry collaborations to improve gear selectivity: feedbacks and future strategies

Authors: Marie Morfin, Sonia Méhault, Fabien Morandeau, Pascal Larnaud

Presenter: **Marie Morfin**

Since the 1960s, the selectivity of fishing gears has been widely studied in order to improve the conservation and management of the marine resource. Gear selectivity consists in avoiding to catch undesired species or specific lengths in order to decrease the discards while limiting commercial loss. In addition to the conservation interest, selectivity improves the quality of the commercial catch and reduce the sorting time onboard. Furthermore, the recent implementation of the Landing Obligation in the new European Common Fisheries Policy aroused an increased interest from the fishing industry to improve selectivity. A new technical measures framework regulation is indeed currently proposed to help to achieve the aim of the landing obligation. These mutual interests for both scientists and fishers encouraged them to collaborate in multiple selectivity projects. We propose to relate how these collaborations were conducted, how they were initiated and for which purposes, what was the role of the different stakeholders, and what did succeed or not. The involvement of the fishing industry helps to improve the acceptation from the industry and good compliance of the measures that resulted from the policy, but it appeared that gear selectivity is highly dependent of the fishing, the targeted species, the season, and environmental conditions. Testing selectivity devices from experiments conducted under commercial fishing conditions is thus essential to establish measures that are really effective. Achieving these goals would require exploring even more cases of study, requiring budgets and time. We will describe the initiatives already committed in this direction and potential strategies that would meet the objectives of sustainability.

Building better fish stock assessment and management through effective science-industry partnerships

Authors: Lionel Pawlowski, Marianne Robert, Erwan Duhamel

Presenter: **Marianne Robert**

Sustainable and stable catches are desirable features of an effective management of fisheries. This work explores several examples of how of the changes in the Common Fishery Policy have led scientists and industry to build and improve partnerships for some of the Celtic sea and Bay of Biscay fisheries. Stakeholders have been in recent years in demands for a growing number of reliable stock assessments, which are prerequisites to any form of efficient management. While science has been developing tools to assess data-limited stocks, the lack of analytical estimates generally leads to lowered catch opportunities. To solve this issue, the industry has in some cases provided fishery scientists information from tallybooks or implemented self-sampling programs in order to feed other source of data to the stock assessments. This approach has in some cases allowed the assessments to move from data-limited to fully analytical ones. In parallel, management has been evolving from the traditional "next year single stock catch advice" to other forms of decision support such as long-term management plans and multispecies advice. Both requires strong, and transparent interactions between scientists and industry where EU Regional Advisory Councils and some EU projects have been central forums. Development of such plans is a complex iterative process where the industry agrees on some management scenarios to be tested into simulation frameworks. The biological and economical sustainability of each scenarios is scrutinized and discussed from the outcome of decadal simulations before being eventually implemented.

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