
IMBeR
Integrated Marine Biosphere Research
IMBIZO5
2-5 Oct 2017 - Woods Hole, USA
MARINE BIOSPHERE RESEARCH
FOR A SUSTAINABLE OCEAN
Linking ecosystems, future states
and resource management
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Marine biosphere research for a sustainable ocean:

Linking ecosystems, future states and resource management

2-5 October 2017

Woods Hole, USA

Produced by: IMBeR International Project Office
IMBeR Regional Project Office

Ocean Carbon and Biogeochemistry
www.us-ocb.org

Studying marine biogeochemical cycles and ecosystems in the face of environmental change

WELCOME IMBeR IMBIZO 5!

The Ocean Carbon and Biogeochemistry (OCB) Program and the Woods Hole Oceanographic Institution (WHOI) would like to welcome participants to Woods Hole for IMBeR IMBIZO 5: *Marine biosphere research for a sustainable ocean: Linking ecosystems, future states and resource management*. We are looking forward to a productive and stimulating meeting!

ABOUT US

WHOI (whoi.edu) is a world leader in interdisciplinary ocean research, exploration, and education. With expertise spanning the disciplines of oceanography, ocean engineering, and marine policy, this is an optimal venue for IMBIZO 5! WHOI also hosts the OCB Project Office. OCB (us-ocb.org) is a network of ~1,700 scientists who work across disciplines of ocean chemistry, biology, and physics to understand the ocean's role in the global carbon cycle and the response of marine ecosystems and biogeochemical cycles to environmental change. The OCB Project Office plays multiple support roles for the OCB network, including the organization of workshops and other scientific activities; US and international science planning; training and engagement of early career scientists, and serving as a communication hub for OCB science and opportunities.

Given the overlap between IMBeR and OCB research interests, these two programs have a long history of collaboration. OCB is excited for the opportunity to host IMBIZO 5, and to strengthen research ties and build new collaborations across our communities.

We hope you enjoy IMBIZO 5 and your time in Woods Hole!

Warmly,
Your hosts from the OCB Project Office,

Heather Benway
Executive Officer

Mai Maheigan
Communications Officer

Mary Zawoysky
Administrative Associate

CONTENTS

Organisers

Scientific Committee:

- Carol Robinson (Chair), University of East Anglia, Norwich, UK
- Eileen Hofmann, Old Dominion University, Norfolk, VA, USA
- Julie Hall, NIWA, Wellington, New Zealand
- Alistair Hobday (IMBIZO5 Convener), CSIRO, Hobart, Australia
- Marion Glaser (IMBIZO5 Convener), ZMT, Bremen, Germany
- Laurent Bopp (Workshop 1 Convener), LSCE, Saint-Aubin, France
- Eric Galbraith (Workshop 1 Convener), Universitat Autònoma de Barcelona, Spain
- Gerhard Herndl (Workshop 2 Convener), University of Vienna, Vienna, Austria
- Tatiana Rynearson (Workshop 2 Convener), URI, Narragansett, RI, USA
- Gavin Fay (Workshop 3 convener), University of Massachusetts, Dartmouth, MA, USA
- Ingrid van Putten (Workshop 3 Convener), CSIRO and University of Tasmania, Australia
- Cisco Werner (Workshop 3 Convener), NOAA Fisheries, Washington DC, USA

Organising Committee:

- Lisa Maddison, IMBeR, Bergen, Norway
- Veslemøy Kjersti Villanger, IMBeR, Bergen, Norway
- Fang Zuo, IMBeR, Shanghai, China
- Heather Benway, OCB, Woods Hole, MA, USA
- Mai Maheigan, OCB, Woods Hole, MA, USA
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IMBeR International Project Office (IPO):

Institute of Marine Research, Bergen, Norway

- Lisa Maddison
- Veslemøy Kjersti Villanger

IMBeR Regional Project Office (RPO):

East China Normal University, Shanghai, China

- Yi Xu
- Fang Zuo

About IMBIZO5

The Integrated Marine Biosphere Research (IMBeR) project is an international research initiative co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and Future Earth. To progress IMBeR science, we organise an IMBIZO (the Zulu word for 'a gathering') every second year, and bring together a group of around 120 marine scientists from a variety of disciplines to discuss topical issues pertaining to marine and human systems and their linkages.

This is the fifth IMBeR IMBIZO, and we are delighted to be here at the Woods Hole Oceanographic Institution (WHOI), hosted by the Ocean, Carbon & Biogeochemistry (OCB) Program. We are extremely grateful, not only for the venue and facilities that have been made available to us, but also for all the administrative and logistical help that the OCB staff has provided.

The aim of the IMBIZO5 is to progress the implementation of the new IMBeR Science Plan (2016-2025). The overall theme of IMBIZO5 is *Marine biosphere research for a sustainable ocean: Linking ecosystems, future states and resource management*. This will contribute to achieving the goal of the Science Plan which is to *Understand, quantify and compare the historic and present structure and functioning of linked ocean and human systems to predict and project changes including developing scenarios and options for securing or transitioning towards ocean sustainability.* The topics of the three IMBIZO5 workshops were formulated with the IMBeR Science Plan in mind, and are the initial steps towards addressing some of the Grand and Innovation Challenges that are outlined therein. The workshop presentations and discussions will provide the opportunity to synthesize current research, identify gaps that require attention and determine a way forward.

IMBIZO Format

IMBIZO5 will follow the usual format of three concurrent but interacting workshops. We begin with overview plenary presentations by Eddie Allison, Mary Ann Moran and André Punt that will provide the current state-of-the-art and future directions for each of the three workshops, respectively, and the basis for joint discussions. Then we divide into the three workshops. Participants remain in their assigned workshop for the duration of the IMBIZO. The topics of the three workshops are:

1. Critical constraints on future projections of marine systems (conveners: Laurent Bopp and Eric Galbraith)
2. Metabolic diversity and evolution in marine biogeochemical cycling and ocean ecosystem processes (conveners: Gerhard Herndl and Tatiana Rynearson)
3. Management Strategy Evaluation: Achieving transparency in natural resource management by quantitatively bridging social and natural science uncertainties (conveners: Gavin Fay, Ingrid van Putten and Cisco Werner)

On Wednesday we will reconvene for a fourth keynote address, when David VanderZwaag will link the three workshop topics and consider how science is being integrated, or not, into various governance sectors.

IMBIZO5 at a glance

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Keynote speakers

We have four distinguished keynote speakers!
Eddie Allison, Mary Ann Moran and André Punt will present the state of research and future directions for each of the three workshops. Then, David VanderZwaag has the unenviable task of linking the research and future directions for all three topics covered by the IMBIZO5 workshops!

Eddie Allison will give the first keynote talk for the ***Critical Constraints on Future Projections of Marine Systems*** workshop.

Eddie is a Professor in the College of the Environment at the University of Washington, Seattle, WA, USA. He is an interdisciplinary marine scientist with interests in coastal and marine social-ecological systems, particularly small-scale fisheries. His research centers on the human connection to natural resources, and is often closely linked to policy or management and development practice and spans scales from global meta-analysis, through national policy analysis to local-site case-studies. 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 resources.

Conceptually, his work is informed by scholarship in social-ecological systems and sustainability science, development studies and political ecology. Eddie has worked mainly in tropical areas of Africa, South and South East Asia, and has also been part of projects in the UK, Latin America, Oceania and more recently in the Pacific North West.

Keynote speakers

Mary Ann Moran is the keynote speaker for the workshop dealing with ***Metabolic diversity and evolution in marine biogeochemical cycling and ocean ecosystem processes***.

Mary Ann is a Distinguished Research Professor in the Department of Marine Sciences at the University of Georgia, Athens, GA, USA. Her research focuses on the role of bacteria in marine nutrient cycles. By focusing on the genetic and ecological underpinnings of bacterial sulfur and carbon cycling in the ocean, she aims to understand the role of marine bacteria in the productivity of the ocean and the formation and flux of climatically active gases. She uses molecular microbial ecology and ecological genomics approaches to explore bacterial processes and their regulation.

Mary Ann is a fellow of the American Association for the Advancement of Science and the American Academy of Microbiology.

André Punt will give the keynote address for the ***Management Strategy Evaluation*** workshop.

André is the Director of the School of Aquatic and Fishery Sciences at the University Washington, Seattle, WA, USA. His research relates broadly to the development and application of fisheries stock assessment techniques, bioeconomic modelling, and evaluating the performance of stock assessment methods and harvest control rules using the Management Strategy Evaluation approach. His research group, Marine Population and Management (MPAM), is involved in the development and application of management strategy evaluation (MSE) methods, focusing on specifying and parameterizing the operating models used as the basis for MSE. They are exploring the best ways to manage marine populations, from small pelagic species, groundfishes, rock lobsters to cetaceans, in the face of changing societal goals, climate change, ocean acidification, and the lack of data which is typical of the marine environment. Their results are used to inform management decision making in the USA and Australia, as well as international marine management bodies such as regional fisheries management organizations and the International Whaling Commission. Dr. Punt has been involved in stock assessment and fisheries management for over 30 years and has been recognized for his contributions in this area with awards from CSIRO, the University of Washington, the Australian Society for Fish Biology, and the American Fisheries Society.

David VanderZwaag will give a keynote address linking the three workshops - going on a quest for good governance in marine biosphere research.

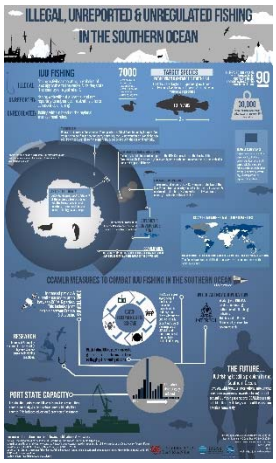
David is Professor of Law and holds the Canada Research Chair (Tier 1) in Ocean Law and Governance at the Marine & Environmental Law Institute, Dalhousie University, Halifax, Canada. He teaches international environmental law and is the past Co-director of Dalhousie's interdisciplinary Marine Affairs Program (1986-1991). He serves as the Associate Director of the Marine & Environmental Law Institute. His research covers a wide range of topics in the field of international ocean law and governance including: aquaculture regulation; fisheries management; marine species at risk; maritime boundary delimitation; transboundary cooperation; Arctic law of the sea; Canada-US ocean relations and principled oceans governance.

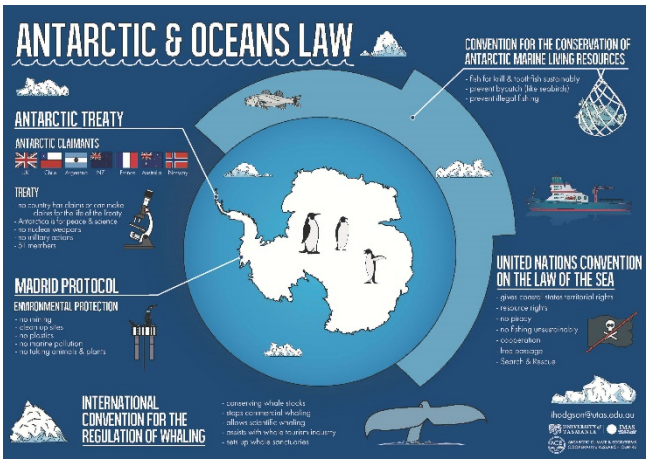
David is currently a member of the IUCN's World Commission on Environmental Law (WCEL) and Co-chair of the WCEL's Specialist Group on Oceans, Coasts & Coral Reefs. He is an elected member of the International Council of Environmental Law. He serves on the editorial boards of various journals including *Ocean & Coastal Management, Marine Policy*, *Ocean Yearbook* and *The Yearbook of Polar Law*. He is a member of several research teams including: the Marine Environmental Observation Prediction and Response Network (MEOPAR), "Governance Challenges and Responses to Ocean Acidification"; and the *OceanCanada* Partnership, "Law and Policy Working Group."

Infographics workshop

Sunday 1 October from 10:00 – 16:00

Indi Hodgson-Johnston from the Integrated Marine Observing System (IMOS) at the University of Tasmania, Hobart, Tasmania is the convener of the Infographics workshop – a bonus workshop for all interested IMBIZO5 participants!





Infographics are a popular and effective way of communicating your research. From data visualisation to explaining a methodology, infographics assist in visually explaining and sharing complex scientific research to a broad audience.

This workshop intends to teach you the basics of infographic creation. It will take you through the initial steps of your research story, by defining who your audience is and what you want to tell them.

The next step identifies your 'factoids', the little snippets of information that tell a greater and engaging story, and hones the information into simple and clear language. Then the design process begins!

Using software of your choice (e.g. Adobe Illustrator, Inkscape, Powerpoint), we will cover concepts such as effective data visualisation, illustrations vs diagrams, basic graphic design concepts, fonts, citations, where to source graphics, basic image creation and so on. These skills have applications beyond infographics, and include conference posters and presentation slides.

Finally, we will cover the communication aspect. This will explain the best ways of communicating your design, through social media, internal communications, and presentations.

Follow up support from Indi will be available following the workshop!

Sponsors

IMBeR is extremely grateful to all our sponsors who have made IMBIZO5 possible.

Institute of Marine Research (IMR)

IMR is Norway's largest centre of marine science. Its main task is to provide advice to Norwegian authorities on aquaculture and the ecosystems of the Barents Sea, the Norwegian Sea, the North Sea and the coastal zone. The aim of the research and management advice provided by IMR is to ensure that Norway's marine resources are harvested in a sustainable way. The IMBeR International Project Office is hosted by IMR at its headquarters in Bergen.

State Key Laboratory of Estuarine and Coastal Research (SKLEC)

East China Normal University (ECNU), Shanghai, China hosts and treasures the well-known State Key Laboratory of Estuarine and Coastal Research (SKLEC). SKLEC has a long history of research and training in estuarine and coastal sciences and their applications. The research focuses mainly in three core areas: (1) estuarine evolution and sedimentation dynamics; (2) coastal dynamic geomorphology and dynamic sedimentary processes; and (3) estuarine and coastal ecology and environment. With the establishment of the School of Marine Science in October 2016, SKLEC will move further into the oceanography field, and will dedicate its research and education to advancing the science and technologies in observing, understanding and predicting shelf seas and oceans.

Asia-Pacific Network for Global Change Research (APN)

APN is a network of member country governments that promotes global change research in the region, increases developing country involvement in that research, and strengthens interactions between the science community and policy makers.

Korean Institute of Ocean Science and Technology (KIOST)

KIOST (previously KORDI - Korea Ocean Research & Development Institute), is the only comprehensive ocean research organization in Korea and has led the development of marine science and technology within the nation. Since its establishment in 1973, it has played a pivotal role in improving Korea's focus on the development and promotion of marine knowledge, exploitation of marine resources, and preservation of marine environment, and thus utilize potentials in ocean for the future of Korea.

Sponsors

National Oceanic and Atmospheric Administration (NOAA)

NOAA is an agency that enriches life through science. Its reach goes from the surface of the sun to the depths of the ocean floor as we work to keep citizens informed of the changing environment around them.
From daily weather forecasts, severe storm warnings, and climate monitoring to fisheries management, coastal restoration and supporting marine commerce, NOAA's products and services support economic vitality and affect more than one-third of America's gross domestic product.
NOAA's dedicated scientists use cutting-edge research and high-tech instrumentation to provide citizens, planners, emergency managers and other decision makers with reliable information they need when they need it.

Ocean Carbon & Biogeochemistry (OCB)

The US-based OCB program focuses on the ocean's role as a component of the global Earth system, bringing together research in geochemistry, ocean physics, and ecology that inform on and advance our understanding of ocean biogeochemistry. The overall program goals are to promote, plan, and coordinate collaborative, multidisciplinary research opportunities within the U.S. research community and with international partners.
The OCB is supported by the NSF and NASA in the USA.

North Pacific Marine Science Organization (PICES)

PICES is an intergovernmental scientific organisation that aims to promote and coordinate marine research in the northern North Pacific and adjacent seas (particularly northwards of 30°N). It is mandated to advance scientific knowledge about the ocean environment, global weather and climate change, living resources and their ecosystems, and the impacts of human activities. Present members are Canada, People's Republic of China, Japan, Republic of Korea, Russian Federation, and the United States of America.

Scientific Committee on Oceanic Research (SCOR)

Formed by the International Council for Science (ICSU) in 1957, SCOR is an interdisciplinary body whose activities promote international cooperation in planning and conducting oceanographic research, and solving methodological and conceptual problems that hinder research. SCOR provides a mechanism to bring together international scientists and has thus been instrumental in the planning and coordination of several large-scale ocean research projects for long-term, complex activities.

Meeting logistics

The venue

IMBIZO5 will be held in the Clark building (306-5 Woods Hole Road) on the Quissett Campus of the Woods Hole Oceanographic Institution.

Plenary sessions will all be in the Clark 507 auditorium,

The three workshops will be held in the following rooms:

1. Workshop 1. Critical constraints: Carriage House
2. Workshop 2. Metabolic diversity: Clark 509
3. Workshop 3. Management strategy evaluation: Clark 507

Poster session

The poster session will follow directly after the close of the workshops on Monday 2 October. Please put your poster up before 4pm on Monday.

Mentoring programme

As part of the IMBIZO5 mentoring programme, students and early-career researchers who requested a mentor when they registered for the IMBIZO, were matched with more established researchers working in a similar field. Mentors provide advice on research ideas, assist with fine-tuning conference presentations, and most importantly help with networking at the IMBIZO.

There will be a "lunch with scientists" on Wednesday, where tables will be reserved so that two or three established researchers can sit with some of the students and early career researchers that they don´t know or are interested in speaking to. This will help everyone to broaden their network a little more. Let Lisa know if you are keen to join us!

IMBIZO dinner

The IMBIZO dinner is kindly sponsored by the Korea Institute of Science and Technology (KIOST) and everyone is welcome to attend. If you would like to bring a guest, please let Lisa before 5pm on Monday.

The dinner will be held in the big tent.

Workshop 1: Critical Constraints on Projections

Workshop 1: Critical Constraints on Future Projections of Marine Systems		
Day 1 Monday 2 October		
Time	**Speaker**	**Title**
09:00 - 09:45	**Welcome to IMBIZO5!**	
09:45 -10:30	**Eddie Allison**	**Keynote address for Critical Constraints workshop**
10:30 -11:00	***Morning Tea***	
11:00 -11:45	**Mary Ann Moran**	**Keynote address for Metabolic Diversity workshop**
12:00 -12:45	**André Punt**	**Keynote address for MSE workshop**
12:45-14:00	***Lunch***	
14:00-14:30	Quick briefing on objectives	
14:30-15:30	Speed talks	
15:30-16:00	***Afternoon tea***	
16:00-17:00	Speed talks (continued)	
17:00-20:00	**Poster session**	

Day 2 Tuesday 3 October		
Time	**Speaker**	**Title**
9:00-9:45	Mapping the global change – marine ecosystem grand challenge	
9:45-10:30	Confronting maps	
10:30-11:00	***Morning Tea***	
	Session 1 : Climate related stressors and response of ecosystems	
11:00-11:20	Yohei Takano	The role of decadal climate variability on changes in oceanic dissolved oxygen in the Pacific Ocean: perspectives from large ensemble simulations
11:20-11:40	Lester Kwiatkowski	Emergent constraints on projections of declining primary production in the tropical oceans
11:40-12:00	Charles Stock	The potential for large changes in regional fisheries catch under climate change
12:00-12:20	Andrew Yool	Future trends in seafloor community biomass in a global, body size-resolved model
12:20-12:45	Additional talks and discussion	
12:45-14:00	***Lunch***	
14:00-15:30	Session 1 (continued)	
15:30-16:00	***Afternoon tea***	
16:00-18:00	**Cross-workshop 'sticky note' activity**	

Workshop 1: Critical Constraints on Projections

Day 3 Wednesday 4 October		
Time	**Speaker**	**Title**
9:00 -10:00	**David VanderZwaag**	**Cross-workshop Keynote address**
10:00-10:30	***Morning Tea***	
	Session 2 : Other stressors and response of ecosystems	
10:30-10:50	Anne Hayden	Multi-scale hierarchies in socio-ecological systems: a challenge for predicting fisheries outcomes
10:50-11:10	Jerome Guiet	New satellite-based constraints on the seasonality of global fishing effort
11:10-11:30	Francisco Bravo	Environmental carrying capacity at marine fish-farm sites: model predictions and uncertainty in management systems
11:30-11:50	Brian von Herzen	Marine permaculture to restore ocean productivity
11:50-12:45	Additional talks and discussion	
12:45-14:00	***Lunch***	
14:00-15:30	(Working groups): Potential products / data constraints	
15:30-16:00	***Afternoon tea***	
16:00-17:00	**Debate**	
After debate	**Pre-dinner drinks and then the IMBIZO5 dinner**	

Day 4 Thursday 5 October		
Time	**Speaker**	**Title**
9:00 -9:30	Update on progress from the working groups	
9:30-10:45	(Working groups): (continued)	
10:30-11:00	***Morning Tea***	
11:00 -12:45	Debriefing from the working groups	
12:45-14:00	***Lunch***	
14:00-15:00	**Summary from the workshops (Infographic and oral presentations)**	
15:00-15:30	***Closing ceremony***	

Alphabetized by the presenters' last name

CONCEPTUALIZING UNCERTAINTIES IN THE MARINE DOMAIN UNDER THE IMPACT OF MULTI-DRIVERS

Ardelan M.V., Tsagaraki T.M., Tiller R., Bailey J., Thorpe R.B., Thingstad T.F., de Kok, J-L., Bizsel. K.C., Öztürk P., Marsi E., Turner D., Iriarte J. L., Salgado H., Vadstein O., Olsen Y.

While realistic scenarios considering the combined effects of multi drivers (physical, chemical and biological) are needed, the more pragmatic approach eliminates the drivers or stressors to the single level by forced simplification. At the same time, in a real world natural variability and complexities have been translated as "uncertainty".

Before estimating and evaluating uncertainties in the marine environment under the effects of multi-drivers (or multi-stressors), we have a challenge to conceptualize the uncertainty in the spectrum of natural reality and political pragmatism in the socio-ecology. Ocean Certain, dealing with combined effects of multi drivers on microbial food web experimentally, through a set of mesocosm and microcosm experiments in different regions and attempts to extrapolate outcomes of the experimental results and other relevant data from natural science into policy making domain. Natural variability in the responses of the marine ecosystem to multi stressors are fundamentally due to temporal and spatial complexities, and interactions of stressors should carefully separated to uncertainty. To be able to do this conceptualizing of uncertainties is an urgent task which is addressed in Ocean Certain.

During the ongoing project OCEAN-CERTAIN we attempt to understand some of the implications of change concurrently with connecting them to society. We utilize a modelling approach in conjunction with experimental results to explore the mechanisms through which we can connect food web structure and export to zooplankton and microzooplankton standing stock. In the current approach we take a step back and do not consider specific environmental stressors, rather how changes in the food web structure, regardless of origin, can influence ecosystem functioning. At the same time we challenge our perceptions on interpreting disturbance in marine ecosystems and communicating the connections between drivers and feedbacks, since these ecosystems do not fall within political boundaries and no single feedback is uniform.

Oral presentation

SARDINELLA AURITA GROWTH PARAMETERS VARIABILITY UNDER THE BALANCED EFFECTS OF CLIMATE CHANGE AND FISHING PRESSURE

Baldé B.S., Sow F.N., Thiaw M., Ba K., Ekau W., Kantoussan J., Fall M., Diouf M., Brehmer P.

Sardinella aurita is an overexploited small pelagic fish and a key species in Senegal at socioeconomics level, nevertheless the growth parameters which is a good indicator of fish stressors, have not been updated since 30 years. In this work, we analyzed *S. aurita* (n = 32 300) age and growth in Senegal taking into account the tropical seasonality. Growth parameters are then compared with those previously obtained in the literature on the same geographical area (since 60 to 34 years) and more widely in different locations in tropical North Atlantic and Mediterranean Sea. The results show a significant difference of growth parameters in Senegal since thirty years, indeed growth of *S. aurita* became slower and its maximum size has significantly decreased. The comparison of *S. aurita* variability in growth performance reported in Mauritania-Senegal coast, as well as in Mediterranean Sea and Eastern/Western Atlantic Ocean reveals a significant influence of environmental parameters and/or the level of exploitation. In one hand in tropical Atlantic, *S. aurita* growth in Atlantic Eastern Central is similar to the one reported in Atlantic Western Central, while *S. aurita* growth is rather slow in Mediterranean Sea where, vs tropical Atlantic, Sea temperature and prey availability are lower. On the other hand, in the Atlantic Western Central, where the fishing pressure is lower over the last decade vs Atlantic Eastern Central, an increase in asymptotic length is observed. However, in the Mediterranean Sea and Atlantic Eastern Central, where the fishing pressure is high, the asymptotic length has drastically decreased. We assume that the fishing pressure and the climate change, or a combination of both, have an effect on the biological parameters of *S. aurita*.

Oral presentation

GLOBAL CONSTRAINTS ON THE BIOMASS AND BIOGEOCHEMICAL ROLE OF FISH IN THE OCEAN

Bianchi D., Galbraith E.D., Carozza D.A.

Following the development of industrial fisheries, humans have dramatically altered fish biomass in the ocean, with consequences for ecosystems and biogeochemistry that are yet to be explored. Here, we use a global ecologic-economic model to reconstruct the trajectory of commercial fish biomass in the ocean, from a pristine state to the current depletion, and estimate the associated changes in global fish metabolic rates and biogeochemical cycling. Using harvest and stock-assessment observations at the scale of large marine ecosystems, we optimize a large ensemble of model simulations against observations, simultaneously reducing the uncertainty in model parameters and projections. The optimized ensemble suggests a global pristine biomass of commercial fish of ~5Gt, which collectively processed biomass and energy at a rate of ~2Gt/year, corresponding to 3.5% of the available net primary production. At peak harvest, the global biomass is reduced to between 1/3 and 1/2 of the pristine levels, and the biomass cycling rate declines by approximately 25%. Most of this reduction takes place in productive waters, where the impacts of fishing are higher, and involves larger individuals in the fish size spectrum. Our approach provides a novel baseline for understanding the role of fish and other consumers in marine ecosystems and biogeochemistry, and the degree of their depletion by human activities.

Oral presentation

ENVIRONMENTAL CARRYING CAPACITY AT MARINE FISH-FARM SITES: MODEL PREDICTIONS AND UNCERTAINTY IN MANAGEMENT SYSTEMS

Bravo F., Grant J.

Finfish aquaculture is one of fastest growing industries in coastal areas around the world. The significant expansion of their operations have led to multiple socio-economic and environmental interactions (positives and negatives). These interactions are expected to continue increasing as aquaculture attempts to meet the global seafood demand, and the decline and stagnation of wild catches.

In this regard, successful environmental management of marine fish farms requires careful consideration of environmental interactions with benthic and pelagic compartments (e.g. untreated wastes, toxic chemicals, mass escapes, HABs, etc.). This implies maintaining production levels within the system's capacity, despite uncertainties in management systems and environmental conditions.

Statistical and dynamical models have arisen as valuable tools to interpret observations in terms of causal factors, as well as for interpolation, extrapolation and budgeting of the studied process. More recently, they have also been applied as management tools, promoting the implementation of anticipatory rather than reactive management strategies.

Among near-field interactions, the eutrophication of fish farm sediments due to deposition of organic wastes (feces, uneaten feed) represents a major factor controlling productive capacity, environmental quality, and social licences to operate. The combination of diagenetic modeling, scenario analysis, and optimization techniques provides a valuable tool to predict ecosystem response, sustainable operation levels, and the recovery of degraded environments.

In this study, the predictive value of model results from both an ecological and management stand-point is discussed. Model uncertainty (forcing, formulation, and parameterization) is contrasted with the current level of uncertainty in decision-making processes related to aquaculture environmental management.

Keywords: Finfish aquaculture; numerical model; environment – aquaculture interactions, eutrophication

Oral presentation

ROLE OF BIOLOGICAL FLEXIBILITY FOR SIMULATING AND STABILISING THE OCEANIC NITROGEN AND CARBON CYCLES

Buchanan P.J., Matear R.J., Chase Z., Phipps S.J., Bindoff N.L.

Biogeochemical properties of the ocean, particularly the store of carbon, exert a strong influence on the climate by modulating the biogeochemical properties of the atmosphere. In turn, the biogeochemical properties of the ocean are dependent on numerous physical and biological processes that interact and change over space and time. Accurately representing these background processes within a model is therefore fundamental for accurately simulating the ocean's role within the climate. However, our mechanistic understanding of important physical and biological processes remains incomplete, and their representation in ocean models is consequently uncertain. With this uncertainty in mind, we combined 6 different physical realisations with 6 different biogeochemical parameterisations (36 unique ocean states) within one Ocean General Circulation Model, and investigated the sensitivity of ocean biogeochemistry to varying physical and biological conditions. In decreasing order of sensitivity, we found that oxygen, apparent oxygen utilisation, carbon, alkalinity and phosphate fields are more sensitive to changes in the ocean's physical state than biology. Only nitrate (NO3) is more sensitive to changes in biological functioning. By exploiting the sensitivity of NO3 to biology, we found that a biogeochemical model that varied the production, remineralisation and composition of organic matter according to changes in the environment was superior to a biogeochemical model where these processes are fixed. Flexibility in biological processes also reduced differences between physical states. The range in carbon and nitrogen inventories decreased by 50 and 20 %, respectively, despite a wide spread of circulations. We therefore find that (1) NO3 is suitable for the assessment of ocean biogeochemical models irrespective of uncertainty in the physical state, (2) incorporating flexibility in biological functioning improves simulated biogeochemical fields, and (3) accounting for such flexibility builds resilience to climate-related changes in the ocean's physical state.

Oral presentation

HOW ECOSYSTEM-LEVEL FISHING HISTORIES CAN DRIVE SYSTEMATIC BIASES IN SINGLE-SPECIES REFERENCE POINTS

Burgess M.G., Szuwalski C.S., Urbisci L.

Most fisheries are still assessed and managed using single-species models, despite frequent calls for transitions to more holistic ecosystem-based approaches. Determining in which types of fisheries single-species approaches are likely to face the greatest challenges is important to prioritizing investments in such transitions. Theory suggests that single-species models can sometimes accurately predict fishery reference points—despite their structural naivety—because single-species models are fit to data produced by the ecosystem context. This allows key information about the ecosystem's effects on the focal stock to be stored in parameter estimates. However, fishery reference points from single-species models can be substantially biased when species or abiotic factors closely related to the focal stock have historical trends that are correlated with trends in the focal stock's abundance, for reasons other than their ecological coupling. While this type of bias can arise for a variety of anthropogenic and non-anthropogenic reasons, here we focus specifically on the role of ecosystem-level fishing histories. We show how coincident trends in fishing pressure among multiple interacting fish stocks can create systematic biases in their single-species reference points. For instance, our theory suggests that fishing through the food web—developing fisheries on predators and prey sequentially—is likely to lead to large positive biases in estimates of the maximum sustainable yields (MSY) of all stocks. We compare our theory to recent empirical studies projecting MSY using single-species and ecosystem models, finding support for our theory.

Oral presentation

ON THE IMPACT OF IMPLEMENTING HIGHER TROPHIC LEVELS INTO NPZD MODELLING APPROACHES: AN EXAMPLE FROM THE NORTH SEA AND BALTIC SEA ECOSYSTEM

Daewel U., Schrum C.

The majorities of marine ecosystem models target only parts of the trophic food chain. This implicates difficulties to consistently simulate the major controls of marine ecosystems and to distinguish between 'bottom-up', 'top-down' or 'wasp-waist' controlled ecosystems. While one solution to this deficit is to couple specific models for the different trophic levels into an interlinked model approach, another approach would be enhancing the existing ecosystem models consistently by defining functional groups for higher trophic level similarly to those for lower trophic levels. The latter would solve the requirements for closing the lower trophic food chain and hence could be used to address questions on spatial and temporal variations of 'top-down' impacts on lower trophic level dynamics, while it further allows estimates of fish production potential. Here we present such an NPZD-Fish modelling approach that bases on the fully coupled biological-physical ecosystem model ECOSMO II. The model represents both fish and macrobenthos as functional groups that are linked to the lower trophic levels via predator-prey relationships.

To understand the role of fish and macrobenthos in this model, especially for long term variations in the ecosystem, we will perform a 68 year long (1948-2015) hindcast simulations for the coupled North Sea and Baltic Sea ecosystem and analyse and discuss the relevance of the implemented higher trophic levels for long term changes in lower trophic level productivity and nutrient availability in the system. The long-term model integration together with sensitivity studies on critical model parameters and assumptions, e.g. the model closure through fisheries and apex predators, entails conclusions on the development needs for consistent functional type "End-to-End" modelling approaches.

Oral presentation

THE EFFECT OF CLIMATE CHANGE ON SEABIRD COMMUNITIES- A RETROSPECTION TO PAST, PRESENT AND FUTURE

Das A.

Although birds are highly mobile, many are restricted to specific habitats and can be important indicators of the condition of those habitats. As climate change modifies the distribution of specialized habitats, it influences the distribution of entire communities of birds. Some communities might find new opportunities as habitats on which they rely become more abundant, other communities might become increasingly rare as the habitats on which they rely become limited in extent. These climate-mediated changes in the abundance and distribution of birds in specialized habitats could be of grave concern for the conservation of rare species. Three search engines were used to collect review of literature on the research on the climate change and birds. The Web of Science from Science Citation Index was searched from 1980 to the present, Biological Abstracts from 1980 to 2017 and Google Scholar in 'Biology, Life Sciences and Environmental Sciences' subject area, with keywords 'birds' and 'climate change' up to 18 May 2017.

The main objectives of the study was to a) illustrate patterns in geographical and latitudinal shifts of selected sea bird communities in temperate and tropical habitats, b) model the influence of climate change on conservation of select species, and c) translate individual species trajectories into a comparative assessment of ecological condition.

The study specifically permitted to test the following hypotheses: a) increase in global temperatures tends to shift species distributions toward relatively colder microclimates, and b) owing to higher species diversity in the tropics, the indirect impacts of climate change through biotic factors (food plants, natural enemies, competitors, guild companions) were more pronounced than in relatively simpler temperate communities. The comparison of temperate and tropical habitats was an important strength of this study.

Oral presentation

DEVELOPMENT OF A NEW GENERALIZABLE SOCIAL-ECOLOGICAL SYSTEMS MODEL EMPHASIZING HUMAN DIMENSIONS OF FISHERIES MANAGEMENT: THE POSEIDON FRAMEWORK

Drexler M., Carella E., Saul S., Marshall K., Bailey R.M., Burgess M.G., Madsen J., Gruss A., Dorsett C., Clemence-McCann M., Cabral R., Axtell R.L., Merkl, A.

Fisheries are complex, coupled social-ecological systems. The behavioral and social responses of individual and groups of fishers to fisheries management interventions remain a critical knowledge gap in developing effective (sustainable and tolerable) management solutions globally. Management and implementation uncertainty can dramatically undermine an adaptive management paradigm. Therefore, research to understand and forecast human systems are needed, but hypothesis-driven, controlled experiments are difficult or impossible to conduct in complex systems like fisheries.

Agent-based models (ABMs) are well suited to address these challenges in the human system; they capture the motives of individual actors in the system but emphasize the emergent, group-level, properties which are relevant to management. Because these models focus on the above-the-water elements of the fishery, data collection schemes can focus on more accessible datasets, from simple interview data to spatial fishing data. We demonstrate the capability and utility of ABMs to incorporate cognitive and behavioral sciences into fisheries management – from data collection through full-system management strategy evaluations – in abstract and real world settings from the Gulf of Mexico and West Coast of the U.S.

Our ABM experiments indicate that agent-based modeling approaches hold much promise for directly incorporating social and economic considerations in fisheries management. A mechanistic approach to simulating human dimensions coupled with machine learning may allow for further improvements to data poor fisheries management by alleviating the need for deep biological knowledge and instead emphasizing economic and cultural indicators.

Oral presentation

UNCERTAINTY IN MARINE ECOSYSTEM MODEL CLIMATE PROJECTIONS FOR FISH & FISHERIES

Eddy T.D., Cheung W.W.L., Galbraith E.D., Lotze H.K., Tittensor D.T.

The Fisheries and Marine Ecosystem Model Intercomparison Project (FISH-MIP) is a network of more than 40 global and regional marine ecosystem modellers from around the world.

Our Goal: Bringing together disparate marine ecosystem models to better understand and forecast the long-term impacts of climate change on fisheries and marine ecosystems.

Our Questions: What is the future of:

- Fish and fisheries?
- Seafood supply?
- Marine biodiversity?
- Marine ecosystem functioning?

Our Approach: We use earth-system models (ESMs) and emission scenarios (RCPs) with shared socioeconomic pathways (SSPs) based on human population growth and GDP - but with some adaptations to represent future fishing scenarios in the ocean.

Our Challenges: Marine ecosystem models use very different basic structures to represent food-web or ecosystem components and the links between them. Ecosystem components can be represented by size classes, functional groups, trophic levels, species groups, and life-history stages, whereas links can be represented by who-eats-whom networks, diet composition or energy transfer. Another challenge is that our models do not all use the same input and output variables. Finally, there are limited observational data for historical runs and model validation, and limited data on spatially resolved fishing effort.

Our Choices: The FISH-MIP simulation protocol represents the choices we have made in order to compare as many global and regional models as possible. These include common inputs with respect to climate, physical and chemical data (temperature, currents, salinity, pH, oxygen), biological data (e.g. primary production, phytoplankton, and zooplankton), and fisheries data (effort, catch, fisheries mortality) as well as common outputs including fish biomass and catch as well as other ecosystem parameters.

In this talk, we will explore FISH-MIP results with respect to historical calibration, sources of uncertainty, and problems of scale for regional and global models.

Oral presentation

THRESHOLDS OF PLANKTON COMMUNITY CHANGE IN A MEDITERRANEAN COASTAL AREA: RESULTS FROM A LONG-TERM (1979-2014) TIME SERIES

Goffart A., Collignon A., Lejeune P., Hecq J.H.

In the Mediterranean Sea, which has been identified as a hotspot for climate change, there is evidence for impacts of climate change on marine organisms. However, the lack of information on environmental drivers and associated thresholds limits our ability to forecast possible changes in biodiversity and ecological interactions.

In this presentation, we use a unique long-term (1979-2014) time series performed in a Mediterranean coastal area unbiased by local anthropogenic pressure (PHYTOCLY station, Bay of Calvi, Corsica) to understand how climate variation controls phyto- and zooplankton dynamics and possibly affect artisanal and small-scale fisheries exploiting areas near the coast.

From high-frequency field data, we describe a mechanism that links winter physics, nutrient replenishment of the surface layer and plankton dynamics under the different combinations of meteorological conditions that occurred during the 36 years of observations. We identify threshold values of physical variables below and above which they strongly impact nutrient availability, phyto- and zooplankton bloom characteristics and seasonality succession of plankton functional groups. We provide identification of environmental thresholds beyond which diatoms, which are crucial for sustaining fish populations, collapse. We discuss links between climate-related changes in plankton availability, fish recruitment and the success of small-scale fisheries. We show that the mechanism we identified from the 1979 to 2014 period of observation in the Bay of Calvi is pertinent to other Northwestern Mediterranean areas, stressing the importance of winter conditions in determining the state of Mediterranean pelagic ecosystems.

We highlight that the thresholds obtained from our long-term time series provide key information for improving model scenarios of the impact of climate change on Mediterranean ecosystems.

Oral presentation

TRACKING HARMFUL ALGAL BLOOM (HABS) AT PORT BLAIR BAY, ANDAMAN ISLANDS: COUPLING IN SITU ANALYSIS AND GIS APPLICATION

Goswami P., Gupta S., Das A.K., Vinithkumar N.V., Dharani G., Kirubagaran R.

The Andaman and Nicobar Islands (A & N), India comprises of diverse pristine terrestrial and marine ecosystems like mangrove, evergreen rain forests etc. and these support varied group of flora and fauna. Port Blair city is the capital of A & N Islands and congregate major share of the total population. Increasing anthropogenic pressure in this city cause deterioration of coastal water quality and increasing the risk of harmful algal bloom (HABs) occurrences. An intense heterotrophic dinoflagellate bloom caused by *Protoperidinium pellucidum* was observed at Port Blair Bay, South Andaman Island during May, 2016. The bloom appeared during a relatively high sea surface temperature (SST> 34°C) condition with seawater salinity > 33 psu. We investigated the impact of this bloom on the water quality and plankton community structure. Obtained data were plotted with ArcGIS 10 to visualize the temporal changes in the bloom dynamics. A considerable increase in silicate concentration was observed that coincided with lack of diatom growth during the bloom phase. Similarly, high level of ammonia was recorded during post-bloom phase, associated with anaerobic decomposition of dead bloom biomass. *P. pellucidum* population density increased from 20 cells l-1 (pre-bloom) to 3.36 x 106 cells l-1 (bloom) and contributed up to 99.93% of total phytoplankton community. Both phytoplankton and microzooplankton communities were affected greatly as the dinoflagellate grazed on the micro-diatom and smaller tintinnids, resulted significant decrease in their abundance. Cyclopoid copepod *Oithona* spp. responded positively to the *P. pellucidum* population and subsequently caused considerable reduction in their abundance during post-bloom phase. This bloom was resulted as a response of micro-diatom dominance during pre-bloom phase coupled with high temperature conditions. Further, long-term studies are being carried out to monitor and predict such HAB occurrences in future in this ecologically sensitive zone.

Poster presentation

NEW SATELLITE-BASED CONSTRAINTS ON THE SEASONALITY OF GLOBAL FISHING EFFORT

Guiet J., Galbraith E.D.

Fishing effort is determined in part by the influence of the ocean state on habitat, metabolism and behavior of fish populations, or determined by human related constraints such as fish demand, cost of fishing or stock management. Both natural and human factors can have seasonal aspects, which may play a role in determining the mean state and influencing the response of global fishing effort to change.

We provide a first glimpse of seasonality in global fishing effort using Automatic Identification System (AIS) - derived fishing patterns, recently generated by the Global Fishing Watch project. This dataset provides an estimate of the daily spatial distribution of fishing effort in the global ocean, differentiated by nationality and fishing gear type, for all vessels equipped with AIS.

When summed at global scale, the observed fishing effort seasonality is dominated by the summertime closure of the Chinese fishery, a management measure. But when disaggregated by fishing gear type, different sensitivities to seasonality appear, which are unlikely to be related to management. For instance, while trawler fisheries invest a constant effort yearly on high latitude continental shelves, squid jiggers fisheries invest their effort in few spring months in the Peru upwelling. Moreover, yearly constant global fishing efforts hide spatial seasonal variabilities. For instance, while regions exploited by trawler fisheries remain subject to constant efforts, fisheries using drifting gears show strong seasonality of target regions despite a constant cumulative effort.

We use a global bioeconomic model forced by seasonal cycles of primary production and temperature in order to identify the drivers of these variabilities. The metabolically-constrained model suggests that the seasonal variation of fish production has only a small impact on the seasonality of fishing effort. Rather, we suggest that the bulk of non-management imposed seasonality reflects the effect of fish behaviour on catchability.

Oral presentation

MULTI-SCALE HIERARCHIES IN SOCIO-ECOLOGICAL SYSTEMS: A CHALLENGE FOR PREDICTING FISHERIES OUTCOMES

Hayden A.

Fisheries are hierarchically organized, socio-ecological systems. The complex dynamics, including cross-scale interactions, within such systems generate emergent properties that present challenges for predictive modelling. Applying complex adaptive systems theory to fisheries provides a framework for understanding potential trajectories of such systems.

Many, if not most, fish populations are now understood to occur as metapopulations of demographically isolated subpopulations. The multi-scale, hierarchical structure of metapopulations is a function of the complex interaction of oceanographic and ecological processes with geomorphological features that results in phenomena at a range of scales around which subpopulations organize themselves.

Fishermen organize their activity around finding and exploiting subpopulations. As landings decline, they seek less exploited subpopulations; expansion of fishing activity without constraint risks metapopulation collapse. Where fishermen are constrained from expanding their fishing activity, and under certain social circumstances, they can use the feedback from the effects of their harvesting on fine-scale subpopulations to solve the collective action dilemma represented by declining harvests.

In managed fisheries, administrative necessities of the state often constrain fisheries scientists to analysis and management of the highest levels of metapopulation hierarchies, information at the finest scale is lost. Where fisheries governance and management are scaled to reflect the levels of a metapopulation hierarchy, connecting the local knowledge of fishermen and the broad scale knowledge of fisheries scientists improves fisheries outcomes and allows for improved adaptation to fishing, climate and ecosystem impacts.

Oral presentation

COMBINING BIO-OPTICAL GLIDER OBSERVATIONS AND BIOGEOCHEMICAL MODELING TO EXAMINE POTENTIAL ROSS SEA PHYTOPLANKTON CHANGES IN THE 21ST CENTURY

Kaufman D.E., Friedrichs M.A.M., Smith W.O., Hofmann E.E., Dinniman M.S., Hemmings J.C.P.

The Ross Sea is characterized by high primary productivity in comparison to other Antarctic coastal regions and, over the next century, is expected to experience changes including warmer temperatures, reduced summer sea ice concentrations, and shallower mixed layers. To investigate the future impacts of these climatic changes on Ross Sea phytoplankton, glider observations were used in conjunction with the Model of Ecosystem Dynamics, nutrient Utilisation, Sequestration and Acidification, which was adapted for use in the Ross Sea (MEDUSA-RS) to include both solitary and colonial forms of *Phaeocystis antarctica*. Biogeochemical model parameters were explored and constrained by assimilating bio-optical glider observations with the Marine Model Optimization Testbed (MarMOT), a one-dimensional model analysis and assimilation framework. Scenario experiments were carried out using projected physical drivers for mid- and late-21st century. These future scenarios project an increase in primary productivity and proportional increase in carbon export flux over the next century. In addition, these scenarios demonstrate increases of diatom biomass with decreases of *P. antarctica* biomass in the first half of the 21st century, whereas *P. antarctica* biomass increases and diatom biomass remains relatively constant in the second half of the century. Scenarios examining the independent contributions and uncertainties of expected future changes (temperature, mixed layer depth, irradiance, and surface iron inputs from melting ice) indicate that earlier availability of low light due to reduction of sea ice early in the growing season is the primary driver of productivity increases over the next century; shallower mixed layer depths additionally contribute to changes of assemblage composition and export. This study demonstrates the effectiveness of using bio-optical observations from autonomous gliders for the development and constraint of biogeochemical model projections in the context of climate change.

Oral presentation

EMERGENT CONSTRAINTS ON PROJECTIONS OF DECLINING PRIMARY PRODUCTION IN THE TROPICAL OCEANS

Kwiatkowski L., Bopp L., Aumont O., Ciais P., Cox P.M., Laufkötter C., Li Y., Séférian R.

Marine primary production is a fundamental component of the Earth System, providing the main source of food and energy to the marine food web, and influencing the concentration of atmospheric CO_2. Earth System Model (ESM) projections of global marine primary production are highly uncertain with models projecting both increases and declines of up to 20 % by 2100. This uncertainty is predominantly driven by the sensitivity of tropical ocean primary production to climate change, with the latest ESMs suggesting 21st century tropical declines of between 1 and 30 %. Here we identify an emergent relationship between the long-term sensitivity of tropical ocean primary production to rising equatorial zone sea surface temperature (SST) and the interannual sensitivity of primary production to El Niño/Southern Oscillation (ENSO) driven SST anomalies. Satellite based observations of the ENSO sensitivity of tropical primary production are then used to constrain projections of the long-term climate impact on primary production. We estimate that tropical primary production will decline by 3±1 % per kelvin increase in equatorial zone SST. Under a business-as-usual emissions scenario this results in an 11±6 % decline in tropical marine primary production and a 6±3 % decline in global marine primary production by 2100.

Oral presentation

THE IMPACT OF DAILY WIND STRESS AND HEAT FLUXES ON THE SEASONAL VARIABILITY OF CHLOROPHYLL AND PRIMARY PRODUCTION IN THE NORTHERN MOZAMBIQUE CHANNEL (NMC)

Langa A.A.A., Calil P.H.R.

In the Northern Mozambique Channel the shallow mixed layer depth in austral summer is a consequence of strong solar heating and relatively weak wind stress. In austral winter, the mixed layer deepens to its maximum values due to strong wind stress and heat loss in the surface ocean. Chlorophyll concentrations are strongly modulated by the temporal variability of the mixed layer depth. Climatological chlorophyll data derived from MODIS and SeaWIFS shows two peaks in chlorophyll concentrations, one in austral summer and another one in austral winter. Coupled physical-biogeochemical models using climatological forcing reveal the same seasonal changes but with marked biases in terms of the spatial distribution and concentration of surface chlorophyll. In this study we test the effect of daily wind stress and net heat fluxes on the seasonal cycle of surface chlorophyll in the Mozambique Channel using a coupled physical-biogeochemical model (ROMS-PISCES). Two simulations are performed: (1) a control run using climatological, monthly forcing and (2) a run forced with daily Ocean Surface Winds and net heat fluxes were derived from CCMP (Cross-Calibrated Multi-Platform) and WHOI (Woods Hole Oceanographic Institution). The CCMP wind stress and WHOI heat flux simulations allowed the correction of the chlorophyll seasonal cycle by increasing its concentrations and primary production two-fold when compared to the control run. This rectification effect was achieved with considerable changes of subsurface physical and biogeochemical properties, such as intense nutrients uplifting into the surface layer from the base of the mixed layer in the open ocean and from upwelling in coastal regions. The use of daily CCMP and WHOI products highlight the importance of the combined effect of wind stress and heat flux in deepening the mixed layer and the associated entrainment of nutrients into surface waters to reproduce the seasonal cycle of surface chlorophyll concentrations in the Northern Mozambique Channel.

Poster presentation

THE OCEAN COLOUR CLIMATE CHANGE INITIATIVE: A GLOBAL TIME SERIES FOR USE IN CLIMATE STUDIES

Lavender S., Sathyendranath S., Brockmann C., Brotas V., Chuprin A., Ciavatta S., Bel Couto A., Grant M., Groom S., Farman A., Jackson T., Krasemann H., Mélin F., Müller D., Regner P., Steinmetz F., Swinton J., Valente A., Zühlke M. and the wider Ocean Colour Climate Change Initiative collaborators and contributors

Spectrally-resolved water-leaving radiances (or remote-sensing reflectances) and chlorophyll concentration are recognised as Essential Climate Variables by the Global Climate Observing System. Global time series datasets of these ECVs are key to studying phytoplankton dynamics at seasonal and inter-annual scales, leading to an understanding of the role of phytoplankton in marine biogeochemistry and the global carbon cycle, in addition to the marine ecosystem's response to climate variability and change. Yet, generating a long time series from ocean-colour data is not a trivial task: there are a number of algorithms to choose from, for both the atmospheric correction and product retrieval; satellites have finite life spans, so data from multiple sensors needs to be merged without introducing artifacts.

The European Space Agency's Ocean Colour Climate Change Initiative (OC-CCI) undertook this activity, with support and help from the global climate research community. An approach was adopted whereby community user requirements were gathered by consulting marine ecosystem modellers and remote sensing scientists throughout an on-going (iterative) process. The remote-sensing reflectance data are derived using the individual sensors (MERIS, MODIS-Aqua, SeaWiFS and VIIRS) covering the period from late 1997 to end of 2016, and then band-shifted and bias corrected before merging. Selected in-water algorithms are then applied to generate the products that include maps of chlorophyll concentration, inherent optical properties and the diffuse attenuation coefficient. The products are then validated against in situ observations and, furthermore, uncertainties are quantified on a pixel-by-pixel basis to facilitate applications and interpretations that are consistent with the quality of the data. The latest of these merged products have now been released as version 3.1, with each version having been downloaded and used for peer-reviewed climate research. Lessons learned are discussed, and further inputs from the broad user community are welcomed.

Oral presentation

BRIDGING THE SOCIO-ECOLOGICAL DIVIDE TO ENHANCE MARINE STEWARDSHIP

Lundquist C.J., Blackett P., Davies K.K., Fisher K.T., Hewitt J.E., Lewis N.I., Thrush S.F., Le Heron R.

A better understanding of interactions between ecological and social systems is critical to sustainable management of coastal and marine systems. Most of the changes in our oceans, including loss of biodiversity and taonga (treasured) species, the modification of seascapes, and climate change, are driven by human activities. In New Zealand, Māori and civil society are demanding a greater say in how these activities are managed, calling for new marine policy and management frameworks that recognise the non-economic benefits provided by our oceans, incorporate multiple uses, and can better cope with change. Here, we discuss collaborative socio-ecological approaches from the New Zealand "Marine Futures" programme, and the National Science Challenge "Sustainable Seas". Research initiatives include: using scenarios to explore management of cumulative effects; methods to build trust between science, government, industry and society; valuation methodologies to incorporate societal and cultural values in ocean management; quantifying and mapping of ecosystem services to provide a scientific foundation for evaluating consequences of management actions; and examining societal and industry perceptions of risk, uncertainty, and cumulative impacts that inform granting of social license. These insights will enable enhanced involvement of stakeholders (including Māori and civil society) in the development of participatory frameworks and prioritisation of science and management activities that inform decision-making.

Oral presentation

HOW ARE WE DOING AT MODELING CHANGING OCEAN ECOSYSTEMS? EARTH SYSTEM MODEL INTER-COMPARISON AND THEORETICAL APPROACHES

Marinov I., Cabre A., Smith L.

Future warming is expected to significantly alter nutrients, light and temperature, with potentially critical implications for ocean biology and the carbon cycle. We propose two separate approaches to understand and predict the behavior of ocean phytoplankton ecology with climate variability and change:

1. Model intercomparison. We analyze extensively output of 16 CMIP5 Earth System Models to identify the common mechanisms involved in projected phytoplankton biomass, productivity and carbon export changes over the 21st century (RCP8.5). For each major biome, we analyze inter-model consistency of the mechanisms, and study potential emergent constraints: e.g., can the mean "historical" state determine the biological response across models? Across biomes, we discuss decoupling between biomass, productivity and export, and present inter-model statistical significance and consistency using a novel bootstrapping technique combined with a weighting scheme based on inter-model similarity.

2. Theory. As an added complication, interaction with the environment varies among different phytoplankton size groups. For example, in nutrient-poor subtropical waters, small phytoplankton can acquire nutrients more efficiently due to their higher surface area-to-volume ratio. Conversely, in nutrient-rich waters, larger phytoplankton/diatoms dominate because of their higher intrinsic growth rates.

We analyze theoretically the biological equations behind a simple NPP model and a well-known ESM (GFDL-TOPAZ) and make analytical predictions about the relative response of two major phytoplankton size classes to climate change. We predict the existence of critical background nutrient thresholds which separate regimes where small (large) phytoplankton respond more (less) to nutrient, temperature or light changes, respectively. We focus on defining emerging relationships between (a) large phytoplankton biomass and total biomass; (b) percent large phytoplankton in the community and total biomass; (c) Chl and biomass (carbon). We test our theoretical predictions across CMIP5 models and also with observations of phytoplankton community composition from both in-situ and novel satellite color data.

Oral presentation

POPULATION DYNAMICS OF SEAGRASS CYMODOCEA NODOSA IN THE VICINITY OF VOLCANIC CO_2 SEEPS

Mishra A.K., Cabaço S., Apostolaki E., Vizzini S., Santos R.

Rising carbon dioxide (CO_2) concentrations in the atmosphere will increase the average pCO_2 level in the world oceans, which will have a knock-on effect on the marine ecosystem. Coastal seagrass communities one of the most productive marine ecosystems are predicted to benefit from the increase in CO_2 levels, but long term effects of elevated CO_2 on seagrass communities are less understood. This study investigated the population dynamics of seagrass *Cymodocea nodosa* meadows, exposed to long term elevated CO_2 at shallow volcanic vents of Milos, Paleochori islands in Greece and Vulcano in Italy, using population reconstruction techniques. Effect of elevated CO_2 was noticed on the growth, morphometry, density, biomass and age structure. Above to below ground biomass ratio of *C. nodosa* were higher at CO_2 vents than at control sites at both locations of Greece and Italy. The plastochrome interval for CO_2 vent sites of Greece were similar and different from Italy. The shoot age and shoot longevity of plants were lower at the vents than at control sites. The present recruitment (sampled year) of the seagrass was higher the long-term average recruitment of the communities near the vents. Carbon to nitrogen ratios (%DW) of *C. nodosa* were higher in leaves at CO_2 vents and lower at control. Annual leaf production was higher near the CO_2 vent sites than control. This study suggests increased production of *C. nodosa* under elevated CO_2, but other co-factors such as nutrients, trace metal toxicity must also be taken into consideration while predicting effects of future CO_2 concentrations.

Oral presentation

CONSEQUENCE OF CLIMATE STRESS ON COMMERCIAL AND ECOLOGICAL IMPORTANT FISH SPECIES OF INDIAN SUNDARBANS: PERSPECTIVE FROM METABOLIC AND REPRODUCTIVE ATTRIBUTES AND FUTURE PREDICTION OF THEIR CONSERVATION STATUS

Moniruzzaman M., Chakraborty S.B.

Mangrove estuaries of India are experiencing escalated variability of temperature, salinity. This shall jeopardize 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 future. Increase in temperature and salinity are influencing oxygen consumption rates, heat shock protein (Hsps) expressions and reproductive status of commercially exploited fishes. Chronic respiratory and reproductive stress under plausible scenarios of escalated abiotic variability was tested to predict future distribution of these two species.

Indian Sundarbans are experiencing wide salt shifts driven by stochastic events (e.g. cyclones and storm surges) and climate changes. In 2009, the severe tropical cyclone 'Aila' hit the Sundarban, inundating extensive areas with brackish water. It brought about 25.2% increases in salinity (Mitra et al., 2011). Thereby it is likely that estuarine fishes are experiencing eco-physiological stresses some of which may be related to metabolic and reproductive efficiency. These stressors have chronic effect on their abundance and distribution in longer terms.

Salinity, temperature variability of Sundarban estuaries have reached to an unprecedented level. Such climatic stress is correlated with reproductive performance in fish. We hypothesized earlier that change in temperature and salinity affects the reproductive efficiency and abundance of estuarine fish. Internationally there is no comprehensive understanding of molecular dynamics of metabolic and reproductive stress when subjected to simultaneous salinity, temperature changes. Speculation is salinity and temperature act antagonistic to each other to suppress a liner signature possibly because non-linearity reigns. Finally we observed that fish, experiencing simultaneous salinity and temperatures changes its respiratory stress which were cross validated from oxygen consumption rates, Hsp expression & evolutionary conserved signal molecule regulating reproductive potency and survival. This is because oxygen consumption rates, signal proteins & Hsp expression patterns are co-linear.

Oral presentation

DEVELOPING USEFUL PROJECTIONS FOR SOUTHERN OCEAN ECOSYSTEMS

Murphy E.J., Cavanagh R.D., Hofmann E.E., Johnston N.M., Bracegirdle T.J. and Turner J.

The structure and functioning of Southern Ocean ecosystems, and the services they provide, are being impacted by changes in multiple drivers. These include changes in atmospheric circulation and temperatures that are affecting oceanic and sea-ice processes, and the impacts of ocean acidification are expected to be manifest within a few decades. These ecosystems also support globally important fin-fish and crustacean fisheries. They were also perturbed by harvesting of marine mammals over the last two centuries, the consequences of which are expected to continue over the next century. The direct and indirect ecological effects of change in these multiple drivers are complex and highly uncertain. Yet the conservation and management of Southern Ocean ecosystems must account for these changes. Here we note progress in understanding the impacts of variability and change on the structure and functioning of Southern Ocean ecosystems and in the development of ecosystem models for assessing these impacts. We highlight the systematic development of scenarios of change and assessments of associated uncertainties. We illustrate the process with a focus on sea-ice, which is a major influence on Southern Ocean ecosystem structure and functioning, and highlight progress towards a community agreed future sea-ice scenario for use in ecological projections. Finally we discuss the development of joint activities between Southern Ocean ecologists, climate scientists and fisheries scientists aimed at providing information on climate change impacts for use in ecosystem-based management strategies.

Oral presentation

ATMOSPHERIC CARBON INVASION IN THE DYNAMIC SOUTERN BOUNDARY OF THE CALIFORNIA CURRENT

Contreras Pacheco Y.V., Herguera García J.C., Quintanilla Terminel G.

Eastern Boundary Upwelling Systems (EBUS), such as the California Current System (CCS), alternate seasonally between more acidic surface waters than most of the rest of the surface ocean due to the vertical mixing of carbon rich subsurface waters driven by the intensification of equatorward winds during spring to early summer. These processes make EBUS especially sensitive to ocean acidification and play an important role in the ocean carbon exchange.

We present the 13C isotopic records of organic and inorganic carbon for the last century, that show the direction and magnitude of the atmospheric carbon invasion in the surface waters for the last 3 decades. Results reported here depict the importance of these processes in the southern dynamic boundary of the California Current System. Cores were retrieved from San Lázaro basin (25° 10’ N and 112° 44’ W), a 540 m deep enclosed in the west by a 100 m deep uplifted fault system that is broken in the southwest by a narrow sill of 350 m depth. The constriction on circulation imposed by this sill coupled with the oxygen poor waters entering through this depth, and the relatively high export productivity of organic carbon control to suboxic conditions of the bottom waters. These conditions inhibit biological bioturbation processes and allows for the well preserved laminated sediments on the sea floor.

We present results from the carbon isotopic composition of organic fraction and the inorganic carbon, calcitic from planktic foraminifera, from three different cores. Preliminary results show similar trend toward lighter isotopic compositions of both, calcitic and organic carbon during the last three decades that mimic the atmospheric record, but with different slopes. We discuss the physical, chemical, and biological processes that could influence this behavior and their relative importance with implications on the dynamics that control the CCS.

Poster presentation

THE POTENTIAL FOR LARGE CHANGES IN REGIONAL FISHERIES CATCH UNDER CLIMATE CHANGE

Stock C.A., Asch R.G., Cheung W.W.L., Dunne J.P., Friedland K.D., Froelicher T., John J.G., Lam V.W.Y., Rykaczewski R.R., Sarmiento J.L., Watson R.A.

Changing net primary production (NPP) has been identified as a potential ocean ecosystem stressor under climate change. The connection between projected NPP changes and fisheries catch, however, is complicated by concurrent changes in marine food webs. Multiple recent lines of evidence have suggested that food web processes are likely to amplify changes in fisheries catch relative to NPP, possibly causing regional changes in maximum fisheries catch in excess of 50%. This contribution reviews the mechanisms linked to "trophic amplification" of NPP trends, assesses confidence in these mechanisms, and identifies critical additional constraints to improve confidence. The most prominent amplification mechanism suggested by previous work is a decline in trophic transfer efficiency that accompanies NPP declines and/or warming. This effect may be augmented by a concurrent increase in the number of trophic levels separating phytoplankton and fish. While there is considerable room for quantitative refinement of the impact of these mechanisms, they are consistent with basic principles of biological oceanography and large-scale empirical patterns. While projected NPP changes for different earth system models still often disagree at regional scales, the robust amplification of projected trends across models emphasizes the value of management strategies that are resilient to potentially large changes in fisheries productivity baselines.

Oral presentation

THE ROLE OF DECADAL CLIMATE VARIABILITY ON CHANGES IN OCEANIC DISSOLVED OXYGEN IN THE PACIFIC OCEAN: PERSPECTIVES FROM LARGE ENSEMBLE SIMULATIONS

Takano Y., Ilyina T.

Ocean deoxygenation is one of the major stressors on marine ecosystems under climate change. Detecting the deoxygenation signals from limited observations is challenging and requires further understanding on the characteristics of energetic internal (natural) variability. This could also lead to better understanding on uncertainties in future projections from the state-of-the-art models. Here, we analyze the 100 ensemble simulations from the Max Planck Institute for Meteorology Earth System Model's (MPI-ESM) for the historical period (1850-2005). The advantage of using large ensemble simulations is that it allows for a consistent investigation of the internal variability and forced trend within the same model. In this study, we first focus on understanding the dominant timescales of internal variability of basin-wide dissolved oxygen (motivated by recent observational studies such as Schmidtko et al., (2017)) and then discuss how Pacific decadal climate variability (particularly focus on the Pacific Decadal Oscillation (PDO)) could impact on variability and changes in dissolved oxygen. We will also present recent results from the analysis of the RCP2.6 and RCP4.5 ensemble simulations and further discuss implications on future climate change and deoxygenation.

Oral presentation

REDUCING UNCERTAINTY IN SCENARIO DEVELOPMENT THROUGH TRANSDISCIPLINARY INTEGRATION OF QUALITATIVE AND QUANTITATIVE DATA IN A DECISION SUPPORT SYSTEM

Tiller R., De Kok J.L., Ardelan M., Tsagaraki, T.

Stakeholders are increasingly being sought out for their opinions on environmental policy. The direct inclusion of their perceptions in environmental models, however, has been limited given the challenges in among others incorporating non-numerical data into mathematical models. However, excluding stakeholders from the model-building process can lead to models that provide policy advice that prove difficult to implement because of a lack of stakeholder acceptance of model results (legitimacy). Natural resource management is one area where stakeholder engagement in the 'modelling process' has strong efficacy. For example, the projected increase in sea surface temperature due to climate change, and the pivotal role of the microbial food web in determining carbon cycling in the euphotic zone, is expected to facilitate large changes in the marine food web under different scenarios. An integrated model as such will give scenarios to regional marine or coastal authorities and stakeholders on the long-term changes in fisheries or aquaculture productivity, and how this could affect local communities in their area. We explore this approach with qualitative data from stakeholder driven workshops in Northern Norway that have been quantified by combining systems thinking with fuzzy cognitive mapping. We then integrated this data with a combination of ecosystem- and climate models and experimental outputs that take into account the effects of increased carbon inputs in Arctic ecosystems and the structure and function of the food web, and combine this into an operational decision support system. This integration helps us identify the relevant stakeholder perceptions of challenges, opportunities and adaptive capacity under different climate- and ecosystem scenarios and how these translate into real-life perceptions on the effect of these changes. This information is useful for management purposes, and as such is a working example of an integrated system that can be applicable to other geographical and issue areas.

Oral presentation

MARINE PERMACULTURE TO RESTORE OCEAN PRODUCTIVITY

Theuretzbacher T., Schmitt R., von Herzen B.

Today's warmer surface waters limit natural overturning circulation and vertical mixing by increasing the density stratification particularly in the subtropics, reducing nutrients for algae, fish habitat, fish feed and forage fish upon which other fish depend. Warmer, more stratified oceans require new approaches to managing marine ecosystems.

In order to increase food security and restore marine ecosystems, Marine Permaculture (MP) developed by the Climate Foundation lowers ocean surface temperatures by restoring the vertical mixing, thereby restoring environmental conditions supporting seaweed forests and building resilience into fisheries that provide food for burgeoning human populations. MP uses locally available renewable energy – such as from wave-driven pumps – to restore the vertical mixing and overturning circulation with cooler, nutrient-rich water that provides favorable conditions for growth and thereby creates habitat at sea and food for forage fish. MP enables larger offshore open-ocean cultivation to take place. We are developing self-guided arrays using the vertical shear from mesoscale eddies for maneuvering. Renewable energy provides the power needed for seaweed irrigation and guidance, enabling cultivation across subtropical oceans, eliminating the limitations of nearshore cultivation.

MP provides a range of benefits beyond habitat restoration, including primary resources for marine economic sustainability such as fish and many high-value products produced by seaweed. Feeding growing global populations is straining diminished marine ecosystems. These resources need to be protected from overexploitation and climate disruption to meet future food security challenges and human health needs. MP has the potential to grow enough fish to meet the daily protein needs of most of the global population over the next few decades while increasing the protein availability per capita. Each 1000-meter-long MP array can fix >3000 tons of CO_2 per year, providing local adaptive strategies for ocean acidification, protecting coral reefs from coral bleaching and counteracting climate change at scale.

Oral presentation

FUTURE TRENDS IN SEAFLOOR COMMUNITY BIOMASS IN A GLOBAL, BODY SIZE-RESOLVED MODEL

Yool A., Martin A., Anderson T., Bett B., Jones D., Ruhl H.

Deep water benthic communities are an important source of seafood, are highly biodiverse, and mediate long-term carbon burial in seafloor sediments. However, they are almost wholly dependent on near-surface pelagic ecosystems for their supply of energy and material resources. This supply is channeled through complex food webs that extensively recycle particulate organic carbon (POC), but a residual of it reaches the seafloor and ultimately drives diverse assemblages of heterotrophs on the seafloor. Recent advances have led to an understanding of the importance of the size structuring in these communities. Here we drive a size-resolved benthic biomass model using the seafloor POC flux from a coupled ocean biogeochemistry model to investigate global patterns in size structure. Simulations find a wide range of seasonal responses to differing patterns of POC forcing, with both a decline in seasonal variability and an increase in peak lag times with increasing organism size. However, our key finding is the dominance of seafloor POC flux magnitude in guiding the behaviour of the benthos on annual timescales and above. We also investigate how benthic communities may change under different scenarios of future change in food supply to the benthos under climate change and ocean acidification. Against a backdrop of falling surface primary production and driven by changes in pelagic remineralisation with depth, our results show that while benthic communities in shallow water generally show higher biomass in a warmed world, deep sea communities experience a disproportionate decline under a high greenhouse gas emissions scenario. These changes underscore the importance for benthic ecology of reducing uncertainty in seafloor POC fluxes, both for the present-day and in the factors that may drive it in the future.

Oral presentation

JELLYFISH BLLOMS AROUND CHINESE COAST

Zhang F., Sun S., Li C.

Since the end of the 20th century, the Chinese coastal sea has suffered from jellyfish blooms, which are considered to be among the most serious ecological disasters, together with the harmful algae blooms (HABs), impacting the marine ecosystem, environmental safety, and the development of the maritime economy. To better understand the mechanisms for such a prominent increase of jellyfish blooms and to assess their ecological and economic impacts on the marine ecosystem, Chinese marine scientists participated in several large national level research projects on jellyfish. The first and the largest one was a National Basic Research Program of China project "The Key Processes, Mechanisms and Ecological Consequences of Jellyfish Blooms in China Coastal Waters" which was conducted from 2011 to 2015 by the Ministry of Science and Technology, China. Some detailed scientific contributions from this project have been published elsewhere (e.g., *Oceanol. Limnol. Sin*. Vol. 43, 2012; *Hydrobiologia* Vol. 754, 2015).The second one was the Public Science and Technology Research Fund Project of Ocean, conducted by scientists of the National Bureau of Oceanography, China, from 2010 to 2014. The main objectives of this project were to develop monitoring technique of jellyfish and prediction methods for jellyfish blooms. And the new one (from 2017 to 2020) will be granted by the National Key Research and Development Program of China, the main objectives of this new project combined the contents of the two previous big projects. This presentation will provide a brief overview of the major progress on jellyfish study conducted in Chinese coastal sea.

Oral presentation

GRAZING OF MICROZOOPLANKTON AND COPEPOD ON MICROBIAL FOOD WEB IN SPRING IN SOUTHERN YELLOW SEA, CHINA

Zhao Y., Zhao L., Zhang S., Lin S., Zhang W., Huang L., Xiao T.

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.

Poster presentation

Workshop 2: Metabolic diversity and evolution in marine biogeochemical cycling and ocean ecosystem processes		
Day 1 Monday 2 October		
Time	**Speaker**	**Title**
09:00 - 09:45	**Welcome to IMBIZO5!**	
09:45 -10:30	**Eddie Allison**	**Keynote address for Critical Constraints workshop**
10:30 -11:00	***Morning Tea***	
11:00 -11:45	**Mary Ann Moran**	**Keynote address for Metabolic Diversity workshop**
12:00 -12:45	**André Punt**	**Keynote address for MSE workshop**
12:45-14:00	***Lunch***	
14:00-14:30	Overview: goals for the workshop	
14:30-15:30	Small group discussions: What we know and what we do not know regarding climate change and metabolism, and climate change and evolution	
15:30-16:00	***Afternoon tea***	
	METABOLISM 1	
16:00-16:15	Nina Bednarsek	Pelagic calcifiers use avoidance mechanisms and activated oxidative pathways under multiple stressors
16:15-16:30	Justin Suca	Competing or sharing? Comparisons of early life trophic ecology of Tuna species in the Gulf of Mexico
16:30-16:45	Stacy Deppeler	Southern Ocean phytoplankton in a changing climate
16:45-17:00	Christian Tamburini	Biodegradation of *Emiliania huxleyi* aggregates by NE Atlantic prokaryotic communities under increasing hydrostatic pressure
17:00-20:00	**Poster session**	

Workshop 2: Metabolic Diversity and Evolution

Day 2 Tuesday, 3 October		
Time	**Speaker**	**Title**
	METABOLISM (1) – 4 talks	
09:00-09:15	Oscar Sosa	Bacterial degradation of phosphonates: a key methanogenic pathway in the ocean
09:15-09:30	Daniel Repeta	Microbial acquisition of iron in the oligotrophic ocean through siderophore production and uptake
09:30-09:45	Barbara Bayer	Comparative proteomics of three *Nitrosopumilus* species and their interaction with a heterotrophic *Alphaproteobacterium*
09:45-10:00	Federico Baltar	Metabolic evolution in marine biogeochemical cycling is not only a matter of the living things: cell-free enzymes and factors controlling their activity
	EVOLUTION	
10:00-10:15	Colin Kremer	Anticipating the consequences of climate change: detecting and modeling evolutionary constraints to thermal adaptation
10:15-10:30	Gerhard J Herndl	Deep ocean chemolithoautotrophy and the contrasting ecological strategies of ammonia and nitrite oxidizers
10:30-11:00	***Morning Tea***	
	EVOLUTION (continued)	
11:00-11:15	Elena Litchman	Theoretical and experimental approaches to understand ecology and evolution of different metabolic strategies
11:15-11:30	Punyasloke Bhadury	Exploring the functional diversity of marine phytoplankton assemblages across ocean realms
11:30-11:45	Tatiana Rynearson	The implications of global dispersal of phytoplankton on projections of climate change
11:45-12:00	Olivia Ahern	Co-evolutionary relationships between diatoms and bacteria
12:00-12:45	Posters: (half poster group)	
12:45-14:00	***Lunch***	
14:00-14:40	Posters: (other half poster group)	
14:40-15:30	Small group discussions: What are the big questions in metabolism/evolution and climate change?	
15:30-16:00	***Afternoon tea***	
16:00-18:00	**Cross-workshop 'sticky note' activity**	

Workshop 2: Metabolic Diversity and Evolution

Day 3 Wednesday, 4 October		
Time	**Speaker**	**Title**
9:00 -10:00	**David VanderZwaag**	**Cross-workshop Keynote talk**
10:00-10:30	***Morning Tea***	
10:30 -11:15	Report back from small group discussions	
11:15-12:45	Discussion & brainstorming about group manuscript based on small group discussions, talks and posters	
12:45-14:00	***Lunch***	
14:00-15:30	Discussion/ writing activities. Self-assignment to writing teams. (either separate papers or sections of one paper)	
15:30-16:00	***Afternoon tea***	
16:00-17:00	**Debate**	
After debate	**Pre-dinner drinks and then the IMBIZO5 dinner**	

Day 4 Thursday, 5 October		
Time	**Speaker**	**Title**
9:00 -10:00	Writing teams strategize. Sections/ figures/ toy models/ conceptual diagrams	
10:30-11:00	***Morning Tea***	
11:00 -12:45	Discuss timeline for post-workshop writing plan. Work on writing.	
12:45-14:00	***Lunch***	
14:00-15:00	**Summary from the workshops (Infographic and oral presentations)**	
15:00-15:30	***Closing ceremony***	

Alphabetized by the presenters' last name

CO-EVOLUTIONARY RELATIONSHIPS BETWEEN DIATOMS AND BACTERIA

Ahern O.M., Williams T., Whittaker K.A., Hunt D.E., Rynearson T.A.

Interactions between marine diatoms and bacteria shape community structure and influence oceanic biogeochemistry by regulating nutrient and carbon cycling and rates of primary production. The diatom's phycosphere, a hotspot for diatom-bacteria interactions, hosts a curated subset of the bacterioplankton community that survives off of diatom-derived extracellular products and performs metabolic functions necessary for diatom growth. Diatom-bacteria interactions have been on-going over evolutionary time scales and associations between diatoms and bacteria are species specific. To examine co-evolutionary dynamics within a single diatom species, we characterized the taxonomic composition of bacterial assemblages associated with 66 single cell isolates of the diatom *Thalassiosira rotula* from six genetically distinct populations sampled from three ocean basins. Using high-throughput sequencing of the 16S rDNA, we found that bacterial community composition was significantly associated with *T. rotula* population genetic structure. Importantly, these associations were robust even when a single genetic population of *T. rotula* was sampled from different ocean basins, suggesting the potential for interkingdom coevolution and parallel cladogenesis. The taxonomically distinct composition of bacteria associated with genetically distinct diatom populations suggests unique metabolic activities and potentials may be part of long-term and intimate interactions between a diatom population and its associated bacterial community. The specificity of bacterial communities between subspecies divisions in photosynthetic eukaryotes has implications for our predictions of how climate change will influence primary production and biogeochemical processes.

Oral presentation

A COMPARATIVE ASSESSMENT OF THE BLACK SEA ANCHOVY STOCK BY USING HOLISTIC PRODUCTION AND ANALYTICAL AGE STRUCTURE MODELS

Akkuş G., Gucu A.

The Black Sea anchovy (*Engraulis encrasicolus*) is economically and ecologically the most important fish species in the Black Sea. It supports 60% of the total fish catch among all Turkish fisheries. However, this precious resource has been exploited recklessly, so far, disregarding the consequences. A sound management plan targeting maximum sustainable yield therefore necessitates scientifically proven stock assessment. Therefore, the aim of the present study is to provide a comprehensive stock assessment by using only Turkish data to evaluate the condition of the Black Sea anchovy stock. To achieve this goal, two different models of ASPIC (1968-2014) and XSA (2005-2014) are used both to analyze the same stock from two different perspective and to examine the conformity of these two models. ASPIC estimates the carrying capacity (K) of Black Sea as 12x10^5 tons of anchovy and there should be 6.1x10^5 tons (BMSY) of fish present in the sea to achieve the maximum sustainable yield (MSY) of 2.44x10^5 tons fish from the system. It is estimated 3.99x10^5 tons (B2015) for 2015, this shows, now, it presents 35% less fish in the sea. Hence, the Black Sea anchovy is exposed to low overfishing. In XSA, the stock-recruitment relationship cannot be established. Therefore, the current status of anchovy stock is estimated from the Patterson's (1992) precautionary exploitation rate of Etarget=0.4 as a reference point. Accordingly, the current exploitation rate is calculated as Ecurrent=0.5 which is 25% higher than the Etarget. Hence, XSA results also suggest that the Black Sea anchovy is exposed to low overfishing. This result and the other comparable parameters for the two models show the concordance and comparability of holistic (ASPIC) and analytic (XSA) models.

Poster presentation

COMPARATIVE METAGENOMICS OF MICROBIAL COMMUNITIES FROM THE SERPENTINITE-HOSTED HYDROTHERMAL SYSTEM OF THE PRONY BAY AND OTHER RELATED HYDROTHERMAL ECOSYSTEMS

Frouin E., Postec A., Quemeneur M., Armougom F., Erauso G.

Marine hydrothermal field are commonly located in areas like undersea mountain ranges and mid-ocean ridges. The ecological functioning of hydrothermal systems generates considerable interest since these environments may contribute to a better understanding of the origins and maintenance of life in earth. The Prony Hydrothermal Field (PHF) is a serpentinized system located at shallow depths in the Prony Bay, in New-Caledonia. The serpentinization reaction, an hydration process of ultramafic rocks, generates hydrogen, methane and other organic compounds in alkaline (pH>11) and hot (~40°C) fluids. These by-products of serpentinization represent a valuable source of carbon to sustain microbial communities inhabiting the chimney walls of PHF. In this study a comparative metagenomic of eleven serpentinite-hosted hydrothermal systems was initiated to clarify the functional microbial profiles of PHF and related ecosystems, as well as to evaluate the influence of serpentinization on the metabolic capabilities. Unexpectedly, the functional profile of PHF was rather distant from one of its analog, the Lost City Hydrothermal Field. The latter shared more similarities with deep magmatic hydrothermal sites due to genes associated with ionic transporters and bacterial secretion system. This exploratory study revealed potential key metabolisms shared by serpentinized ecosystems exemplified by abundant genes encoding for methylphosphonate degradation. Microorganisms could use organic phosphorus compounds, like methylphosphonate, since phosphorus is limited in serpentinized ecosystems. In addition, the degradation of this compound could also contribute to biotic methane production in these environments. Finally, our results showed an over-representation of heat-inducible regulator genes that might be an indicator of highly changing environments. At this time, our metagenomic analysis led us to identify a functional core shared by all microbiomes, but also to rise new hypotheses on the environmental factors that may shape serpentinized ecosystems. This study constituted the first comparison of the metabolic potential of microbial communities inhabiting submarine serpentinized sites.

Poster presentation

METABOLIC EVOLUTION IN MARINE BIOGEOCHEMICAL CYCLING IS NOT ONLY A MATTER OF THE LIVING THINGS: CELL-FREE ENZYMES AND FACTORS CONTROLLING THEIR ACTIVITY

Baltar F.

Microbes are the engines driving biogeochemical cycles, they produce the enzymes that perform the major redox reactions essential for life and biogeochemical cycles. Microbial extracellular enzymatic activity (EEA) is the rate-limiting step in the degradation of organic matter in the oceans, and as such, recognised as the 'gatekeepers' of the carbon cycle. These extracellular enzymes exist in two forms, cell-bound which are attached to the microbial cell wall, and dissolved which are completely free of the cell. Evidence is piling up suggesting that cell-free enzymes make up a substantial proportion of the total marine EEA. Although we are starting to learn more about how microbial diversity and function (including EEA) will be affected by future environmental changes, little is known about what factors control the importance and activity of these abundant cell-free enzymes once they are away from their sites (cells). This presentation will deal with recent field and experimental studies ran to assess what controls the production of dissolved (relative to cell-bounded) EEA, and the lifetime and activity of the cell-free enzymes in the marine environment. These studies include a 1.5 years long field sampling in the Baltic Sea, experiments with microbial communities from the Great Barrier Reef performed in the Australian Institute of Marine Science SeaSimulator, and investigations on the effect of UVR (UV radiation) and temperature on cell free enzymes from New Zealand coastal waters. Overall, these studies revealed the importance of temperature and organic matter substrates diversity on controlling the proportion of dissolved relative to total EEA, as well as the importance of UVR and temperature as control mechanisms for cell-free enzymes. Given the projected warming ocean environment and the variable UVR light regime, there could be major changes in the activity of cell-free EEA and their contribution to organic matter remineralization in the future

Oral presentation

STORAGE COMPOUNDS AS POTENTIAL "LIFELINES" FOR DEEP-SEA PROKARYOTES

Bayer B., Offre P., Bittner M.J., Pachiadaki M., Stepanauskas R., Herndl G.J.

Heterotrophic deep-sea prokaryotes rely on sinking organic matter that is exported from the euphotic zone, however, most of it is respired in the upper mesopelagic layer (200-600 m depth) and does not reach deeper waters. We hypothesized that deep-sea prokaryotes store carbon and energy in the form of storage compounds, in order to overcome long periods of starvation. Indeed, we detected an increase with depth in the relative abundance of genes encoding cyanophycin and polyhydroxyalkanoate biosynthetic pathways in the Atlantic and Pacific Oceans. Our analyses of metagenomics datasets indicate that around 50% of the prokaryotes in the aphotic ocean have the potential to synthesize one of these two compounds. In contrast, polyphosphate and glycogen storage appears to be a feature of prokaryotes inhabiting surface waters, possibly reflecting an adaptation to phosphate limitation and an imbalance of the C:N:P supply ratio, respectively. Single cell genomics identified the uncultured lineages Marine Group III Euryarchaeota, Marinimicrobia (formerly SAR406 and MGA), and SAR324 (Deltaproteobacteria) as the predominant groups encoding for cyanophycin in the aphotic realm of Altantic and Pacific Oceans. To the best of our knowledge, this is the first report of cyanophycin, an amino acid polymer typically considered a nitrogen reserve in phytoplankton, in deep-sea prokaryotes. These findings suggest that storage compounds play an important role for deep-sea prokaryotes, possibly providing them with a selective advantage in this overall rather oligotrophic habitat that occasionally exhibits patchy nutrient distributions.

Oral presentation

PELAGIC CALCIFIERS USE AVOIDANCE MECHANISMS AND ACTIVATED OXIDATIVE PATHWAYS UNDER MULTIPLE STRESSORS

Bednarsek N., Carter B., Feely R., McCabe R.

Pteropods are zooplanktonic pelagic snails with thin aragonite shells that makes them vulnerable to ocean acidification (OA). The effects of corrosive waters on pteropod shell dissolution are well documented, making shell condition a useful indicator of declining habitat suitability due to OA. The southern part of the California Current System (CCS) on the West Coast of North America has a high abundance and biodiversity of pteropods. However, interactions of corrosive conditions and other stressors such as temperature have not been fully investigated in the CCS. During a NOAA cruise conducted in the early upwelling season of May 2016, pteropods were entirely absent from a large area stretching over ~1000 km across Central and Northern California. Following the 'Blob' event, a strong El-Niño in 2014-2015 created anomalously warm water conditions. At the same time, strong upwelling along the California coast enhanced corrosive conditions, simultaneously exposing pteropods to temperature and corrosive stress. Onboard the cruise we investigated the effect of temperature and corrosive stress on pteropods, incorporating an oxidative stress study that can provide a mechanistic understanding of pteropod vulnerability and acclimatization in the natural environment. Experimental studies showed the combined stressors to additively increase pteropods mortality, while the oxidative stress response demonstrated how the two stressors interacted on the cellular level to increase oxidative stress. The responses were associated with specific temperature and corrosive conditions, allowing the synthesis of the relevant pteropod thresholds in the natural environment of the CCS. We integrated these results into a habitat niche model to make future predictions about habitat compression along the CCS due to multiple stressors. Pteropods acclimatization strategy to survive was to avoid the unfavorable conditions by escaping to northwards regions without the present stressors. Highly activated pathways of oxidative stress shows high level of physiological acclimatization.

Oral presentation

EVOLUTIONARY METABOLOMICS SUGGESTS *PROCHLOROCOCCUS* DRIVES AN OCEANIC NUCLEOTIDE ECONOMY

Braakman R., Longnecker K., Becker J.W., Dooley K., Kido Soule M.C., Kujawinski E.B., Chisholm S.W.

Dissolved organic carbon is a major component of the ocean carbon cycle, and microbial activity is the primary factor underpinning its composition and distribution. However, much remains unknown about the pathways involved in the production and consumption of organic carbon, how pathways are distributed across microbial taxa, and what controls pathway flux. We combined comparative targeted metabolomics and phylogenomics to examine the ecology and evolution of organic carbon production in *Prochlorococcus*, the most abundant photosynthetic cell in the oceans. We find that unexpectedly high levels of thymidine are exported by *Prochlorococcus*, and that levels are higher in more recently diverging strains. Indeed, calculations suggest that over the course of our experiments the total accumulated extracellular thymidine is greater than the total amount of thymidine incorporated into DNA. In addition we find that *Prochlorococcus* cells excrete significant amounts of adenine and methylthioadenosine in P-limited relative to P-replete conditions. Methylthioadenosine is a by-product of polyamine synthesis that contains an adenine side group and is recycled through the methionine salvage pathway. Genomic analyses reveal that over the course of evolution *Prochlorococcus* lost the methionine salvage pathway, leaving methylthioadenosine or methylthioribosephosphate as alternative waste products. Our results thus suggest that *Prochlorococcus* evolved to become a major source of nucleotides, particularly thymidine and adenine, to ocean ecosystems, and that phosphorus availability affects the relative production of nucleotides. Since nucleotide levels allosterically control DNA synthesis and polyamines stabilize DNA secondary structure, we speculate that the evolution of nucleotide export in *Prochlorococcus* may be related to the evolution of its tightly regulated cell cycle. Finally, to explore potential ecological impacts of nucleotide export by *Prochlorococcus*, we examined the genomes of highly abundant co-occurring heterotrophic bacteria. Preliminary results suggest that some heterotrophic clades co-evolved with *Prochlorococcus* to recycle thymidine while others did not.

Oral presentation

METABOLIC FUNCTION NOT MICROBIAL TAXONOMY DETERMINES OCEAN BIOGEOCHEMICAL GRADIENTS IN A GENE BASED MARINE ECOSYSTEM MODEL

Coles V.J., Stukel M.S., Moran M.A., Hood R.R.

Biogeochemical models have adapted to simulate novel metabolic pathways discovered with sequencing techniques but in general modelers have not developed strategies for directly comparing model results with in situ “omics” datasets. Here, we develop a marine ecosystem model, GENOME, that generates metagenomes and metatranscriptomes as a new approach for developing direct comparisons with omics observations. Model microbes with randomly assigned genes for different metabolic functions are modeled in the Atlantic. Communities self-organize, developing adaptive community genomes and transcriptomes. To incorporate broad genetic potential, we replace organisms if they do not succeed anywhere in the model. Most organisms are rapidly replaced but others persist for long periods before being supplanted by a new organism. This process of replacement invokes the competitive lottery hypothesis with the important caveat that in pelagic marine ecosystems there is no competition for space, so organisms with similar function may be more likely to coexist. The model communities generate realistic vertical and horizontal ocean nutrient, genome, and transcriptome gradients as a function of the genetic library available to the community. The emergent model communities differ genetically between simulations with identical physics but different randomized source communities, but the metabolic functions for each assemblage are similar for a given environment across model runs, supporting the hypothesis that metabolic capacity may be undertaken by diverse organisms serving similar functions regardless of the specific assembly of the community.

Poster presentation

OCEAN ACIDIFICATION OF A COASTAL ANTARCTIC MARINE MICROBIAL COMMUNITY REVEALS A CRITICAL THRESHOLD FOR CO_2 TOLERANCE IN PHYTOPLANKTON PRODUCTIVITY

Deppeler S., Petrou K., Schulz K., Westwood K., Pearce I., McKinlay J., Davidson A.

High-latitude oceans are anticipated to be some of the first regions affected by ocean acidification. Despite this, the effect of ocean acidification on natural communities of Antarctic marine microbes is still not well understood. In this study we exposed an early spring, coastal marine microbial community in Prydz Bay to CO_2 concentrations ranging from ambient (343 µatm) to 1641 µatm in six 650 l minicosms. Productivity assays were performed to identify whether a CO_2 threshold existed that led to a decline in primary productivity, bacterial productivity, and the accumulation of Chlorophyll a (Chl a) and particulate organic matter (POM). In addition, photophysiological measurements were performed to identify possible mechanisms driving changes in the phytoplankton community. A critical threshold for tolerance to ocean acidification was identified in the phytoplankton community between 953 and 1140 µatm. CO_2 concentrations ≥1140 µatm negatively affected photosynthetic health, causing a significant decline in rates of carbon fixation and biomass accumulation. Low rates of primary productivity also led to declines in nutrient uptake and POM production, although there was no effect of CO_2 on C:N ratios. Despite this, the community displayed the ability to adapt to high CO_2 conditions, down-regulating their carbon concentrating mechanisms (CCMs) and likely adjusting other intracellular processes. In contrast, bacterial abundance increased when exposed to high CO_2, although production was unaffected. Instead, increased bacterial production coincided with increased organic matter supply from phytoplankton primary production. Such changes in phytoplankton community production could have negative effects on the Antarctic food web and the biological pump, resulting in negative feedbacks on anthropogenic CO_2 uptake. Increases in bacterial abundance under high CO_2 conditions may also increase the efficiency of the microbial loop, resulting in increased organic matter remineralisation and further declines in carbon sequestration.

Oral presentation

THE INTERPLAY BETWEEN ZOOPLANKTON DIVERSITY AND METABOLISM IN AN EASTERN BOUNDARY UPWELLING SYSTEM

Frederick L., Escribano R.

There is much concern about the effect of a changing ocean on the diversity of lower trophic levels in the marine ecosystem. Changes In the community structure of the plankton system may have major implications for the food web dynamics in the ocean and the C flow. Community structure may also affect metabolism due to species-dependent and size-dependent vital rates. However the relationship between plankton diversity and community structure has not received sufficient attention in the ocean. This work presents results from several experiments carried out in two locations of Chilean upwelling systems during 2014-2016 under variable upwelling conditions. Community metabolism of mesozooplankton was estimated by measuring respiration (oxygen consumption) through short-term (4-6 h) incubations of zooplankton assemblages, under controlled conditions (microcosms) of temperature, oxygenation and light simulating field conditions. Community structure of zooplankton was assessed with automated analysis using a ZooScan allowing estimations of taxonomic diversity, size diversity and the size spectrum. C-specific community respiration rates were in the range of 150-450 µg O_2 mgC^{-1} h^{-1} and were significantly correlated to the Shannon-Wiener diversity index and to the slope of the size spectra. Zooplankton diversity and size structure changed significantly with upwelling conditions (both in time and space) and these changes affected community respiration. Our findings suggest that alterations in taxonomic and size structure of zooplankton may impact metabolism with consequences for the C dynamics in the upwelling zone.

Poster presentation

LINKING BIODIVERSITY AND BIOGEOCHEMICAL PROCESSES ACROSS AN OCEANOGRAPHIC GRADIENT IN THE EASTERN SOUTH PACIFIC: THE ZOOPLANKTON MODEL

González C.E. , Escribano R.

The strong zonal gradient in the eastern South Pacific is characterized by the eutrophic upwelling zone, the mesotrophic coastal transition zone, and the oligotrophic/ultraoligotrophic region in the central south Pacific gyre. Along this oceanographic gradient the zooplankton community is subject to changes in temperature, oxygenation, salinity, pH, food quality and quantity, and different processes modulating the sources of nutrients. The interaction between the physical/biogeochemical gradient and the zooplankton community structure is not fully understood for plankton systems. Understanding such relationship can provide insights on the evolutionary processes controlling diversity and adaptability of plankton to a changing ocean. We studied taxonomic composition, size structure and biogeochemical properties of 5 size fractions of mesozooplankton in terms of C, N contents and isotopes composition (N15 and C13) from cruise carried out in September 2015 between the Chilean coast (70°W) and Easter Island (110°W), in the middle of the south Pacific gyre. The zooplankton was analyzed with a ZooScan for taxa composition and size spectra. The oceanographic gradient showed marked differences in temperature, oxygen, salinity and Chlorophyll-a among the four zones. Also, these biogeochemical zones along the gradient (eutrophic, mesotrophic, oligotrophic, ultraoligotrophic) had significantly different zooplankton communities (diversity and size spectra), C/N ratios and C13 and N15, revealing variability in the sources of nutrients, linked to biogeochemical processes, such as new production in the upwelling zone, denitrification associated with an intense oxygen minimum zone within the coastal and coastal transition zones, potential diazotrophy and highly regenerated C and N, depending on the size fraction, in the oligotrophic and ultraoligotrophic zones. Our findings suggest a strong link between zooplankton biodiversity (taxonomic and size) and the sources of nutrients that fuel phytoplankton, as a major food resource, suggesting that ongoing climate change altering nutrient cycling may have critical ecological effects on plankton diversity.

Poster presentation

TEMPERATURE DEPENDENCE OF PROKARYOTIC INORGANIC CARBON ASSIMILATION IN THE DARK OCEAN

Hansman R.L., Debeljak P., Gasser B., Herndl G.J.

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. These data correspond to Q10 temperature coefficient values ranging from 3.8 to 292, in contrast to samples from the Ross Sea that showed only slight increases in uptake rates with increased temperature and a more typical average Q10 of 2. Exploiting the natural warmer ambient temperatures found at depth in the Mediterranean Sea, the sensitivity and temporal variability of this response are being further explored at the DYFAMED (Dynamics of atmospheric fluxes in the Mediterranean Sea) time-series site.

Poster presentation

DEEP OCEAN CHEMOLITHOAUTOTROPHY AND THE CONTRASTING ECOLOGICAL STRATEGIES OF AMMONIA AND NITRITE OXIDIZERS

Yao Zhang, Lei Hou, Xianhui Wan, Nianzhi Jiao, Shuh-Ji Kao, Kai Tang, Xiabing Xie, Wenchao Deng, Xiaofeng Dai, Chang Liu, Hao Li, Zihao Zhao, T. Reinthaler, Gerhard J Herndl

Chemolithoautotrophy in the dark ocean is in the same order of magnitude as heterotrophic microbial production. Nitrification, is a major chemoautotrophic process mediated by ammonia and nitrite oxidizing microbes, thought to exhibit similar activity levels as nitrite is not significantly accumulating in the oceanic water column. However, there are fundamental differences in abundance and activity between ammonia and nitrite oxidizers. The dominant ammonia oxidizing microbial group, the *Thaumarchaeota* are relatively high in abundance but slow growing with cell-specific ammonia oxidation and dissolved inorganic carbon (DIC) fixation rates 1-2 orders of magnitude lower than the cell-specific nitrite oxidation and DIC fixation rates of the fast-growing but low abundance nitrite oxidizers. Despite these striking eco-physiological differences between these two chemolithoautotrophic groups of microbes, however, the bulk oxidation rates of ammonia match those of nitrite. Moreover, similar bulk DIC fixation rates of ammonia and nitrite oxidizers indicate that nitrite oxidizers play a much larger role in the dark DIC fixation in the ocean than hitherto assumed.

Oral presentation

ANTICIPATING THE CONSEQUENCES OF CLIMATE CHANGE: DETECTING AND MODELING EVOLUTIONARY CONSTRAINTS TO THERMAL ADAPTATION

Kremer C.T., Thomas M.K., Vasseur D., Sarmiento J.L., Stock C.A., Litchman E.

Temperature is a key factor influenced by climate change with large effects on the growth and metabolism of marine plankton. Predicting the effects of altered ocean temperature regimes on key primary producers like phytoplankton depends in part on (i) uncovering the fundamental evolutionary constraints that limit the maximum performance of well-adapted species, and (iii) determining the capacity of phytoplankton to adapt to novel future temperatures, as well as the consequences of delayed evolutionary responses. Here, I will synthesize the results of two of our recent studies that address these aims. First, I will present an analysis of the temperature- and size- dependence of the maximum growth rates of phytoplankton, drawing on a database of >400 species. These analyses show that the growth of phytoplankton is constrained by the temperature sensitivity of photosynthesis, reconciling the divergent predictions of the Eppley curve and the metabolic theory of ecology. This relationship acts as a fundamental constraint on the evolution of thermal tolerance in phytoplankton. Second, I will describe the results of an Earth Systems Modeling exercise, where we explored the ecosystem level effects of warming in tropical oceans when thermal adaptation is either rapid (and limited only by the Eppley curve), or constrained by standing variation. This study reveals that evolutionary constraints can limit the flow of energy through food webs, resulting in significant (although not catastrophic) reductions in the function and productivity of zooplankton communities by ~10%. These effects are driven by reductions in the top-down control of food webs, and could negatively affect the yield of tropical fisheries. Taken together, these two studies illustrate how determining the evolutionary constraints and capacities of plankton, merging empirical and theoretical approaches, advances our understanding of the effects of climate change.

Oral presentation

THEORETICAL AND EXPERIMENTAL APPROACHES TO UNDERSTAND ECOLOGY AND EVOLUTION OF DIFFERENT METABOLIC STRATEGIES

Litchman E., de Tezanos Pinto P., Grimaud G., O'Donnell D.R., Klausmeier C.A.

Here we present examples of how using experimental and theoretical approaches can help us understand the ecological interactions and evolution of different metabolic strategies. We experimentally investigated competition between a nitrogen-fixing cyanobacterium and a green alga and found a diversity of competitive outcomes under different N:P ratios that could not be explained by the standard model of competition. A novel model that allowed more flexible nutrient requirements matched well the observed experimental results. Our experimental evolution study showed that phytoplankton can rapidly adapt to higher temperatures and thermal adaptation can alter nutrient utilization traits. The cost-benefit model showed that the observed changes in thermal curve are consistent with the costs associated with increased protection in the evolved lines. Finally, we combine metabolic modeling (flux balance analysis, FBA) with the adaptive dynamics techniques from evolutionary ecology to explore the rise and persistence of metabolic innovations. These case studies demonstrate the advantages of combining experiments and different modeling approaches to better understand microbial physiology and ecological interactions.

Oral presentation

COMPARING INTRACELLULAR AND EXTRACELLULAR METABOLITES IN THREE STRAINS OF *PROCHLOROCOCCUS*

Longnecker K., Becker J.W., Braakman R., Dooley K., Kido Soule M.C., Chisholm S.W., Kujawinski E.B.

Prochlorococcus is an abundant, cosmopolitan, marine cyanobacterium with ecotypes that vary temporally and spatially across oligotrophic regions of the global ocean. This group of organisms can serve as a model system to understand the accumulation of organic compounds synthesized by primary producers in marine ecosystems. Previous research has considered the physiological, genomic, and metabolic differences across strains of *Prochlorococcus*; however, studies of the organic compounds accumulating within the cells or excreted to the surrounding environment are limited. We applied mass spectrometry to three axenic cultures of strains of that span the *Prochlorococcus* phylogeny: a high-light adapted HLII-clade strain, a low-light adapted LLI-clade strain, and a low-light adapted LLIV-clade strain. Intracellular metabolites were extracted from cells captured in exponential growth and extracellular metabolites were adsorbed, from the same samples, to solid-phase extraction resin. Both pools were quantified using a triple quadrupole mass spectrometer. The results reveal notable accumulation of intracellular glycine betaine in the LLIV strain (the only clade with the genetic capacity to synthesize this osmolyte). Here, it accounted for 20% of the intracellular carbon but <0.01% in the HLII strain, and was completely absent from the LLI strain. Large strain-specific differences in the accumulation of organic compounds occurred particularly in the intracellular amino acids such as arginine, glutamic acid, tyrosine, proline, and tryptophan. Excretion of amino acid precursors varied across strains, and in some cases, represented a significant fraction of excreted metabolites. Both changes in light level and extracellular phosphate concentration had significant and different impacts on intracellular and extracellular metabolite levels. These intraspecific differences provide clues about the selective pressures shaping the meta-metabolism of the *Prochlorococcus* collective, and its interactions with the surrounding microbes that depend on them.

Poster presentation

PHYTOPLANKTON COMMUNITY ADAPTATION AND VARIABILITY IN RESPONSE TO DIFFERENT ENVIRONMENTAL CONDITIONS OF INDIAN OCEAN SECTOR OF THE SOUTHERN OCEAN

Mishra R.K., Naik R.K., Anilkumar N., Jena B.

The variability of Chlorophyll-a (Chl-a) and phytoplankton communities in the frontal ecosystems of Indian sector of The Southern Ocean (IOSO) have been investigated along with the sea surface temperature (SST), sea surface wind (SSW), photosynthetically active radiation (PAR), and nutrients for the period of 1998-2014. Combined analysis of in situ, model and satellite observations during austral summer 2013 indicates that the variability of Chl-a and diatoms were primarily influenced by light and wind. The Chl-a was higher in the sub-Antarctic front (SAF) followed by the sub-tropical front (STF) and the polar front (PF). However in throughout period during 1998-2012, the diatoms concentration was higher at the SAF followed by the PF and STF. Dominance of diatoms at the PF may be attributed to their adaptability for low light conditions. During a time series (1998-2014) in austral summer the diatoms contribution to the Chl-a biomass was ≥80% at the PF. On the other hand, the chlorophytes to Chl-a biomass showed ≥70% at the STF and gradually decreased towards the PF mainly attributed to the temperate adaptation. However the trend of diatoms increased at the STF and decreased at the SAF and the PF, On the other hand the flagellates were dominant in the STF and progressively declined toward SAF and PF during austral summer 2013. The variability of flagellates and diatoms from the STF to PF is attributed to the variability of PAR, SST, SSW.The results from this study in the frontal ecosystems would help to understand the shifting of communities in the ecosystem, biogeochemical cycle of the IOSO.

Poster presentation

MICROBIAL ACQUISITION OF IRON IN THE OLIGOTHROPHIC OCEAN THROUGH SIDEROPHORE PRODUCTION AND UPTAKE

Repeta D.J., Boiteau R.M., Bundy R.M., Babcock-Adams L., Mende D., DeLong E.F.

Microbial production across approximately one third of the surface ocean is limited by extraordinarily low (picomolar) concentrations of dissolved iron. Essentially all iron in seawater is complexed to strong organic ligands of unknown composition. Amendment experiments using commercially available siderophores, organic compounds synthesized by microbes to facilitate iron uptake, show these ligands can both facilitate or impede iron uptake depending on the siderophore composition and available uptake pathways. Over the past few years we have been working on analytical techniques that allow us to rapidly identify and quantify siderophores in the seawater. Using these techniques, we routinely find siderophores in iron limited and low iron surface waters, as well as in some samples collected well below the euphotic zone. Our analyses show that in many areas of the ocean, marine microbes produce siderophores to facilitate iron uptake, suggesting that the ability to produce and/or take up siderophores may confer a competitive advantage to microbes living under iron stress. Although genes encoding siderophore uptake are common in metagenomes from low iron regions, genes encoding siderophore biosynthesis have only recently been reported. To address this, and to further explore potential sources of siderophores, we interrogated the TARA Oceans and Station ALOHA metagenomic catalogues for synthesis genes associated with ferrioxamine and amphibactin synthesis. Ferrioxamines and amphipbactins are the two most common siderophores we find in seawater samples analyzed to date. Our preliminary analyses show that genes for the synthesis of these two siderophores are common in many regions of the ocean, and may be more abundant in low iron areas.

Oral presentation

TRANSCRIPTIONAL RESPONSES OF *THALASSIOSIRA ROTULA* TO PHOSPHATE STRESS

Rubin E.R., Dyhrman S.T., Jenkins B.D., Whitney L.P., Mercier M., Rynearson T.A.

Diatoms are one of the most ecologically and evolutionarily successful phytoplankton groups in the ocean. They are able to thrive under dynamic environmental conditions including nutrient, temperature and light fluctuations. Here, we examined the transcriptional response of the centric diatom *Thalassiosira rotula* to phosphate stress. RNA-seq (Illumina) methodology was used to profile the whole transcriptome of *T. rotula* cells cultivated in nutrient replete and phosphate-stressed cultures. The analysis revealed a significantly increased relative abundance of phosphate ion transmembrane transporters as well as alkaline and serine/threonine phosphatases in the phosphate-stressed treatment relative to the nutrient replete control. Interestingly, these changes are similar to those found in the diatoms *T. pseudonana* and *Phaeodactylum tricornutum* suggesting the presence of canonical responses to phosphate stress across a broad phylogenetic range. *T. rotula* also displayed unique transcriptional responses to phosphate stress relative to these other species including an increased relative abundance of amino acid and oligopeptide transporters, suggesting that active transport of amino acids may be an important response to inorganic nutrient stress in some diatoms.

Poster presentation

METABOLIC POTENTIAL OF PHOSPHONATE FOR HETEROTROPHIC MICROBES THROUGHOUT THE ATLANTIC WATER COLUMN

Sintes E., De Corte D., Langer T., Yokokawa T., Nunoura T., Herndl G.J.

Phosphonates contain a carbon-phosphorus (C-P) bond. Different enzymes and the genes encoding them are implicated in the synthesis and metabolism of phosphonates in marine microorganisms, some leading to the utilization of C and P moieties, and others only of P. Although deep ocean prokaryotes represent 75% of the ocean's prokaryotic biomass, their metabolic potential remains largely enigmatic. The phylogenetic community composition and metabolic potential of total and active prokaryotic communities were characterized in the North Atlantic. Genes involved in phosphonates synthesis were relatively low in abundance as compared to genes involved in their catabolism and uptake. Transporters, as well as genes involved in synthesis and catabolism of phosphonates were most abundant in mesopelagic and bathypelagic waters. Most phosphonate metabolic genes were overrepresented in the active community as compared to the total community. Phosphonoacetate hydrolase (phnA) was highly abundant in the active prokaryotes inhabiting epipelagic waters. PhnA and phnX (phosphonoacetaldehyde hydrolase), which have been linked to C limitation, were relatively more abundant than enzymes linked to P limitation (phnK, phnL). Our results indicate that phosphonates can be utilized preferentially as C source in open ocean prokaryotes, while some resulting by-products of their metabolism, such as methane, can fuel additional microbial metabolic processes and affect the ocean's C and P biogeochemical cycles.

Oral presentation

BACTERIAL DEGRADATION OF PHOSPHONATES: A KEY METHANOGENIC PATHWAY IN THE OCEAN

Sosa O.A., Ferrón S., DeLong E.F., Repeta D.J., Karl D.M.

Phosphonates, organophosphorus compounds with a carbon-phosphorus (C-P) bond, are widespread in the environment and serve diverse functions in organisms. A variety of marine organisms synthesize phosphonates, from bacteria and archaea to invertebrates. The largest pool of phosphonates in the sea is arguably methylphosphonate and 2-hydroxyethylphosphonate esters found in dissolved organic matter (DOM), comprising 20% of dissolved organic phosphorus (DOP) in the oligotrophic North Pacific. Bacteria encode specialized enzymes like the C-P lyase pathway to breakdown phosphonates to obtain phosphorus for growth. Methylphosphonate is particularly relevant to methanogenesis because its degradation results in the release of methane, while 2-hydroxyethylphosphonate produces ethylene. Here we describe field experiments and laboratory studies with bacterial model systems that demonstrate that phosphonates are an important source of phosphorus to microbial communities, especially when inorganic phosphate is scarce, and are thus a key methanogenic substrate in the aerobic ocean. In our field incubation experiments we induce DOP and phosphonate degradation using glucose and inorganic nitrogen amendments. Microorganisms quickly exhaust 83-90% of inorganic phosphorus and subsequently proceeded to degrade 22-44% of DOP. We estimated phosphonate degradation accounted for 3.4-6.4% of DOP based on the net production of methane and ethylene. Additionally, using two model bacteria, a Pseudomonas strain and a Roseobacter encoding C-P lyase, we demonstrate DOM phosphonates are available to bacteria and are thus an important source of methane in the ocean. Exploring the Tara Oceans expedition metagenomes, we observe that C-P lyase pathways become more prevalent in regions known to be periodically phosphorus limited. We are now pursuing genetic studies with bacteria to further elucidate the enzymes and regulatory mechanisms underpinning DOM phosphonate degradation. We are also expanding this work from Hawaii to the North Atlantic Ocean to determine how widespread this methanogenic pathway is in the global ocean.

Oral presentation

COMPETING OR SHARING?: COMPARISONS OF EARLY LIFE TROPHIC ECOLOGY OF TUNAS SPECIES IN THE GULF OF MEXICO.

Laiz-Carrión R., Gerard T., Suca J.J., Uriarte A., Malca E., Privoznik S., Quintanilla J.M., Llopiz J.K., García A., Lamkin J.T.

This study aims to assess the larval trophic ecology of bluefin tuna (*Thunnus thynnus*) larvae from the Gulf of Mexico, together with blackfin (*Thunnus atlanticus*), bullet (*Auxis rochei*) and skipjack (*Katsuwonus pelamis*) tuna through stable isotope analysis of carbon (δ13C) and nitrogen (δ15N). Bulk stable isotope analysis (SIA) and compound-specific isotope analysis (CSIA) were combined to examine nutrient pathways in the planktonic pelagic food web. The significantly different isotopic signatures found among species point to variability in their trophic specialization and partitioning. Further, isotopic niche overlap and niche widths are analyzed to elucidate the degree of trophic specialization and resource utilization in the early life stages of these four cohabitating species. Preliminary results reveal different trophic behavior for post-flexion bluefin tuna larvae relative to the other species in the food sources utilized and for trophic food web enrichment, suggesting different metabolic pathways and variability of larval metabolic and growth rates. Differences in trophic behavior among these four species may be an adaptive process that allows tunas to share the ecosystem during the overlapping summer spawning season in the Gulf of Mexico, where their larvae compete for common food sources.

Oral presentation

BIODEGRADATION OF *EMILIANIA HUXLEYI* AGGREGATES BY NE ATLANTIC PROKARYOTIC COMMUNITIES UNDER INCREASING HYDROSTATIC PRESSURE

Tamburini C., Veloso S., Armougom F., Bhairy N., Garel M., Guasco S., Riou V., Santinelli C., Bonin P.

In the deep ocean, fluxes of particulate organic carbon (POC) and calcium carbonate ($CaCO_3$) are positively correlated, suggesting $CaCO_3$ could increase sinking particle densities and/or protect the organic matter from prokaryotic degradation, the so called “ballast effect”. In this study, the PArticle Sinking Simulator (PASS) system was used to simulate an increase in pressure from 100 to 1000m-depth in order to investigate the pressure effect on the 200m-depth natural prokaryotic community incubated with calcifying *Emiliania huxleyi* aggregates. The diversity of the prokaryotic community and its fraction active was characterized by 16S Miseq sequencing (16S DNA and 16S RNA) at different pressure conditions.

In this experiment, the increase in hydrostatic pressure reduced both prokaryotic growth and activities. The composition of the bacterial community was mainly dominated by Proteobacteria representatives (mostly Alpha- and Gammaproteobacteria), followed by Actinobateria, Bacteroidetes, Firmicutes. Compared to the results at atmospheric pressure (ATM), the bacterial community under increasing hydrostatic pressure (HP) showed major shifts in some phyla abundance. While the Proteobacteria phylum abundance reached 93% at ATM, the proportion significantly dropped to 63% under HP. In addition, the abundance of Actinobacteria, Bacteroidetes and Firmicutes phyla significantly increased under HP. Interestingly, the archaeal Euryarchaeota community increased only under HP. Finally, the characterization of the prokaryotic diversity showed the presence of some phyla, including GN02, KSB3 or Gemmatimonatedes, that may be promoted by increasing pressure. This experiment support our assumption that increasing hydrostatic pressure affects the structure of prokaryotic communities originating from the sub-surface (100m-depth), which are not adapted to high pressure condition.

Oral presentation

CARBOXYSOME PROTEINS AS BIOMARKERS FOR CARBON METABOLISM OF *PROCHLOROCOCCUS* IN THE OCEAN

Valentin L., Hawco N., Mcllvin L., Moran D., Saito M.

Proteomics has great potential for studies of marine microbial metabolism. While almost 50% of carbon fixation is from photosynthetic organisms in the ocean, it is still difficult to quantify how fast these organisms grow. Here we show that carbonic anhydrase from the abundant marine cyanobacterium *Prochlorococcus*, (Strain MIT9215) is a promising biomarker for estimating the growth rate of this organism. Carbonic anhydrase (CA) is a bi-functional enzyme capable of converting carbon dioxide (CO_2) into bicarbonate (HCO3-) or vice versa. When acclimated cultures of *Prochlorococcus* were exposed to a range of light levels; low light cultures showed a growth rate low and the CA protein was produced in small concentrations. In contrast, cultures exposed to high light levels showed high growth rate and produced significantly greater concentrations of CA protein. The recombinant overexpression of this carbonic anhydrase was successful enabling quantitative measurement in cultures and field samples and biochemical studies of this enzyme. Targeted proteomics is a useful tool in diagnosing carbon metabolism of a dominant phytoplankton group and better understand the role of phytoplankton in the systems biology of the oceans.

Poster presentation

Workshop 3: Management Strategy Evaluation: Achieving Transparency in Natural Resource Management by Quantitatively Bridging Social and Natural Science Uncertainties		
Day 1 Monday 2 October		
Time	**Speaker**	**Title**
09:00-09:45	**Welcome to IMBIZO5!**	
09:45-10:30	**Eddie Allison**	**Keynote address for Critical Constraints workshop**
10:30-11:00	***Morning Tea***	
11:00-11:45	**Mary Ann Moran**	**Keynote address for Metabolic Diversity workshop**
12:00-12:45	**André Punt**	**Keynote address for MSE workshop**
12:45-14:00	***Lunch***	
14:00-15:30	WORKSHOP: Panel discussion (including demonstration of VES-V tool to visualize different scenarios)	
15:30-16:00	***Afternoon tea***	
16:00-17:00	WORKSHOP: Toy MSE model presentation	
17:00-20:00	**Poster session**	

Workshop 3: Management Strategy Evaluation

Day 2 Tuesday 3 October Morning		
Time	**Speaker**	**Title**
09:00-10:00	WORKSHOP Continuation: Toy MSE model presentation and Question & Answer session	
10:00-10:30	**WORKSHOP: Invited Talks**	
5 min	Jason Link	What good are MSEs when the oceans, and people that use and manage stuff in them, are so stinking uncertain?
5 min	Ana Parma	Looking for robust harvest control rules: learning from MSE applications to specific fisheries
10:30-11:00	***Morning Tea***	
11:00-12:00	**WORKSHOP: Talks (natural science)**	
5 min	Cecilie Hansen	Dealing with 'the boss' in the Barents Sea – as easy as it sounds?
5 min	Ana Bevilacqua	Dealing with the discard ban issue: coupling methodologies in a MSE framework
5 min	Stephanie Brodie	Quantifying the utility of dynamic ocean management through management strategy evaluations
5 min	Gizem Akkuş	A comparative assessment of the Black Sea anchovy stock by using holistic production and analytical age structure models
5 min	Isaac Kaplan	Testing harvest control rules within end-to end ecosystem models: a stepping stone toward management strategy evaluation
5 min	Lisa Kerr	Modeling the implications of stock mixing and life history uncertainty of Atlantic bluefin tuna
5 min	Eileen Hofmann	Factors affecting distribution of the Atlantic surfclam (*Spisula solidissima*), a continental shelf biomass dominant, during a period of climate change
5 min	Robert Wildermuth	Developing a framework for evaluating structural uncertainty in social –ecological system models: a Bayesian network approach
5 min	Daniel Howell	REDUS MSE: a flexible Management Strategy Evaluation modelling tool
5 min	Zeyu Zeng	Effects of climate change and fishing on the Pearl River estuary ecosystem and fisheries
12:00-12:45	WORKSHOP: Discussion & writing activities	
12:45-14:00	***Lunch***	

Workshop 3: Management Strategy Evaluation

Day 2 Tuesday 3 October Afternoon		
14:00-15:00	**WORKSHOP: Talks (small scale fisheries)**	
10 min	Maria Rebecca Campos	Bioeconomic Modelling of Fisheries Conservation Policies in the Philippines
5 min	Ane Dwijayanti	Fishermen Social Rebound to Meet the Equilibrium in Fisheries Management: Study Case New Regulation on lobster fisheries in Southern Java, Indonesia
5 min	Samantha Williams	Finding synergy in conservation and small-scale fisheries: Case studies from the Western Cape, South Africa
5 min	Helven Naranjo-Madrigal	A model-based approach for strengthening resilience of responsible marine fishing areas in Costa Rica
5 min	Nemillie Qaqara	Exploring Traditional Ecological Knowledge (TEK) marine resources use: a case study from two villages in Fiji
5 min	Ivan Martins	Factors of social vulnerability to climate change among small-scale fishing communities from the South Brazil Bight
5 min	Samiya Selim	Evidence of ecosystem based adaptation in coastal fisheries of Bangladesh
5 min	Dhanya Kandarattil	Fisheries and livelihood options of marginalized communities; in the scenario of changing climate, in Kerala, India
15:00-15:30	WORKSHOP: Discussion & writing activities	
15:30-16:00	***Afternoon tea***	
16:00-18:00	**Cross-workshop 'sticky note' activity**	

Workshop 3: Management Strategy Evaluation

Day 3 Wednesday 4 October Morning		
Time	**Speaker**	**Title**
9:00 -10:00	**David VanderZwaag**	**Cross-workshop Keynote talk**
10:00-10:30	***Morning Tea***	
10:30-12:00	**WORKSHOP: Talks (human dimension)**	
10 min	Robert Scott	Developing Harvest Strategies for the Western Central Pacific Tuna Fishery
5 min	Per Arneberg	Marine Ecosystems and Social Needs: The importance of merging social and natural science for servicing policy needs to the best for humans and nature
10 min	Sarah Gaichas	Getting on the same page, or at least in the same library: lessons in communication from a stakeholder driven MSE for Northeast US Atlantic herring
10 min	Julie Hall	How do we move to ecosystem based management?
10 min	Derek Armitage	Integrating governance into management strategy evaluation
5 min	Carla Sbrocchi	Comparative analysis of wellbeing frameworks for multi-objective scenario development
5 min	Natasa Vaidianu	Emerging governance requirements: manage fish and people for a coherent and sustainable exploitation in the Romanian Black Sea
10 min	Prateep Nayak	Fishing for power: Conceptualization of social-ecological change and marginalization through local metaphors and political ecology narratives
5 min	Sara Miñarro	A new conceptual framework to evaluate drivers of fishing behavior in small scale fisheries
5 min	Katherine Mills	Climate adaptation in Northeast U.S. fisheries: eliciting and evaluating strategies of interest to stakeholders and communities
5 min	Kalpana Chaudhari	Bridging social and natural science uncertainties and changes in marine ecosystem: evaluating the impacts of climate change and management strategy evaluation using application of E-governance and ICTs
5 min	Gaku Ishimura	Optimizing fishing strategies and spatial management by linking spatial abundance information and economic indicators
12:00-12:45	WORKSHOP: Discussion & writing activities	
12:45-14:00	***Lunch***	

Workshop 3: Management Strategy Evaluation

Day 3 Wednesday 4 October Afternoon	
14:00-15:00	WORKSHOP: Discussion & writing activities
15:00-15:30	WORKSHOP: Talks (overflow from previous sessions)
15:30-16:00	***Afternoon tea***
16:00-17:00	**Debate**
After debate	**Pre-dinner drinks and then the IMBIZO5 dinner**

Day 4 Thursday 5 October		
Time	**Speaker**	**Title**
9:00-10:30	WORKSHOP: Discussion & writing activities	
10:30-11:00	***Morning Tea***	
11:00 -12:45	WORKSHOP: TBD	
12:45-14:00	***Lunch***	
14:00-15:00	**Summary from the workshops (Infographic and oral presentations)**	
15:00-15:30	***Closing ceremony***	

LOOKING FOR ROBUST HARVEST CONTROL RULES: LEARNING FROM MSE APPLICATIONS TO SPECIFIC FISHERIES

Parma A.M.

Increasing recognition of the wide uncertainty that surrounds fisheries assessments has prompted a change in the science used to formulate management advice. While initially the focus of policy analysis was on optimality, the emphasis has shifted first to risk avoidance, and more recently to achieving robustness in the face of uncertainty. Experience has shown time and again that the use of a "best-assessment" approach, i.e. a best estimate of the absolute exploitable biomass coupled with a function that specifies the target fishing mortality, can fail to achieve the desired robustness and lead to unnecessary disruptions in the conduct of fisheries. The most important selling point for MSE is that it allows quantification of the performance of management procedures in advance of implementation, so that their robustness in the face of alternative future scenarios can be evaluated. In addition, unresolvable arguments about which model is best to represent past and future system dynamics can give way to more productive discussions about the scenarios to include as operating models for MSE. These important benefits are well illustrated by the process of designing and implementing a strategy for rebuilding the stock of southern bluefin tuna (SBT). Not only did the MSE approach allow progress away from stagnation in the scientific process, but it delivered a strategy that in practice proved to be robust to appreciable changes in the best assessments of absolute stock size. Relatively simple management procedures, like the one adopted for SBT, that work by adjusting allowable catches up or down in response to trends in stock size indicators may, in general, afford higher robustness to changes in the scale of abundance estimates than the standard best-assessment approach.

Invited Talk

INTEGRATING GOVERNANCE INTO MANAGEMENT STRATEGY EVALUATION

Armitage D., Davies I., Francis T., Levin P., Okamoto D., Punt A., Silver J.

Our aim in this paper is to examine if and how governance issues can be effectively integrated into formal management strategy evaluation (MSE). Governance refers to the broader processes and institutions (e.g., regulatory/top-down, community-based or collaborative) through which societies make decisions that affect the environment and natural resources. Governance arrangements and processes exert a significant influence on how management objectives are defined, the effectiveness and implementation of management decisions (e.g., total allowable catch or effort control), information included in evaluations, and assessments of management outcomes. Despite its influence, however, there is limited explicit consideration of governance in MSE, and this may undermine efforts to develop realistic simulations of particular management plans and their trade-offs. In this paper, we 1) outline and define key attributes of governance that can influence MSE (e.g., role of different knowledge systems, perceptions of legitimacy, flexibility and adaptiveness); 2) examine how these attributes can manifest differently depending on the model of governance (e.g., top-down vs. collaborative), with implications for compliance (e.g., with harvest control rules); and 3) reflect on the influence of governance at various stages in an MSE where decisions are made and behaviors may change in ways that influence simulation modelling. This paper is one outcome of the Ocean Modelling Forum which aims to improve the way models are used to address the most pressing challenges facing the world's oceans.

Oral presentation

MARINE ECOSYSTEMS AND SOCIAL NEEDS: THE IMPORTANCE OF MERGING SOCIAL AND NATURAL SCIENCE FOR SERVICING POLICY NEEDS TO THE BEST FOR HUMANS AND NATURE

van der Meeren G.I., Arneberg P.

The oceans and seas are of vital importance for nature and human life but face multiple challenges including climate change, overfishing. Norwegian marine management plans are since 2012 in place to provide a framework for the sustainable use of resources and ecosystem services and at the same time maintain the structure, functions, productivity and diversity of the areas ecosystems. Yet, still missing is a way to include socio-ecological research to service policy needs. Based on what researchers know, stakeholders with different interests need more knowledge to achieve sufficient understanding to make well-informed decisions. It is equally important for scientists to understand what is important for the stakeholders. This gap has not been bridged. The issues to be challenged to mend this gap are known. The main challenge is to remove the cultural differences between social and natural science to open for true integrated research as well as actual holistic management, based on fully integrated marine strategy evaluation.

Oral presentation

DEALING WITH THE DISCARD BAN ISSUE: COUPLING METHODOLOGIES IN A MSE FRAMEWORK

Bevilacqua A.H.V., Pennino M.G., Coll M., Bellido J.M.

Discards are one of the most important topics in fisheries management, both for economic and ecological aspects. The Common Fisheries Policy plan proposed by the European Commission for 2014-2019 presents a controversial goal: to enforce the landing of fishing discards as a measure to promote their reduction. This political decision will shape the future of the fishing exploitation in European Seas with socio-economical implications in the short term. For these reasons, both stakeholders and policy makers are now claiming for more effective tools that can be used to support the decision-making framework. Within this context, the management strategy evaluation (MSE) can be a decisive tool to identify a best management action among a set of different scenarios under the discard ban application. In the present study we implemented a MSE approach coupling hierarchical Bayesian spatial models (HBSM) with the Ecopath with Ecosim (EwE) food web ones, exploring different future developments in the North Western Mediterranean Sea under the landing obligation. In particular, we firstly assessed high density discard areas using HBSM with discard and environmental data, and secondly, we simulated possible spatial closures in the identified areas using Ewe. We discuss the socio-economical implications of each one of the simulated cases and we argue that a combination of fishery management measures will be a more effective global strategy to deal with this important issue.

Oral presentation

QUANTIFYING THE UTILITY OF DYNAMIC OCEAN MANAGEMENT THROUGH MANAGEMENT STRATEGY EVALUATIONS

Brodie S., Welch H., Hazen E., Scales K., Jacox M., Briscoe D., Maxwell S., Crowder L., Lewison R., Bograd S.

Spatiotemporal management strategies are often implemented at overly coarse scales that do not consider the physical and biological dynamics inherent in ocean ecosystems. Dynamic Ocean Management (DOM) is a strategy that rapidly changes in space and time in response to changes in the ocean and its users. DOM has theoretically been shown to increase the efficiency and efficacy of fisheries management, but there is a need to empirically quantify the benefits of DOM compared to static strategies. This quantification can be achieved using an MSE framework. We review the benefits and drawbacks of existing MSE tools (e.g. Marxan, SeaSketch, EcoSpace), and describe how DOM applications can act as a complementary tool for examining the utility of spatial management strategies. To showcase this, we used a case study from the California Drift Gillnet (DGN) fishery which has a number of static spatial management closures. A bycatch reduction tool, named EcoCast, has been developed for this fishery and provides real-time habitat maps of target and bycatch species. Here, EcoCast was used as an operating model to test the utility of DOM as a spatial management approach. This was done using a hindcast analysis of the predicted distribution and observed catch of three bycatch species (leatherback turtle, sea lion, blue shark) and one target species (swordfish). We explored four MSE performance measures: bycatch reduction, reduction in landings, efficiency of bycatch reduction, and the spatiotemporal efficiency of existing closures. The existing DGN seasonal closures are effective in encompassing the predicted habitat distribution of bycatch species. But under anomalous conditions, the boundaries of spatial closures could be reduced or expanded to satisfy competing objectives of bycatch reduction and economic viability of the fishery. Our work highlights that dynamic ocean management strategies can help achieve conservation targets, support economic viability, and sustain social sustainability.

Oral presentation

BIOECONOMIC MODELLING OF FISHERIES CONSERVATION POLICIES IN THE PHILIPPINES

Campos M.R.

The Philippines is surrounded with many fishing grounds. In spite of this, most fishermen in the area live in poverty, and their plight is getting worse, not better. Current fisheries policies for the area have failed to improve the situation but no research has been done to find out why. This report uses a bioeconomic model to simulate the effects of changes in the enforcement levels of current policies. Investments of the government on different levels of enforcement were assessed using benefit cost analysis. The report assesses the effects of enforcing current fisheries policies more stringently. The situation would be transformed into one in which large and perhaps increasing numbers of people would continue to fish, expending larger amounts of effort to comply with various gear restrictions but, in all likelihood, harvesting no fewer fish. Because the bay is already overfished, catch per unit effort and marginal productivity would decrease. Any additional fishing effort in the bay will result in a decrease in the average catch of all fishermen. Enforcement of current policies will not address the underlying problems of open access and the overfishing it leads to. One policy to deal with the problems of open access and overfishing is to set a limit on the total number of fish that can be caught and divide this quota among Lamon Bay's fishermen.

Oral presentation

BRIDGING SOCIAL AND NATURAL SCIENCE UNCERTAINTIES AND CHANGES IN MARINE ECOSYSTEM : EVALUATING THE IMPACTS OF CLIMATE CHANGE AND MANAGEMENT STRATEGY EVALUATION USING APPLICATION OF E-GOVERNANCE AND ICTS

Chaudhari K.L., Philip P.J.

Marine and human systems are complex in the Ocean Management System. The impacts of climate change and environment variability are dynamics on the coastal society. The empowerment of coastal communities is crucial for the development of the marine resources. Bringing the coastal population in to the mainstream of the digital technologies for the assessing the impacts of climate change on marine resources and mitigation is a major concern now. Management strategy evaluation (MSE) of the climate change and its impact on marine ecosystem is a complex process based on the real time data analysis related to climate, natural recourses and socio- economic conditions along coastal region. In order to provide the people along coastal region with better prospects and opportunities for economic development,aquaculture development and management; increased participation of people along coastal region in electronic governance through information and communication technologies are envisaged. The Information and Communication Technologies (ICTs) plays an important role bridging the gap between social and natural science uncertainties in marine ecosystem.

This presentation aims to explore the nature, role and relevance of the Electronic/Digital Governance using ICTs for assessing the impacts of climate change and mitigation for marine resources along coastal region and its impacts to highlight approaches and methods for improving local environmental governance for actors involved in socio-political process. The presentation will examine the current status of management strategy evaluation of marine ecosystems along the coast in different coastal regions of Asia- Pacific for the assessment of impacts of climate change and environment resilience along coastal regions using ICTs. The presentation deals with innovative ideas for effective communication strategies to convey MSE predictions and best-practice paradigms in the Asia-Pacific coast to decision-makers for effective planning and management of ocean and marine ecosystems.

Oral presentation

FISHERMEN SOCIAL REBOUND TO MEET THE EQUILIBRIUM IN FISHERIES MANAGEMENT: STUDY CASE NEW REGULATION ON LOBSTER FISHERIES IN SOUTHERN JAVA, INDONESIA.

Dwijayanti A.D., Suadi S.S., Setyobudi E.S., Adharini R.I.A.

Lobster is high economic value commodity in the last 30 years in Indonesia and most in the South East Asia. Most of these commodities are exported alive to several countries such as China, Hongkong, Vietnam, and Singapore. Since 2015 there has been a regulation issued by the Ministry of Marine and Fisheries of Indonesia. The prohibition of catching and selling lobster and lobster juvenile and set the size limit for the catch. The implications of this regulation decrease the lobster exports to China by 74.19%, and Vietnam by 94.03% from 2013-2016, meanwhile there was an export increase to Hong Kong 67.59% and Singapore 453%. This prohibition is stringent and causes some changes in social interaction in fisherman community and requires the fishermen and sellers to adapt. The fishermen's adaptation strategy which is affected stakeholders is important to be noted to evaluate the effectiveness of established rules and providing the proper management communication to gain the fishermen awareness of the uncertainty lobster resource. The research was conducted in four provinces; West Java, Central Java, Yogyakarta and East Java by conducting surveys and interviews to 200 fishermen and stakeholders. During the transition's period, the fisherman has been split into several groups which are based on decision options which have the correlation with the economic return and consideration of the lobster sustainability. Regarding the implementation of the new regulations, there are significant changes both in value and supply chain in upstream and downstream. The new domestic demand for ineligible lobster for export is growing and treated the effectiveness of the regulation. However, this occurrence is predicted as a social rebound for the new regulation and by implementing a precautionary approach to gain the fisherman and local market awareness because the regulation has significant advantages to be maintained eventually.

Oral presentation

GETTING ON THE SAME PAGE, OR AT LEAST IN THE SAME LIBRARY: LESSONS IN COMMUNICATION FROM A STAKEHOLDER DRIVEN MSE FOR NORTHEAST US ATLANTIC HERRING

Deroba J.J., Gaichas S.K., Lee M-Y., Feeney R.G., Boelke D., Irwin B.

Management Strategy Evaluation (MSE) should include stakeholder input, but such a process can have communication challenges. Atlantic herring in the northeast US has diverse and engaged stakeholders. An MSE was recently conducted to evaluate harvest control rules for Atlantic herring, possibly the first in the US to use open, public workshops for development. Two, 2-day workshops were each attended by about 65 members of the public, with about 30 attending both. Participants had diverse backgrounds with differing levels of interest and preparedness. This diversity of participation was generally positive, but led to frequent misunderstandings about terminology and intentions for the MSE. The process overcame some of these communication problems by providing a forum for repeated interactions and presenting information using a range of methods (e.g., verbally and graphically). Improved understanding of MSE and technical methods was also achieved through informal lines of dialog that opened through the MSE process. MSEs more broadly would benefit from repeated opportunities for interactions among stakeholders, scientists, and managers. Conducting stakeholder driven MSEs will require investment in organizers, facilitators, and technical experts, preferably with expertise in a particular system, and such investments can improve communication, understanding of MSE, to the betterment of fisheries management.

Oral presentation

HOW DO WE MOVE TO ECOSYSTEM BASED MANAGEMENT?

Hall J.A.

Ecosystem base management (EBM) for the marine environment has been discussed for long time but there are few examples where it has been consistently applied and none at the national level. The development of approaches, tools and frameworks for implementing EBM requires the integration of social science, economics, biophysical science, law, policy and indigenous knowledge. In addition, it needs to acceptance of EBM as a useful and practical management approach for the marine environment by marine resource managers, policy makers, industry, NGO's, indigenous people and the wider community. In New Zealand we have the opportunity to build approaches, tools and frameworks to support the evolution of EBM from our current system of single species fisheries management and managing each activity in the marine environment in isolation through the Sustainable Seas National Science Challenge, http://sustainableseaschallenge.co.nz/. A set of principles for EBM in New Zealand have been developed which include

- A co-governance and co-design structure that recognises the Māori constitutional relationship and mana whenua at all levels together with the guiding concepts of mauri, whakapapa, kaitiakitanga, and manaakitanga,
- Place- and time-specific, recognizing/understanding the ecosystem as a whole in all its ecological complexities and connectedness
- Acknowledgement of humans as ecosystem components with multiple values
- Long-term sustainability as a fundamental value, in particular maintaining values and uses for future generations
- Collaborative and participatory management throughout whole process, considering all values and addressing cumulative and multiple stressors,
- Clear goals and objectives based on knowledge
- Adaptive management, appropriate monitoring, and acknowledgement of uncertainty

This presentation will discuss how we have developed an interdisciplinary research programme to undertake the research needed to move New Zealand to EBM for our marine environment, what we have learnt so far and what our biggest challenges are in the future.

Oral presentation

DEALING WITH 'THE BOSS' IN THE BARENTS SEA – AS EASY AS IT SOUNDS?

Hansen C., Kaplan I.C., Skern-Mauritzen M., Morzaria-Luna H.N.

The cod stock in the Barents Sea is the largest cod stock in the world, often dubbed 'the boss' with current landings having a total value of 6.2 billion NOK. One of its favorite prey is capelin, however, cod is a top predator and generalist, and prey on almost all trophic levels. Lately, questions are being raised from pelagic fishermen about prioritizing the catches of cod 'on behalf' of other commercial species in the region. When the cod stock is at such high levels as present, it consumes a considerable amount of prey species. One of these is the Norwegian Spring-Spawning herring, which spends their juvenile period in the Barents Sea. Compared to the cod stock, the herring landings have a total value of 2.4 billion NOK at present stock levels. The suggestion from the fishermen is to fish harder on a high cod stock, and that way get more pelagic fish, but is the solution as easy as that? Could indirect predator-prey effects kick in and give fishermen, scientists and managers a bit of a surprise?

We propose that the structural uncertainty in multispecies models is of importance to the performance of management strategies. How crucial is a correct cod diet in an ecosystem model, in terms of the consequences of increased or decreased harvest pressure? To enlighten this, we use the Nordic and Barents Seas Atlantis model to evaluate the effects of changes in management strategies for the cod stock in the Barents Sea and evaluate the trade-offs and effects on the ecosystem and fisheries in the area.

Oral presentation

FACTORS AFFECTING DISTRIBUTION OF THE ATLANTIC SURFCLAM (SPISULA SOLIDISSIMA), A CONTINENTAL SHELF BIOMASS DOMINANT, DURING A PERIOD OF CLIMATE CHANGE

Hofmann E.E., Powell E.N., Klinck J.M., Munroe D.M., Mann R., Haidvogel D.B., Narváez D.A., Zhang X., Kuykendall K.M.

The Atlantic surfclam (*Spisula solidissima*) is a dominant member of the biological community of the Middle Atlantic Bight continental shelf and also 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 that ultimately appear as social and economic effects, which in turn inform development of management policies for the resource. This presentation provides an overview of the components of the surfclam MSE, relevant results, 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.

Oral presentation

REDUS MSE: A FLEXIBLE MANAGEMENT STRATEGY EVALUATION MODELLING TOOL

Howell D.

In principle, MSEs give the potential to move beyond our traditional single-species dominated management approaches. MSEs allow for testing of different single- and multi-species HCRs, for evaluating impacts beyond the target species, and for evaluating and communicating which uncertainties have the greatest impact on our management success. These factors have the potential to combine to give a wider scope to strategic management than has traditionally been possible. However, existing MSE tools tend to have been hardcoded and inflexible, and written with a much narrower scope, focusing only on single species, typically concentrating on numeric uncertainties in recruitment and assessment. This is beginning to prove a limitation on both research and the provision of management advice. For example, IMR Norway was recently asked by governments to evaluate a HCR for NEA cod which partially depended of varying food (capelin) availability. None of the existing tools could adequately handle this request. Equally, there was a recent MSE in the US to evaluate a HCR for herring considering its role in the ecosystem. Rather than continue to develop ad hoc solutions as such instances arise, IMR is therefore working as part of the REDUS project to create a modular MSE tool, where a central core in R connects via APIs to existing state-of-the-art single- and multi-species operating models. This will allow a much wider range of structural uncertainties to be evaluated, as well as including a wider multispecies perspective in the analyses. This presentation will briefly present the design and aims of the MSE tool. We present this hoping to feed into, and learn from, the discussion on the future development of MSEs.

Oral presentation

OPTIMIZING FISHING STRATEGIES AND SPATIAL MANAGEMENT BY LINKING SPATIAL ABUNDANCE INFORMATION AND ECONOMIC INDICATORS

Ishimura G.I.

Spatial analysis is used extensively in natural resource management to optimize resource uses as well as fishing operations. This study undertakes the daily log-book and market data for a Japanese off-shore longline fishing vessel for the North Pacific swordfish fishery. To explore optimum fishing strategies, this study intergrades two analysis (a) spatial analysis of resource abundance with identified fishing grounds by cluster analyses and (b) the development of an empirically-estimated production function with the ex-vessel price model upon quality and quantity of landings and the cost model. The results suggest that; 1) the possibilities for the seasonal fishing strategies to improve and optimize their profitability and 2) potential boundaries for the spatial fishery resource management with consideration of fishers' behavior.

Oral presentation

TESTING HARVEST CONTROL RULES WITHIN END-TO-END ECOSYSTEM MODELS: A STEPPING STONE TOWARD MANAGEMENT STRATEGY EVALUATION

Kaplan I.C., Hansen C., Morzaria Luna H., Girardin R., Marshall K.N.

Management strategy evaluation (MSE) provides a simulation framework to test the performance of living marine resource management. MSE has now been adopted broadly for use in single-species fishery management, often using a relatively simple 'operating model' that projects population dynamics of one species forward in time. On the other hand, many challenges in ecosystem-based management involve tradeoffs between multiple species and interactions of multiple stressors. Efforts are underway to include these dynamics in more complex 'end-to-end' ecosystem models that can serve as operating models for MSE, but to date the most fruitful ecosystem-based MSE approach has often been to strip the ecosystem model (operating model) down to intermediate levels of complexity (often 3-5 species). Here we take a different tack, retaining the complexity of end-to-end ecosystem models (for the California Current and Nordic/Barents Sea), stripping down the simulated assessment in the MSE, and testing harvest control rules that explicitly address the linkage between predators and prey, and between forage needs of predators and fisheries.

We test harvest control rules that

1) Explicitly include potential for prey-driven shifts in predator productivity. We vary the intensity of fishing on a predator (Pacific hake) dependent on the availability of prey (euphausiids) that may drive productivity shifts in the predator.

2) Provide a threshold of forage biomass, below which fishing on forage is eliminated and forage is reserved for predators. We test threshold levels of prey (copepod *Calanus finmarchicus*) abundance below which copepod fisheries are closed.

These ecosystem-based harvest control rules that address shifting productivity or threshold forage biomass are not novel, but here we explore their implications for different trophic levels and the structure, function, and catches at the ecosystem level. We adopt lessons learned from other (mostly single-species) MSE efforts in terms of how to score, plot, and summarize model performance.

Oral presentation

MODELING THE IMPLICATIONS OF STOCK MIXING AND LIFE HISTORY UNCERTAINTY OF ATLANTIC BLUEFIN TUNA

Kerr L.A., Cadrin S.X., Morse M., Secor D.H., Taylor N.G.

Atlantic bluefin tuna (*Thunnus thynnus*) is currently managed as separate eastern and western stocks. However, tagging and otolith chemistry patterns suggest that the two stocks mix seasonally and return to natal areas to spawn. Using a simulation model, we explored how scenarios of population-specific migration and uncertainty in aspects of bluefin tuna biology affect the long-term magnitude, distribution, and mixed stock nature of the resource and catch of its associated fisheries under current fishing conditions. The analytical framework was a stochastic, age-structured, stock-overlap model that was seasonally and spatially explicit with movement of eastern- and western-origin tuna informed by tagging data. Alternate estimates of movement and assumptions regarding maturity and recruitment regime for western origin fish were considered. Simulation of the operating model indicated considerable stock mixing in the western and central Atlantic, which resulted in differences between the stock and population view of western bluefin tuna. The relative biomass of the western population and its spatial and temporal distribution in the Atlantic was sensitive to model assumptions and configurations. Based on this model we developed biological reference points for bluefin tuna that incorporate the influence of mixing, as well as different productivity regimes, and maturity assumptions. Management strategy evaluation based on the spatially complex operating model and simpler estimation models are being used to test alternative management strategies against the goal of maximum sustainable yield of eastern and western spawning populations.

Oral presentation

FACTORS OF SOCIAL VULNERABILITY TO CLIMATE CHANGE AMONG SMALL-SCALE FISHING COMMUNITIES FROM THE SOUTH BRAZIL BIGHT

Martins I.M., Gasalla M.A.

Small-scale fishers are often susceptible to climate change due to a series of factors and policy trends that limit their adaptive capacity. Understanding the vulnerabilities of fishing communities and their strategies to cope with and adapt to climatic change is crucial for promoting actions that secure their livelihoods in multiple contexts. Vulnerability has been seen as a function of sensitivity, exposure, and adaptive capacity which involves the ability to anticipate, respond, and recover from the consequences of change. In such a context, the present study aimed to understand the patterns of vulnerability and adaptive capacity among eight different coastal communities of the South Brazil Bight. An integrated framework developed by the GULLS consortium (a Belmont Forum multilateral project) was adopted to allow for international and inter-regional comparisons. A total of 151 households were locally approached, interviewed and sampled in the selected communities that represent a comprehensive illustration of fishing villages from this region. Results shows that communities remoteness and lack of institutional support related to climate change are important drivers of vulnerability, while community organization, strong leadership, partnership with researchers, and resources co-management are factors that reduce vulnerability and increase adaptive capacity. Our findings represent the first social vulnerability assessment of fishing communities to climate change in the region, and generate new understanding of the issue by providing perspectives that should enhance resilience and adaptation.

Oral presentation

CLIMATE ADAPTATION IN NORTHEAST U. S. FISHERIES: ELICITING AND EVALUATING STRATEGIES OF INTEREST TO STAKEHOLDERS AND COMMUNITIES

Mills K.E., Hudson M., Colburn L.L., Eayrs S., Hartley T.W., Labaree J., Allyn A., Franklin B., Hare J.A., Kennedy B., Pershing A.J., Sun J., Thunberg E.

Across the globe, climate change is affecting marine ecosystems, fish populations, and fisheries. At local scales, climate impacts emerge in distinct ways depending on the nature and rate of ecosystem change, ways in which societies use marine resources, and adaptive capacity. In the Northeast United States, marine waters have warmed rapidly over the past decade, and impacts have been felt in culturally and economically important fisheries. Fisheries are responding to changes in resource populations and the marine ecosystem in a variety of ways: fishermen travel further to target their traditional species, switch to new species that have become prevalent in their typical fishing areas, and diversify into opportunities outside of capture fisheries. However, adaptation has largely been limited to individual-level and industry-motivated actions to date, and there is widespread recognition that management system flexibility is necessary to facilitate further adaptation. Interviews with fishery stakeholders and municipal officials in four Northeast U. S. ports (i.e., Stonington, ME; Portland, ME; New Bedford, MA; Point Judith, RI) that span a range of geographies and fisheries reveal ways in which fishermen and their communities have already responded to climate-related ecosystem changes, ways in which they want to be able to adapt in the future, and factors that facilitate and constrain adaptation (e.g., capital, knowledge, institutional arrangements). The adaptation strategies derived from these interviews are being evaluated as scenarios within a social-ecological vulnerability assessment framework that uses ecological and economic models to evaluate costs, benefits, and outcomes for fishing communities. As these strategies reflect stakeholder interests and community objectives, they can also be valuable for shaping objectives and selecting management strategies within MSE initiatives, particularly for informing social dimensions of initiatives that seek to represent the influence of climate change.

Oral presentation

A NEW CONCEPTUAL FRAMEWORK TO EVALUATE DRIVERS OF FISHING BEHAVIOR IN SMALL SCALE FISHERIES

Miñarro S., Galbraith E.

Current overpopulation and technological advances inevitably increase human pressure on marine resources, leaving responsible management as the only viable solution to achieve fisheries sustainability. In particular, the influence of small-scale fisheries' in the global wild catch appears to be much stronger than previously thought, and their catch is declining, while their complexity and context-dependency are displayed by contradicting studies of successful and failed small-scale fisheries management examples around the world. We present a conceptual framework to quantify the effect of fishers' goals and motivations on their fishing behavior and proneness to change. The framework aims to be applicable to small scale fisheries regardless of geographic location, and is based on the three-dimensional well-being concept. Fishing community characteristics such as their perceived fairness of the fishery organization, community cohesion, access to fisheries-derived benefits or environmental identity are assessed against the fishers' preferences of time allocation to fishing under different scenarios of resource abundance, invested capital, catch and seafood market price. This framework aims to contribute to disentangle the complexity of social dynamics and priorities influencing human exploitation behavior and trade-offs toward coastal marine resources.

Poster presentation

A MODEL-BASED APPROACH FOR STRENGTHENING RESILIENCE OF RESPONSIBLE MARINE FISHING AREAS IN COSTA RICA

Naranjo-Madrigal H., Elizondo-Mora S.

The complexity of socio-ecological fisheries systems, defined by their importance as a source of income, employment, food security and cultural traditions, requires the use of emerging systemic thinking concepts to face the challenges involved in their management. Although, the management of marine fisheries in developing countries is still restricted to optimization paradigms as well as top-down management initiatives, data inefficient, and poorly adapted to case-specific ecological and socioeconomic conditions. The Responsible Marine Fishing Area (RMFA), created in 2008, is a management tool developed by the Costa Rican government in order to recognize the role of fishers´ organizations in small-scale fisheries management. It was investigated case studies primarily from the Pacific Gulf of Nicoya region with the aim to identify linkages between the property right (PR) management approach, the Operational Procedure of the Code of Conduct for Responsible Fishing (OPCCRF) and the RMFAs in practice. Three sources of information -Users, Experts and Government entities- are analyzed to define the functioning of RMFAs, its relation to the OPCCRF and the quality of the PR. Bayesian Networks are used to evaluate relationships between the function of RMFAs, the OPCCRF, the quality of the PR, and the degree of co-management achieved. An alternative model of a desirable scenario of governance is proposed to guide management interventions and strengthening resilience of RMFAs, such as capacity building and research projects.

Poster presentation

FISHING FOR POWER: CONCEPTUALIZATION OF SOCIAL-ECOLOGICAL CHANGE AND MARGINALIZATION THROUGH LOCAL METAPHORS AND POLITICAL ECOLOGY NARRATIVES

Nayak P.K.

The main focus of this paper is on the role of qualitative data in further developing and implementing Management Strategy Evaluation (MSE) as a tool for sustainable fisheries. The paper investigates social-ecological change and marginalisation in small-scale fishing communities of Bay of Bengal, India. It considers changes in recent decades, impacting the social, cultural, economic, political and environmental life of fishers that have resulted in their disconnection from the fishery and marginalisation. However, there exist a paradox with regard to environmental change and fishers' marginalisation in Bay of Bengal: an official account of ecological stability along with local economic growth vs. fishers' experience of fishery depletion and decrease in their income levels. The paradox of the official account of "development" and the fishers' views about their own marginalization indicates a conundrum which I examine further in this paper. Fishers' views through metaphors they use to express environmental change processes and their marginalization are combined with political ecology narratives as a qualitative framework and an analytical tool for achieving management success and sustainable fisheries.

Linking political and ecological strands of environmental change discourses in the Bay of Bengal helps to analyze issues across a range of levels, from very micro to macro, by focusing on the influence that society, state, corporate, and transnational powers have on creating or intensifying environmental problems and influencing environmental change. The paper seeks to address gaps in dominant approaches to the study of environmental history and politics by bringing into focus the perspectives (e.g., metaphors) of local fishers, marginal groups, and vulnerable populations and using them in tandem with more sophisticated approaches such as Political Ecology. The promise lies in the potential contribution this novel approach can bring to Management Strategy Evaluation (MSE) as a tool to assess fisheries sustainability.

Oral presentation

EXPLORING TRADITIONAL ECOLOGICAL KNOWLEDGE (TEK) MARINE RESOURCES USE: A CASE STUDY FROM TWO VILLAGES IN FIJI

Qaqara N., Lowry J., Piovano S., Ryle J., Veitayaki J.

Traditional Ecological Knowledge (TEK) is the body of knowledge, beliefs, values and traditions held by a specific people about their local ecosystems. Pacific Islands are considered a region with rich knowledge of TEK which has been practiced by the people for many years and passed down from generation to generation. TEK has been rapidly changing in past years due to the influence of foreign ideas and scientific knowledge on marine resource management. In depth research is required to understand the importance of TEK and incorporate this knowledge into marine resource management plans in the Pacific.

The gaps between TEK and scientific knowledge have been acknowledged. Thus researchers need to put emphasis in documenting TEK so that factors that influence the ineffectiveness of the integration between TEK and scientific knowledge could be recognized.

This research will identify the TEK of two communities in relation to how different gender and age group use perceive and locate their fishing ground and marine resources. This pilot study will be carried out in two communities in Fiji. Several research methods will be employed such as Participatory GIS (PGIS), biological survey and ethnographic research. These research methods will complement each other and primarily aim to build effective collaboration between local resource owners and researchers in data collection.

In developing a GIS database it will be useful for the people in Fiji as well as the Pacific Islands to recognize the impact of natural and anthropogenic influences on marine environment and areas where better solutions for marine management can be identified. Recommendations and lessons learn from this research will be used to strengthen fisheries management in Fiji and the Pacific Islands communities.

Oral presentation

MAPPING THE HUMAN DIMENSIONS OF ANALYTIC TOOLS FOR FISHERIES MANAGEMENT

Sbrocchi C.D., Barclay K., Fulton E.A.

Fisheries are often more than a business – they are a connection to the sea, a livelihood and part of a wider social fabric. However, existing fishing rules typically do not account for the myriad interactions happening below and above the sea - the complexity of ecological interactions, external drivers, local socio-economic issues and institutional constraints.

My PhD project involves evaluating existing fisheries decision support tools for their ability to account for environmental, social, economic, institutional and sustainability objectives. This comparative analysis will provide some understanding of the strengths and weaknesses of different tools as socio-ecological assessment frameworks for reporting on multiple objectives, particularly the socio-political dimensions of fisheries. This process will highlight how and where information from the social sciences can influence or direct MSE development.

Finding ways to better integrate the 'human' with the 'environmental' will help managers and policy makers to make more transparent, equitable and fair decisions. It will also help fishers and other community members become an integral part of the decision making process, by making their long-term needs a factor in the decision.

Oral presentation

DEVELOPING HARVEST STRATEGIES FOR THE WESTERN CENTRAL PACIFIC TUNA FISHERY

Scott R., Reid C.

The annual tuna catch from fisheries of the Western Central Pacific Ocean (WCPO) in recent years has been in excess of 2.5 million tonnes, accounting for more than 50% of the global tuna catch and having a total estimated catch value in 2015 of around $5 billion. As the fisheries have developed, management discussions at the sub-regional (e.g. the Parties to the Nauru Agreement and the Forum Fisheries Agency members) and regional (Western and Central Pacific Fisheries Commission) level have moved toward a formalised harvest strategy approach. The development of harvest strategies has been challenging due to the differing management objectives within the region's fisheries, in particular those of the different stakeholders within the purse seine fishery and target skipjack stock, and the south Pacific longline fishery and its albacore target stock. We provide an overview of the state of the tuna fishery in the WCPO, the challenges encountered in developing and agreeing the components of WCPO harvest strategies, and anticipated developments in the near future.

Oral presentation

EVIDENCE OF ECOSYSTEM BASED ADAPTATION IN COASTAL FISHERIES OF BANGLADESH

Selim S.A., Bhowmik J.

Coastal waters of Bangladesh support extraordinary high levels of biological productivity including productive fisheries vital to the economy and food security of Bangladesh. At the same time, Bangladesh coast globally among the most vulnerable to climate change, where the coastal population are highly dependent on coastal ecosystem natural resources. The importance of fish habitats and biodiversity is enormous for the livelihoods of millions of people, trade, jobs and protein supply here. There is mounting evidence that demonstrate the impacts of climate change on fisheries.

Ecosystem Based Adaptation (EBA), a type of Ecosystem-based management, uses biodiversity and ecosystem services as part of an overall adaptation strategy to help people and communities adapt to the negative effects of climate change at different scales. Ecosystem based Adaptation (EbA) has great potential to increase people's resilience and ability to adapt, but it is not yet integrated in national and international policy processes and its use in fisheries sector is limited. In this study, we review a selection of community based adaptation practices that were developed as part of the CREL (Climate Resilient Ecosystem and Livelihoods) project along the coastal region of Bangladesh. We use an EbA framework to understand benefits and co-benefits, opportunities and challenges in management and adaptation of coastal ecosystems and fisheries to impacts of climate change.

Oral presentation

EMERGING GOVERNANCE REQUIREMENTS: MANAGE FISH AND PEOPLE FOR A COHERENT AND SUSTAINABLE EXPLOITATION IN THE ROMANIAN BLACK SEA

Vaidianu N.

In Romania, there is a more intense pressure on the marine resources, especially on fisheries. Marine fisheries have been overexploited in the last 70 years, in the form of open-access common until 1989 and under regulations after 1990, especially after EU accession in 2007. Consequently, the fish stocks are on the huge decline which induce evidence that these declines are being countered by changes in either fishing regulations or fishing practices. Because of these shifts, fishermen frequently comply with new regulations and operationalisations. In these circumstances understanding how fishermen perceive the new Natura 2000 expansion and use resources is very important for management and policy implications. Our study examined fishermen's perceptions about the state of fish stocks and emerging governance and management strategies in Romania. We surveyed fishermen in Sfantu Gheorghe village, Danube Delta Biosphere Reserve. We found that all fishermen perceived a decline in catch and this extend (until 40 m depth) will affect their activity. Conflicts raise because they must adapt to these declines by increasing fishing area and time spent, changing their gear, and overlapping in fishing zones. Even there is a Strategy for sustainable development in the Danube Delta, we identified an incoherence of regulations with government incentives. Questions regarding sustainable governance in its encompassing understanding come more to the fore, by far not only relating to environmental concerns. Until now, those interactions have not been tackled very actively neither in governance nor conservation planning. However, the need is well recognised. Valuable applied approaches, like integrated coastal zone management and marine spatial planning, have attempted to take a more holistic approach. We recommend strengthening local fishing communities by enabling them to enforce fishing regulations locally. However, this is often not yet reflected in the existing governance regimes.

Oral presentation

DEVELOPING A FRAMEWORK FOR EVALUATING STRUCTURAL UNCERTAINTY IN SOCIAL-ECOLOGICAL SYSTEM MODELS: A BAYESIAN NETWORK APPROACH

Wildermuth R.P.

Management strategy evaluation entails modeling the dynamic response of a social-ecological system to prescribed management actions and determining whether system indicators are likely to meet thresholds for one or more objectives. Developing models of marine social-ecological systems means analysts must confront multiple uncertainties that are difficult to test empirically due to the complexity of marine systems and gaps in data availability. Notably, choices about model structure and functional forms have important influences on model estimates and management outcomes. Sensitivity analyses assessing these choices are difficult and costly to perform, particularly for whole-of-system models. I develop a framework to assess uncertainty in social-ecological model structure using a Bayesian network approach for the Georges Bank marine system. Bayesian networks define semi-quantitative probability relationships between potential states of system components in a network. I describe how empirical data on Georges Bank indicators and expert knowledge are combined to construct a dynamic Bayesian network to assess performance of ecosystem-based management strategies. The Georges Bank system model is composed of physical, ecological, and socioeconomic components signifying indicator data. Two levels of complexity representing simpler and more complex bioeconomic model structures are explored to contrast assumptions and hypotheses about the human dimensions of the system found in classical assessments. Evaluating "what if" queries from these Bayesian network structures helps assess robustness of management strategies to structural uncertainty and provides an ensemble of potential outcomes related to multiple management objectives. This framework helps address 1) sensitivity to choices about model structure when incorporating economic and social factors and objectives in whole-of-system models and 2) difficulties integrating qualitative information into social-ecological models to fill quantitative data gaps. Finally, the approach presented here proposes the development of whole-of-system models using Bayesian network methods and explores the strengths and weaknesses of these methods for use in management strategy evaluation.

Oral presentation

EFFECTS OF CLIMATE CHANGE AND FISHING ON THE PEARL RIVER ESTUARY ECOSYSTEM AND FISHERIES

Zeng Z., Cheung W.W.L., Li S., Hu J., Wang Y.

Climate change is considered as a new threat to fish stock and marine ecosystems and a new challenge to management of ocean biodiversity. In Pearl River Estuary (PRE), climate change would make this area confront unprecedented and hard to predict stresses, which has experienced overexploiting fish recourse since 1980's. Understanding the ecosystem response to climate change and interactions with fishing activity is paramount to predicting future ecosystem states in the PRE. We linked the simulation results of climate change scenarios (RCP 2.6 and RCP 8.5) from Geophysical Fluid Dynamics Laboratory Earth System Model ESM2M with Ecosim for the PRE to predict changes in landings, biomass and indicators of community composition under individual climate factors and combined climate impacts with different level of fishing efforts in 2050. Under individual factors effects, primary production change and temperature change are important implications for landings and biomass. Biomass changes indicate that the response of species to climate change depended on interactions between the physiological and ecological processes. Physiological processes are likely modified when indirect effects are taken into consideration alongside direct effects in ecological level, specially for top-down control ecosystem state. Climate change is predicted to be potential threat to fisheries and ecosystem in PRE, especially for the overexploited high-value demersal fish species. Reducing fishing efforts can mitigate the effects of climate change on some functional groups, but some traditional commercial demersal fish are potential to experience higher predation mortality which causes their biomass decreasing in low fishing scenarios. Our consequences highlight the sensitivity of demersal fish to both fishing and climate change impacts in PRE. Our projection provides future analytical and empirical studies with hypotheses of climate change impacts, which can be a climate change-adaptation foundation for the future fish resource management in PRE.

Oral presentation

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