REPORTING FORM 2025

Insert Name of Science Team: CMWG

Operating Period as an IMBeR Member:

- *Start Year: 2018*
- *End Year: 2025*

List of Authors

1. Ongoing activities, in line with the IMBeR Grand and Innovation Challenges

(Among other uses, information will be used to update the IMBeR Annual Report to SCOR)

1.a. Grand Challenge I

Understanding and quantifying the state and variability of marine ecosystems - with focus on Research Objectives 1 to 3:

***Research Objective 1**. Evaluate and predict the cumulative effect of multiple stressors*
***Research Objective 2**. Integration of climate change and climate variability*
***Research Objective 3**. Impacts on society – preparation for a changed future*

Add text…

Oyster farming enhances seawater carbon removal through dual pathways: direct calcification and indirect filtration effects. Field and lab studies in Sanggou Bay show farming areas have significantly lower dissolved inorganic carbon (DIC) levels. Experiments demonstrate oyster filtration rapidly improves water transparency, stimulating phytoplankton growth and photosynthetic carbon uptake, accelerating DIC removal beyond direct calcification effects. This reveals oysters' ecosystem engineering role in marine carbon cycling (Li et al., MER, 2024).

Aquaculture impacts on silicon cycling in Sanggou Bay: Farmed species significantly influence nutrient cycles, yet their role in silicon (Si) dynamics remains unclear. Our study reveals seasonal variations in dissolved silicate. While bivalve excretion and harvesting strongly affect nitrogen/phosphorus cycles, Si cycling depends more on external inputs and internal processes. Key findings show high biogenic silica burial efficiency; bivalve biodeposition enhances Si retention; suspension feeders accelerate Si cycling through biodeposit production, potentially boosting diatom-mediated CO_2 uptake. These results demonstrate bivalves' unique capacity to modify Si budgets in aquaculture systems through biodeposition mechanisms (Li et al., FMS, 2024).

Many aquaculture environments suffer from significant silicon deficiencies and severe heavy metal contamination, posing substantial risks to both production and safety in aquaculture. Rice husk ash significantly enhanced diatom populations while showing no detectable heavy metal residues, proving its safe application as both phytoplankton stimulant and heavy-metal adsorbent for sustainable aquaculture management (Jiang Aquaculture, 2025).

A Kuroshio-spawned eddy reshaped nitrogen cycling in the northern South China Sea, doubling particulate export while sustaining 12% new production via atmospheric/fixed nitrogen. The eddy accelerated DIN turnover and layered isotope signatures: nitrification (upper 800m), Pacific-sourced denitrification signals, and surface assimilation - demonstrating mesoscale control on regional biogeochemistry (Zhou et al., JGR, 2025).

Nitrogen cycling in Changjiang Estuary shows light-dependent competition: phytoplankton dominate NH_4^+ uptake in surface layers, while nitrifiers prevail at depth. Peak activity in bloom/turbidity zones highlights how NO_3^- availability and NH_4^+ regeneration drive estuarine productivity under anthropogenic nutrient loads (Hou et al., MER, 2025).

1.b. Grand Challenge II

Improving scenarios, predictions and projections of future ocean-human systems at multiple scales - with focus on Research Objectives 4 to 6:

Research Objective 4*. Development of integrated data systems and approaches for predictions and projections*
Research Objective 5*. Development of predictive models and projections for use at regional scales*
Research Objective 6*. Development of alternative scenarios to bridge the gap between physical climate sciences and humanities*

Add text…

1.c. Grand Challenge III

Improving and achieving sustainable ocean governance - with focus on Research Objectives 7 to 9:

Research Objective 7*. Develop knowledge on best practices for multilevel governance approaches to ocean climate adaptation and mitigation*
Research Objective 8*. Develop understanding on key ingredients for transformation towards more sustainable, equitable and inclusive governance approaches to fisheries and aquaculture*
Research Objective 9*. Support implementation of post-2020 biodiversity targets for marine spatial planning and marine protected areas*

Add text…

oysters not only remove the inorganic carbon in the seawater through calcification but also create a suitable environment for phytoplankton photosynthesis through their filtering activity, and subsequently accelerating the removal of inorganic carbon in the seawater of the oyster farming area (Li et al., MER, 2024).

Rice husk ash simultaneously addresses aquaculture challenges by releasing bioavailable silicate to boost diatom growth and adsorbing Hg^{2+} without heavy metal residues, demonstrating safe dual utility of agricultural waste for sustainable water management (Jiang Aquaculture, 2025).

1.d. Innovation Challenge 3

To advance understanding of ecological feedbacks in the Earth System

Add text…

Oyster filtration rapidly improves water transparency, stimulating increased Chl-a and photosynthetic carbon uptake, accelerating DIC removal beyond direct calcification effects (Li et al., MER, 2024).

1.e. Innovation Challenge 4

To advance and improve the use of social science data for ocean management, decision making and policy development

Add text…

1.f. Innovation Challenge 5

Interventions to change the course of climate impacts

Add text…

1.g. Innovation Challenge 6

Sustainable management of Blue Carbon ecosystems

Add text…

Oyster filtration rapidly improves water transparency, stimulating increased Chl-a and photosynthetic carbon uptake, accelerating DIC removal beyond direct calcification effects (Li et al., MER, 2024).

2. Selected highlights

2.a. Selected scientific highlights since last report (1-5)

Last report was submitted to SCOR, August 2024

Add text…

Large-scale oyster farming enhances dissolved inorganic carbon (DIC) removal through both direct and indirect mechanisms, as demonstrated by field and experimental studies in Sanggou Bay, China. Field measurements revealed significantly lower DIC levels in oyster farming areas compared to non-farming zones. Controlled experiments confirmed this trend, with higher DIC removal rates observed in water from farming areas, regardless of light conditions. Pond simulations further revealed that oyster filtration indirectly promotes DIC drawdown by improving water transparency within hours, creating favorable light conditions that stimulate phytoplankton growth and subsequent photosynthetic carbon uptake. Notably, water pre-exposed to oyster filtration exhibited faster DIC decline and Chl-a increase compared to controls. These findings highlight a dual carbon-removal pathway: direct calcification and respiration, coupled with filtration-mediated enhancement of phytoplankton-driven carbon sequestration, collectively amplifying DIC removal in oyster farming ecosystems (Li et al., MER, 2024).

2.b. Publications since last report

Please add all publications since last report to the table below (see notes for details on "Class" and "Activity" fields).

***Publication** with DOI*	***Class 1, 2, 3***	***Activity****
Li, J. et al. Large-scale oyster farming accelerates the removal of dissolved inorganic carbon from seawater in Sanggou Bay. Mar. Environ. Res. 202, 106798 (2024). https://doi.org/10.1016/j.marenvres.2024.106798	*1*	
Li R, Jiang Z, Lin F, Zhang Y, Wang W,Zhang K, Li W, Wan D and Shi Y (2024) Silicon balance in an integrated multi-tropical aquaculture ecosystem, Sanggou Bay, China. Front. Mar. Sci. 11: 1431878. doi: 10.3389/fmars.2024.1431878	*2*	
Jiang, W. et al. Utilization of rice husk ash as a potential catalyst for diatom growth and adsorbent for heavy metals in aquaculture systems. Aquaculture 595, 741533 (2025). Doi: 10.1016/j.aquaculture.2024.741533	*2*	
Zhou, N., Liu, S., Ren, J., Wu, Y., Li, L., Wang, J., & Ning, X., 2025. Responses of nutrient biogeochemistry to a mesoscale eddy detached from the Kuroshio loop current. Journal of Geophysical Research: Oceans, 130, e2024JC021792. https://doi. org/10.1029/2024JC021792	*2*	
Dong, Shuhang, Sumei Liu, Jingling Ren, Feng Zhou, Jing Zhang. 2024. Nutrient dynamics and cross shelf transport in the East China Sea. Acta Oceanologica Sinica, 43(10), 48–62. doi: 10.1007/s13131-024-2419-3	*2*	
Hou, Xing, Chongcong Liu, Guodong Song, Jinglong Mu, Wen Liang, Haoming Xu, Nian Wu, Wenqi Xu, Su Mei Liu, 2025. Nitrogen uptake and nitrification in the Changjiang estuary. Marine Environmental Research 209, 107206. https://doi.org/10.1016/j.marenvres.2025.107206	*2*	

[Add more rows if needed]		

**If appropriate, please list the IMBeR activity through / by / from / during which the publication arose*

*******Notes on publications*******

Publications are logged in the IMBeR Zotero library which is publicly accessible online –

[Publications since 2016] | [Publications prior to 2016]

Publications are categorised by "Class" and linked to "Activities":

Class 1 publications are specifically generated through/by/from/during ***IMBeR activities*** - for example, arising from IMBIZOs and IMBeR conferences such as the IMBeR open science meeting and the IMBeR West Pacific symposia and from the activities of the working groups, regional programmes and the SPIS scoping teams.

Class 2 publications are on topics relevant to the IMBeR Science Plan that benefitted from some interaction with IMBeR or ***IMBeR activities***, for example by IMBeR symposium attendees, past and present SSC members, working group, regional programme and endorsed project members, or national contacts.

Class 3 publications are on topics relevant to the IMBeR Science Plan but for which there is no direct link to or benefit from an IMBeR activity. These might include publications by SSC members, working group, regional programme or endorsed project members or members of the IMBeR international community that were written as part of the normal scientific activity of the authors and would have occurred irrespective of IMBeR's existence. You can report Class 3 publications, but they will no longer be logged in the IMBeR database.

[See "What is an IMBeR publication?" for further information]

Why list 'Class' and 'Activity'? This helps us to declare authentically which publications IMBeR has helped to generate, and it makes it easier for us to demonstrate the value of the Regional Programmes, the Working Groups, and IMBeR in general, and it helps us to justify support for IMBeR activities when we can list tangible outputs.

2.c. Events, Meetings, and Workshops

List all international and national events, meetings and workshops. Describe the level of participation: e.g. chairing session/workshop, organising meeting. Include Endorsed Projects committee meetings and workshops.

Format: Title of event. Date. Location. Description of participation. Any other pertinent details.

Add text…

Dr. Su Mei LIU attended the IMBeR Synthesis and Future Planning Conference – Future Oceans 3 (May 13-16, 2025). She delivered a synthesize presentation on behalf of CMWG- Ecosystem health of continental marginal seas under the interaction between ecosystem and society. Additionally, she convened session 8 (Synthesizing ecosystem-social interactions in coastal seas). The session spanned aquaculture carbon storage, coastal geomorphology, ecosystem health models, century-scale phytoplankton shifts, and watershed management across China's coastal bays, culminating in a planned special issue on long-term ecological changes.

Dr. Su Mei LIU attended the CAS-sponsored *Forum on Frontiers of Science & Technology (No. 195): Climate Change and Ecosystems in the Northwest Pacific Ocean* (April 15-17, 2025). As co-chair with Dr. Pavel Ya. Tishchenko for Session 3 (Ocean Biogeochemistry and Ecosystem Sustainability), she delivered the keynote *"Ecosystem and Physicochemical Changes in Marginal Seas"*, analyzing anthropogenic and climatic impacts on coastal marine systems. Her presentation emphasized that given the complex human-nature interactions in marginal seas (demonstrated by China/Japan cases), do Russian marginal seas provide climate-driven counterparts for comparative studies with human-dominated systems?

On October 24, 2024, during the Centennial Celebration of Ocean University of China - the 16th "Haichuan" Academic Forum: Marine Pollution Environmental Chemical Processes and Ecological Effects & the 10th Marine Carbon Neutrality Innovation Forum in Qingdao, and Su Mei LIU delivered a presentation entitled "Evolution of Coastal Ecological Environment in China", which focused on key advancements in one of the core research priorities of the Continental Margins Working Group's Chinese marginal seas case study.

3. International collaboration and links

Add text…

4. Input to management, policy and SOCIETY* over the last year

Add anything that is not covered under "1.c. Grand Challenge III"

**As previous reporting forms requested 'input to management and policy' only, please add any 'input to society' not captured in previous reports*

Add text…

5. Education, outreach and Capacity Development

Add text…

6. Planned activities

6.a. Activities and Outreach and how they link to the Challenges (including, but not limited to convening sessions, meetings, summer schools, workshops, etc)

Add text…

As a core case study of the Continental Margins Working Group, the objective of the Chinese marginal seas case study is to assess the impacts of major socio-economic demands on the ecological health of Chinese marginal seas and their subsequent effects on human well-being, to establish the scientific basis for actions needed to enhance the sustainable use of ecosystems, to meet the current and future societal demands expressed by the UN Sustainable Development Goals, and to provide a set of scientific themes for different countries facing similar challenges across the different climate from tropics to the cold temperate regions. The major progress includes identified the outline of overview of the Chinese marginal seas and discussed the possibilities to curate a special issue exploring long-term ecological changes and their societal linkages.

6.b. Upcoming papers (Community-Position-Review-etc)

Add text…

8. Changes to Organisational Structure

Add text…

9. Images / Figures

*****It is always good to have some recent photos / figures / infographics to create more exposure for the Regional Programmes, Working Groups, etc. These can range from those suitable for a very scientific audience, to those that would engage the general public. IMBeR would use these, on the website (e.g. http://www.imber.info/ and http://www.imber.info/en/news), in tweets (@imber_ipo), in presentations, etc. In addition, Future Earth (one of our sponsors) regularly asks us to provide high quality images for their glossy reports. These can highlight the activities of IMBeR and their other Global Research Projects (see pdfs of past Future Earth reports here https://futureearth.org/publications/annual-reports/)*

*So, please provide any images that you might think are useful. These can be pasted in this document or emailed as an attachment to imber@ecnu.edu.cn.*****

10. Notable achievements over the IMBeR decade (2016-2025)

10.1 Develop a conceptual framework for the Continental Margins Working Group and outline plans for the Chinese marginal seas case study. The Chinese marginal seas are surrounded by densely populated and rapidly developing coastal regions, leading to intense human pressures on adjacent seas. These human-induced stressors compound the existing challenges faced by marine ecosystems already impacted by climate change. The objective of the Chinese marginal seas case study is to assess the impacts of major socio-economic demands on the ecological health of Chinese marginal seas and their subsequent effects on human well-being, to establish the scientific basis for actions needed to enhance the sustainable use of ecosystems, to meet the current and future societal demands expressed by the UN Sustainable Development Goals and to provide a set of scientific themes for different countries facing similar challenges across the different climate from tropics to the cold temperate regions. Key research issues include: Eutrophication and pollution status: past, present, and future; Mariculture and its sustainability; Service variability and sustainable management. Six core research priorities have been identified: The ecosystem and physicochemical changes (1960-present): long-term trends in environmental and ecological shifts (led by Su Mei Liu, Ocean University of China), Mariculture impacts and sustainable sea food supply: evaluating ecological effects and optimizing aquaculture practices (led by Zeng-Jie Jiang from Yellow Sea Fisheries Research Institute), China's Blue Carbon Ecosystems: evolution, conservation and management under global change (led by Qinhua Fang from Xiamen University), Integrated spatial planning: balancing food-secure and carbon neutrality in the blue economy (led by Hui Liu from Yellow Sea Fisheries Research Institute), Coastal pollution mitigation: strategies for sustainable pollution control (jointly led by Jian-Hui Tang from Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences and Nan Zheng from National Marine Environmental Monitoring Center), and Policy-relevant Science: measures to ensure the sustainable development of marginal seas (led by Jia-Yu Bai from Nankai Univerisity)

10.2 The Bohai Sea, a critical marine ecosystem and aquaculture hub in China, has undergone significant transformations due to anthropogenic pressures and climate change. Long-term monitoring (2000–2019) reveals shifting nutrient dynamics: dissolved inorganic nitrogen (DIN) and DIN/DIP ratios peaked in 2013 then declined, with nearshore areas responding fastest to human activities. Recent DIN/DIP ratios near or below Redfield values in deeper waters (>20 m) indicate a potential shift from phosphorus to nitrogen limitation, coinciding with ecological recovery. Seasonal studies highlight spatial-temporal nutrient variability—depletion in spring/summer surface waters versus accumulation in summer bottom layers and autumn/winter—with Laizhou Bay persistently P-limited and other areas experiencing seasonal N/Si limitations. Turbulent mixing and riverine inputs drive nutrient resupply, while anthropogenic factors alter stoichiometry. Mitigation measures like fishing bans, pollution controls, and stock enhancement aim to restore ecosystem balance, offering insights for global marginal seas facing similar multi-stressor impacts.

Concurrently, precipitation studies at Qianliyan Island (Yellow Sea, 1997–2019) demonstrated rising NO_3^- and declining SiO_3^{2-} concentrations, reflecting reduced acid rain due to SO_2/NO_x controls and decreased dust transport. Precipitation nutrient composition varied by source, with oceanic air masses delivering higher PO_4^{3-}, DON, and DOP but lower DIN than northern arid regions, potentially influencing phytoplankton dynamics. **Together, these findings highlight the effectiveness of regional emission and nutrient management policies while underscoring the complex interplay between atmospheric deposition and marine nutrient cycling in driving ecosystem changes.**

10.3 Dam-regulated reservoirs in the Yellow River reshape nutrient cycles via stratification-driven processes, with Xiaolangdi Reservoir acting as a net nutrient source. Long-term declines in dissolved inorganic nutrients but rising dissolved organic phosphorus reflect reservoir retention and phytoplankton uptake. Fertilizer, sewage, and runoff dominate inputs. Prioritizing fertilizer efficiency, sewage treatment, and "green" policies could curb fluxes, leveraging reservoir-mediated stoichiometric adjustments to alleviate P limitation downstream.

10.4 Mariculture impacts and sustainable sea food supply case study: The multi-function ecological anchoring system and coverage improvement of the new variety enhance the efficiency of integrated multi-trophic aquaculture (IMTA) system, the overall economic benefits have increased by more than 30%. Technical specification of IMTA in shallow sea (kelp, oyster and sea cucumber) were formulated and issued by Ministry of Agriculture and Rural Affairs.

10.5 An ecosystem model of Sanggou Bay assessed aquaculture-environment interactions, showing that higher oyster and kelp densities increase production but reduce individual growth, with kelp playing a key role in nutrient cycling. Meanwhile, ocean acidification (OA) studies revealed that elevated pCO_2 impairs Pacific oyster physiology, but co-culture with kelp mitigates these effects by stabilizing pH. Similarly, OA disrupts Manila clam burrowing behavior by altering $GABA_A$ receptor function from inhibitory to excitatory due to acid-base imbalance. These findings highlight integrated aquaculture's potential to buffer OA impacts and underscore the neurophysiological mechanisms behind OA-driven behavioral changes.

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10.x…

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11. A list of Synthesis Products

Add text…

Fan, Lin. et al. A physical-biological coupled ecosystem model for integrated aquaculture of bivalve and seaweed in sanggou bay. Ecol. Model. 431, 109181 (2020).

Jiang, W. et al. CO2-Induced Ocean Acidification Alters the Burrowing Behavior of Manila Clam Ruditapes philippinarum by Reversing GABAA Receptor Function. Environ. Sci. Technol. 57, 8921–8932 (2023).

Jiang, Z. et al. The Potential of Kelp Saccharina japonica in Shielding Pacific Oyster Crassostrea gigas From Elevated Seawater pCO2 Stress. Front. Mar. Sci. 9, 862172 (2022).

Li, J. et al. Large-scale oyster farming accelerates the removal of dissolved inorganic carbon from seawater in Sanggou Bay. Mar. Environ. Res. 202, 106798 (2024). https://doi.org/10.1016/j.marenvres.2024.106798

Liu, Su Mei, Wen Liang, Xinyu Guo, Nian Wu, Wuchang Zhang, Xiujuan Shan, Hua-De Zhao, Juying Wang, Jin Huang, 2023. Biogeochemistry-ecosystem-social interactions on the Chinese margins. Oceanologia, 65, 278—296, https://doi.org/10.1016/j.oceano.2022.12.001

Liang, Wen, Yan Wang, Jinglong Mu, Nian Wu, Juying Wang, Sumei Liu, 2023. Nutrient changes in the Bohai Sea over the past two decades. Science of the Total Environment, 903, 166696. https://doi.org/10.1016/j.scitotenv.2023.166696

Mu, Jinglong, Hongmei Zhang, Su Mei Liu, Nian Wu, Guodong Song, Shuai Ding, Xiaotong Zhang, 2024. Nutrient dynamics in the Yellow River -a case study of different reservoir regulation operations. Journal of Hydrology, 629, 130563. https://doi.org/10.1016/j.jhydrol.2023.130563

Wu, Nian, Su-Mei Liu, Gui-Ling Zhang, Hong-Mei Zhang, 2021. Anthropogenic impacts on nutrient variability in the lower Yellow River (Huanghe), Science of The Total Environment, 755, 142488. https://doi.org/10.1016/j.scitotenv.2020.142488

Zhang, Ke, Sumei Liu, Lingyan Wang, 2024. Two decades variations of nutrients in precipitation at the Qianliyan island, the western Yellow Sea. Atmospheric Environment, 321, 120321. https://doi.org/10.1016/j.atmosenv.2023.120321

11. Reflections

Add text…

Technical specification of integrated multi-trophic aquaculture was formulated and issued by Ministry of Agriculture and Rural Affairs.

12. Recommendation for future work

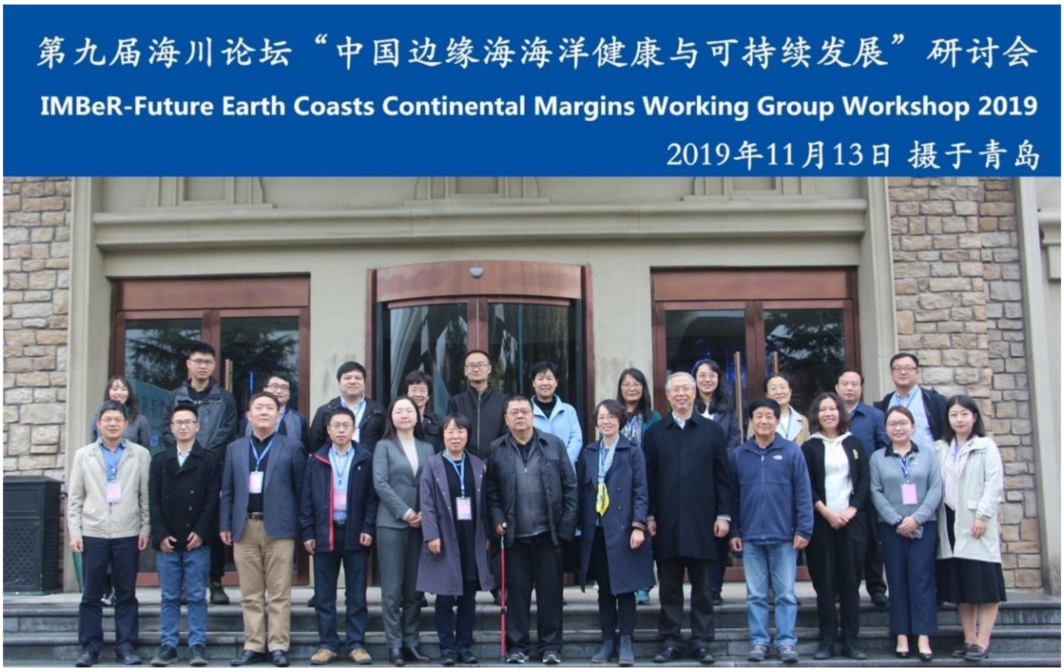
Add text…

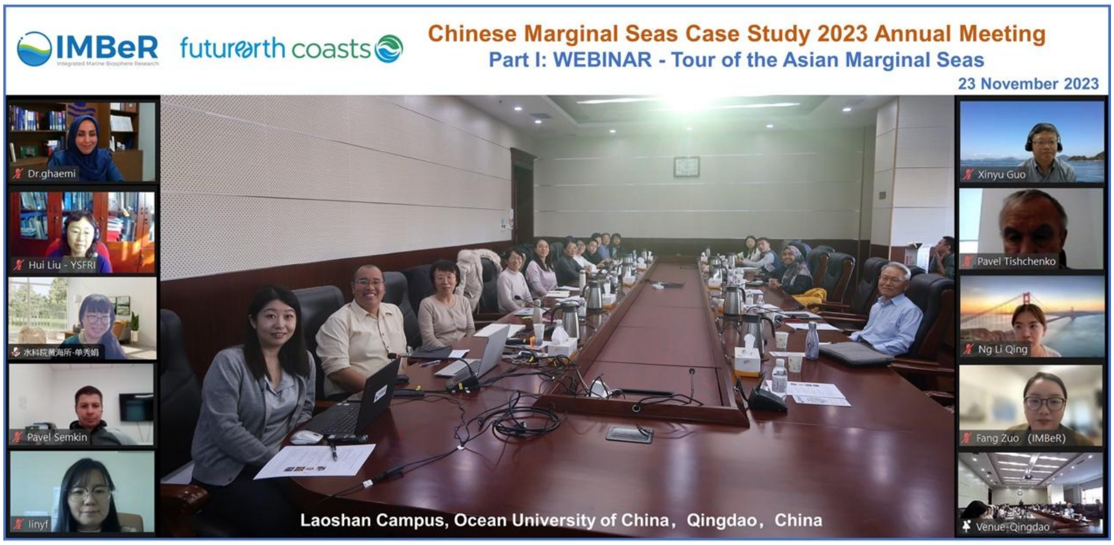
Targeted regions include anthropogenic activities-dominated such as the Chinese marginal seas, the Seto Inland Sea, Japan; climate change-dominated. The key research priorities will be expanded to encompass ecosystem resilience studies and applications of artificial intelligence (Al).

13. Anything not covered above

Add text…

Here are a few examples for CMWG group activities.

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Integrated Marine Biosphere Research
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Part I: WEBINAR - Tour of the Asian Marginal Seas
23 November 2023
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Pavel Tishchenko
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SC/T 2111—2021

浅海多营养层次综合养殖技术规范
海带、牡蛎、海参

Technical specification of integrated multi-trophic aquaculture in shallow sea—Kelp, oyster, sea cucumber

2021-11-09 发布　　2022-05-01 实施

中华人民共和国农业农村部　发布

14. Appendices

Add appropriate meeting / workshop reports and include URLs (this helps to track where online content is missing)

Add text…