Recommendation on Emergent Scientific Issues for Sustainable Use of Marine Ecosystem Services in Southeast Asia

For United Nations Decade of Ocean Science for Sustainable Development (2021–2030) and SDG14 "Life below Water"

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International Committee of Marine Ecosystem Study for

SDG14 in Southeast Asia (IMESSA)

Preface

Marine ecosystems in Southeast Asia are characterized by high biodiversity and high productivity. More than 60% of the population in Southeast Asia live 60 km from sea, and human society has benefited from marine ecosystem services such as food supply, water purification, preventing tsunami damage and storms, aesthetic and spiritual services. Many different cultures are nurtured by services from healthy ecosystems. However, marine ecosystems have been degraded by human activities and global climate change. Impacts of anthropogenic perturbations are now obvious in various ways, such as marine heat waves, coral bleaching, decreasing fishery production, and harmful algal blooms. These are looming threats for the sustainability of our society.

On 5 December 2017, the United Nations proclaimed a *Decade of Ocean Science for Sustainable Development* (2021–2030, hereafter Ocean Decade). The aims of the Ocean Decade are to support efforts to reverse the cycle of decline in ocean health and gather ocean stakeholders from around the world withing a common framework. This will ensure ocean science can fully support countries in creating improved conditions for sustainable development of the ocean and to reach the UN Sustainable Developmental Goals (SDGs), especially for SDG14 "Life below Water".

The UN declaration of the Ocean Decade made clear the request from society to scientists to prepare the best scientific knowledge on conservation and sustainable use of marine ecosystems. However, our understanding of the status of the Southeast Asia marine ecosystem is still limited. It is not possible for one scientist or one country to fully respond to the request from society because marine scientific issues are complex and cut across multiple scientific disciplines and borders of nations. We need to develop an international science network for the Ocean Decade and SDG14. At the same time, capacity building activity to develop marine science technology is also essential to advance science.

To plan scientific activity in the Ocean Decade, scientists from Southeast Asia and Japan gathered in Kashiwa, Japan in September 2019. The attendee exchanged information on changing ecosystems, obstacles to scientific activities, new technology, and, finally, identified emergent issues for sustainable use of marine ecosystem services in Southeast Asia. They established the International Committee of Marine Ecosystem Study for SDG14 in Southeast Asia (IMESSA) for 1) drafting recommendations on emergent scientific issues for conservation and sustainable use of marine ecosystem services in Southeast Asia, and 2) developing an international scientific collaboration network for the Southeast Asia marine ecosystem. The recommendations are based on the attendees' strong desire for conservation and sustainable use of the marine ecosystem services on which our society and human well-being are dependent.

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Terms of references:

To contribute to a draft recommendation on emergent scientific issues for conservation and sustainable use of marine ecosystem services in Southeast Asia.

To develop an international scientific collaboration network for the Southeast Asia marine ecosystem.

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Introduction

Marine ecosystems in Southeast Asian (SEA) are comprised of diverse ecosystems such as coral reefs, mangrove forests, seagrass beds, and a deep basin over 4000-m deep. These diverse environments harbor unique and high biodiversity in the region, and SEA marine ecosystems are known as a hotspot of biodiversity in the world ocean.

One important characteristic of SEA marine ecosystems is the high population along the coasts (>600 million). Coastal regions are highly utilized from artisanal fisheries to tourism and the oil and gas industry. Societies in SEA tightly couple with marine ecosystems. Human well-being, economic growth and culture depend on diverse services form the marine ecosystems. However, there is growing concern over the threat to biological diversity and the degradation of marine ecosystems with increasing human demands and coastal development.

The impacts of global warming are obvious in marine ecosystems. It is an emergent issue to develop an adaptive strategy for conservation and sustainable use of marine ecosystem services in SEA. Preparing the best-scientific knowledge and appropriate timing is the request from society to the scientific community. However, our knowledge on marine ecosystem structure and dynamics is still insufficient, partly due to the complexity of the ecosystem, limited human and financial resources and a rapidly changing ecosystem under anthropogenic forcing. To respond to the request from society, we need to proceed with scientific activities, especially on emergent issues in the Anthropocene, under a scheme of international collaboration and transfer of marine science technology. Here, we recommend the following scientific activities to address the emergent issues of the marine ecosystems in SEA.

Emerging Issues for Sustainable Use of Marine Ecosystem Services in SEA

1. Biodiversity and Marine Ecosystem Dynamics
2. Eutrophication and Pollution
3. Physical Oceanography and Modeling
4. Social-Ecological System

1. Biodiversity and Marine Ecosystem Dynamics

Anthropocene is the era of mass extinction. The impacts of anthropogenic forcing on biodiversity are distinct in SEA marine ecosystems, a hot spot of marine biodiversity in the world. Many species become extinct before they are recorded. Despite their importance, the status and trend of biodiversity and the food-web structure are studied only in limited regions in SEA. This is due to high biodiversity, a highly complex food-web and limited specialists for each taxonomical group of the marine ecosystem components especially for benthos and plankton. It is labor-intensive and time-consuming work to comprehend biodiversity, and t has taken years or decades to construct biodiversity inventories involving many taxonomical specialists for each ecosystem. The situation is now changing through the advancement of molecular techniques for species identification, i.e., metagenomics of environmental DNA (eDNA) by means of high-throughput DNA sequencers and open data-bases of DNA (e.g., Mitofish: http://mitofish.aori.u-tokyo.ac.jp/). These methods are simple, fast, and less expensive than traditional morphological taxonomies. By sampling only one bucket of water, it is possible to detect more than 100 species at one site. The prey-predator relationship and food-web structure can also be examined by stomach/gut content analysis using this method. eDNA also makes it possible to monitor temporal changes in ecosystem structure. Frequent monitoring is necessary to detect the impact of anthropogenic forcing on SEA marine ecosystems. It is essential to use this method in the SEA marine ecosystem for capacity development activities.

eDNA is only useful when a DNA database is developed through morphological taxonomic studies. Therefore, the study of morphological taxonomy needs to be accelerated by collecting DNA information. Application of new techniques to examine morphology, such as digital 3D morphology by means of micro computed tomography (micro CT), is useful to progress the taxonomy and biomimetics. Since there are limited taxonomists in SEA, especially for benthos and plankton, education and training for taxonomists are also necessary to practically use new techniques such as population genetics using a high-throughput sequencer and micro CT. A DNA database, especially for understudied groups of organisms such as benthos and zooplankton, need to be enhanced. The results obtained from taxonomical studies should be published as field guides and/or printed and mobile/digital picture books for supporting scientific and citizen science activities as well as enhancing DNA data-bases.

In SEA, processes and mechanisms of ecosystem change are severely understudied due to high biodiversity and complex food-web structure, lack of funding, and limited specialists. Without the knowledge, it is hard to develop a strategy for conservation and management of marine ecosystems, including fisheries management, marine spatial planning, restoration of degraded ecosystems, and countermeasures of global warming. Understanding the process and mechanisms of ecosystem change under natural and anthropogenic perturbations is the priority of SEA marine ecosystem study in the Anthropocene. To overcome this situation, it is important to invest human resources in Intensive Observation Sites (INOSs) in each member country and/or specific ecosystem, such as coral reef, seagrass bed, sandy beach, etc. It is essential to carry out a multidisciplinary field campaign as well as ecosystem model experiments (see Issue 3) and remote sensing observation to understand the ecosystem structure and process, key stone species, the mechanism of change, and to predict the future.

Observation and experimental equipment, skills, and human resources are to be fully added to the campaign under the international collaboration. The overview of the end-to-end ecosystem with physical and chemical characteristics of the INOSs could be a benchmark of marine ecosystem studies in SEA, and the experience of interdisciplinary and international collaboration, including both best-practice and obstacles, could be transferred to field campaigns in other INOSs. It should be noted that the preparation of documentary and logistic support for the scientists of each country is in accordance with the laws and rules of scientific observation and biological sampling in international collaboration.

Recommendations:

1.1 Conduct an inventory of biodiversity in SEA by means of eDNA and a morphological taxonomy.

1.2 Enhance the DNA database, especially benthos and plankton.

1.3 Increase the capacity to use the eDNA technique through training courses and workshops.

1.4 Apply new techniques for taxonomy such as a high-throughput sequencer and micro CT.

1.5 Increase morphological taxonomists with skills of molecular biological techniques. Develop a medium-long term training/education strategy between countries, including sending young scientists to taxonomy centers of excellence.

1.6 Establish Intensive Observation Sites (INOSs) to comprehensively understand the ecosystem structure, process, and mechanisms of change. Share the obtained results and best practice for interdisciplinary and international collaboration, as well as difficulties, between INOSs.

1.7 Disseminate scientific results from the INOSs campaign to support citizen science and educational activities through a website, field guides, printed and digital books.

2. Eutrophication and Pollution

Marine chemical pollution by human activities is one of the most serious problems in SEA marine ecosystems. In particular, eutrophication caused by industrial, agricultural and residential waste induces hypoxia and harmful algal blooms (HABs) which degrade marine ecosystem services with wide societal impact. Hypoxia severely reduces biodiversity and fisheries production. HABs kill wild and aqua cultured fish, induce shellfish poisoning, and impact the local economy and human health. Coral reef ecosystems are also vulnerable to eutrophication that can subsequently impair biodiversity, food production and cultural services such as tourism from healthy ecosystems. Eutrophication can also induce jellyfish bloom that impacts fishery production, power plant operation, and tourism. Plastic pollution is becoming a global concern and SEA is a major source of plastic debris in the world.

With increasing human population and activity along the coastal region of SEA, excess nutrients are loaded into the waters with more hypoxic incidents observed across SEA. However, the status of hypoxia and its impact on marine ecosystems has not been well studied in SEA. The limited information prevents an appropriate management strategy for water quality in the rivers and coastal regions. In Japan, responding to serious eutrophication and pollution in the 1960s and 70s, central and regional governments legislated against water pollution based on scientific advice, and developed monitoring systems for water quality. To understand the status of eutrophication and hypoxia and to improve water quality in the coastal SEA, it is essential to monitor water quality and nutrient dynamics, as well as the impact on marine ecosystems. Numerical modelling is useful in understanding the mechanisms of hypoxia and its propagation.

Increasing HABs damage the local economy and human health due to eutrophication and the introduction of species by human activity. Increasing temperature and/or a changing benthic environment also increases the chance of adaptation of non-indigenous HAB species. Detecting HABs has been based on enumeration and morphological examination, but it requires specialists working over the long term for analysis. Molecular methods such as DNA microarray (DNA chip) and eDNA can be applied for quick monitoring of HABs. These methods are also useful for early warning of HABs in conjunction with a physical oceanographic model. To support the limited number of HAB specialists, satellite monitoring of discolored water and/or citizen science using smartphone applications (e.g., FishGIS, https://meetings.pices.int/publications/projects/FishGIS/Year-2-FishGIS-progress-report.pdf) can be be applied.

Many HAB species have complex life histories and unique physiology. It is essential to enhance our understanding of the biology of HAB species to clarify the formation mechanisms of HABs and to develop an early warning system in conjunction with the physical oceanographic model. It is commonly observed that HAB species disperse to places remote from the original occurrence. Ballast water, imported fishery products and aquaculture seedlings are potential transporters. Once HAB species adapt to the new environment, their impact can be more serious because of the lack of information about the toxin and its biological characteristics. Sharing information about HAB species and their toxins across SEA and the world is essential for a quick response to new HAB species.

SEA is a major contributor to marine plastic pollution. Initiatives to examine the present status (e.g., concentration, size of the plastic, sources) and the impacts of marine plastic pollution on marine ecosystems are growing. Building a network of field monitoring systems is crucial for decision making regarding plastic pollution in SEA to support SDGs achievement. The other concern about plastic pollution is the influence of chemicals (e.g., PCB) absorbed from plastic by marine organisms and ecosystems. Various organisms take in microplastic and are exposed to the chemicals. We need to evaluate not only the direct impact of feeding microplastic but also the indirect impact through absorbed chemicals. New techniques such as transcriptomic analysis and RNA sequencing could be applied to identify pollution makers and gene and metabolic responses to chemical pollutants.

Recommendations:

2.1 Review the status and impacts of eutrophication on the SEA marine ecosystem.

2.2 Investigate mechanisms that give rise to hypoxia by coupling with field observations and ocean circulation model.

2.3 Promote the study of biology and ecology of HAB species, especially taxonomy, physiology, and triggers of encystment.

2.4 Develop easy detection techniques of HAB species such as by using DNA chips, eDNA, or smartphone applications.

2.5 Develop an early warning system or hypoxia and HABs by means of monitoring, remote sensing and mathematical models.

2.6 Enhance international collaboration to exchange information about biology and ecology of HAB species, training course on the new techniques/tools to detect HAB species, and toxin analysis.

2.7 Enhance monitoring of macro- and microplastic pollution. Exchange the information as part of the on-going scheme of international collaboration.

2.8 Develop chemical pollution markers of plastic debris using model organisms, and investigate the direct (e.g. feeding, entanglement) and indirect (e.g., absorbed chemicals) impacts of plastic pollution on marine organisms and ecosystems.

3. Physical Oceanography and Modeling

In marine ecosystems, dissolved and particulate matters, including plankton, are advected and diffused by ocean currents. Understanding physical process is essential to reproduce the past and to forecast the future of marine ecosystem issues, such as eutrophication, hypoxia, HABs, plastic pollution, and recruitment of fish larvae. Physical circulation models coupled with an ecosystem model or particle tracking model are key tools for understanding local and regional dispersion/expansion of emerging issues. At the same time, physical oceanographic observation is essential to develop and validate the model, and data-assimilation based on monitoring can reproduce realistic ocean physical phenomena.

We need to develop regional oceanographic models based on world standard ocean models, such as Regional Ocean Modeling System (ROMs), and Princeton Ocean Model (POM) or relevant models at INOSs, to understand the dynamics of marine ecosystems and the mechanisms of change. The physical oceanographic model will accelerate the accumulation of knowledge obtained from different disciplinary sciences. Enhancement of the capacity to develop and/or utilize physical oceanographic models is also essential because the number of mathematical modelers are insufficient to examine the physical processes of important marine ecosystems in the SEA.

Recommendations:

3.1 Develop high-resolution physical oceanographic models with chemical and biological components for each key area of eutrophication, hypoxia, and lastic pollution.

3.2 Develop a monitoring system for physical oceanographic properties and undertake interdisciplinary observation for data assimilation of the model.

3.3 Archive historical hydrographic data in SEA coastal seas for boundary conditions and validation of numerical models.

3.4 Enhance capacity to develop and use physical oceanographic models through training courses and educational visits in institutes with advanced modeling capabilities.

4. Social-Ecological System

To reach the goal of the Ocean Decade and SDG14, we need to change our society and encourage people to use marine ecosystems in sustainable ways. To achieve these changes in SEA, understanding the social/economic/legal background of marine sectors in each country is one of the most important prerequisites.

To solve social-ecological issues, the collaborative research of scientists and stakeholders (co-design, co-research and co-delivery) is an effective approach. Several conditions are important for effective collaborative research: 1) the social literacy of marine ecosystems, such as ecosystem services, ecosystem structure, mechanism of change, resiliency and vulnerability, and 2) effective outreach so that scientific knowledge is shared with decision makers, stakeholders and the general public.

Because ecological and social systems are both inherently fluctuating, and our knowledge of these systems is still limited, an adaptive approach (or so-called PDCA cycle) is indispensable. Citizens can participate in monitoring and data collection activities, as well as the interpretation of scientific knowledge for adaptive management. Citizen science is an effective approach to collect data, enhance scientific literacy, and increase social participation as part of the collaborative research and to achieve SDG 14.

Recommendations:

4.1 Enhance understanding about the social background (legal, economic, cultural, etc.) of Southeast Asian countries' marine sectors.

4.2 Develop effective marine science outreach, and enhance the scientific literacy of society.

4.3 Facilitate citizen science for data-collection, monitoring, and the interpretation of marine science for society.

Intensive Observation Sites

At the beginning of the Ocean Decade, it is recommended to have Intensive Observation Sites (INOSs) to accelerate interdisciplinary and international collaboration as well as capacity developments. Potential INOSs sites are listed in the Appendix. The INOSs are selected from the perspectives of 1) ecological and biological importance, 2) increasing concern about ecosystem degradation, 3) importance for the local community, and 4) accessibility to science laboratories/stations. It is desirable if past observation/monitoring records are available.

Collaboration with Scientific and Intergovernmental Organizations

The emerging issues of SEA marine ecosystems are also a concern for scientific and intergovernmental organizations. The IOC sub-commission for the Western Pacific (WESTPAC) held a regional consultative and planning workshop about the Ocean Decade in July–August 2019, in Tokyo. They aimed to identify potential initiatives to be further developed in the Ocean Decade for six societal outcomes: 1) A clean ocean, 2) A healthy and resilient ocean, 3) A predicted ocean, 4) A safe ocean, 5) A sustainable, productive ocean, and 6) A transparent and accessible ocean. The North Pacific Marine Science Organization (PICES) also supported the workshop to contribute to the Ocean Decade and SDG14. WESTPAC and PICES are also active in the transfer of marine technology through IOC Regional Training and Research Centers, and PICES projects in the SEA regions. Integrated Marine Biosphere Research (IMBeR), a global research project of Future Earth, promotes an integrated marine ecosystem and biogeochemical research for the benefit of society. Southeast Asian Fisheries Development Center (SEAFDEC) promotes scientific and management activities for sustainable fisheries and aquaculture, including issues of food security. Sharing scientific information with these organizations/programs and following best practice in dissemination of scientific knowledge is important to reach the goal of SDG14, as well as collaborating in capacity developmental activities, such as sharing pools of lectures, joint field study, and joint symposia.

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Appendix

Potential Intensive Observation Sites (INOSs)

1 Pari Islands (Seribu archipelago, Indonesia)

Type(s) of ecosystem: Mangrove forests, seagrass meadows, coral reefs.

Emerging issues: Ecosystem degradation with increasing tourists. Decreasing water transparency.

Available data/program: Ecosystem restoration program of the Indonesian Institute of Sciences (LIPI).

Relation with society: Local government declares plans to develop this tourist destination. Need strategy for coexistence of local fishers and tourism.

Scientific facility: LIPI has a field station.

2 Lombok Island (West Nusa Tenggara province, Indonesia)

Type(s) of ecosystem: Sandy ecosystem, seagrass ecosystem, coral reef ecosystem.

Emerging issues: Massive coastal development, tourism, and water quality transparency.

Available data/program: Data on coastal ecosystem is available since 2000; Program LIPI on marine bioindustry.

Relation with society: Government of Indonesia target this as one of five tourist destinations to be built in the period 2020–24.

Scientific facility: LIPI has a marine station, and is currently under renovation. Main advantage: it can be reached by international flight.

3 Ambon Island (Maluku Islands, Indonesia)

Type(s) of ecosystem: Sandy ecosystem, seagrass ecosystem, coral reef ecosystem and mangrove ecosystem, very small island ecosystem.

Emerging issues: Massive coastal development, HABs in Ambon bay, decreasing water quality, plastic pollution, and tourism.

Available data/program: Data on water quality and bioecology of Ambon Bay and its surrounding available since 1980s. This small island is unique as surrounded by a deep-sea ecosystem. Several very small islands are within reach by boat within 20 to 45 min.

Relation with society: Provincial Government of Maluku declared as city of music and as one of the tourist destinations.

Scientific facility: LIPI has Centre on Deep Sea Research, currently under renovation.

4 Weh Island (Banda Aceh, Indonesia)

Type(s) of ecosystem: Sandy beach, seagrass ecosystem, coral reef ecosystem and patchy mangrove ecosystem, small island ecosystem.

Emerging issues: Tourism, coastal development, natural condition.

Available data/program: Very limited information from this site. LIPI carry out research since 2014.

Relation with society: Local government target it as a tourist destination.

Scientific facility: A marine station under consideration to be built by LIPI. The site has the advantage of being close to Phuket (Thailand), Penang (Malaysia) and Singapore.

5 Port Dickson (Malacca Strait, Malaysia)

Type(s) of ecosystem: Fringing reefs, mangrove, seagrass meadows.

Emerging issues: Tourist attraction with rapid coastal development. High turbidity.

Available data/program: Plankton and benthos data since 1970's.

Relation with society: Important source of income for local community which relies on tourism as major income. Government proposed to gazette as marine park but many small artisanal fishermen in this place. Need strategy for win-win solution.

Scientific facility: International Institute of Aquaculture and Aquatic Sciences (I-AQUAS) of Universiti Putra Malaysia (UPM) at Port Dickson.

6 Merambong Shoal and Merambong Island (Sungai Pulai Estuary, Johor, Malaysia)

Type(s) of ecosystem: Fringing reefs, mangrove forests, seagrass meadows.

Emerging issues: Rapid coastal reclamation from both Singapore and Malaysia.

Available data/program: Seagrass, plankton, fishes and benthos since 1990s.

Relation with society: Important nursery for fisheries resources and fishing ground for the local artisanal fishermen. Not protected but highly complex.

Scientific facility: Monitoring data from 1990's by UPM.

7 Coastal wetlands (Hai Phong city, Vietnam)

Type(s) of ecosystem: Mangrove forests, seagrass meadows, coastal alluvial land, coral reefs.

Emerging issues: Increasing tourist activities, high sediment transportation from river mouths, plastic waste cause degradation in marine/coastal ecosystem services.

Available data/program: Integrated research on coastal alluvial land (Institute of Marine Environment and Resources).

Relation with society: Local government tries to develop Hai Phong as the green city for tourism via conservation programs to protect biodiversity at key sites like the Cat Ba World Biosphere Reserve. There is an emerging need to build up a responsible fisheries sector based on an ecosystem approach and an improved legal framework.

Scientific facility: IMER has research facilities in Hai Phong city and a marine station to facilitate research in the coastal areas of Hai Phong.

8 Nha Trang Bay (Khanh Hoa province, Vietnam)

Type(s) of ecosystem: Seagrass meadows and coral reefs.

Emerging issues: Increasing tourist activity, overfishing practices, water pollutants cause degradation in biodiversity and associated living resources.

Available data/program: Nha Trang Bay conservation programs (Nha Trang Bay marine protected area management board).

Relation with society: Nha Trang city is a tourist hub in the central south provinces where the Nha Trang Bay is considered the main tourist attraction point. It faces challenges in balancing between economic development and conservation tasks.

Scientific facility: Institute of Oceanography has research facilities in Nha Trang city. Several research projects are on-going to deal with assessment of living resources.

9 Murcielagos Bay (Zamboanga del Norte, Philippines)

Type(s) of ecosystem: mangroves, seagrass, coral reefs, sand/mudflats.

Emerging issues: Harmful algal blooms (HABs) due to eutrophication and temperature rise, cyanide and mercury contamination from gold mining, decreasing fishery production due to siltation, eutrophication and overfishing.

Available data/program: Monitoring of HABs, baseline socio-economic, ecological and fisheries data.

Relation with society: Local residents are aware of changing conditions within the Bay and are generally supportive of measures and efforts to improve conditions. Local governments are taking measures to address these issues as well, but need technical know-how and advice from the scientific community.

Scientific facility: Jose Rizal Memorial State University in Dapitan City (lab facilities). Mindanao State University IIT in Iligan City (Marine Biology Department with field and lab facilities).

10 Mu Koh Sameasan (Chonburi Province, Thailand)

Type(s) of Ecosystem: coral reef ecosystem, sandy ecosystem, seagrass ecosystem

Emerging issues: Marine debris, coral reef degradation, coastal development, tourism, and water quality transparency

Available Data/Program: Data on coastal ecosystem and ecosystem restoration is available since 2001.

Relation with Society: The area is designated as one of the tourist destinations and fishery. Local residents are aware of changing conditions within the area. With the local governments and scientists, local people are trying to solve some emerging issues such as marine debris and coral reef degradation.

Scientific Facility: Chulalongkorn University has a coral hatchery on Sameasan Island.

11 Angsila (Chonburi Province, Thailand)

Type(s) of Ecosystem: sandy ecosystem, rocky ecosystem, mangrove ecosystem

Emerging issues: Marine debris, coastal development, tourism, and water quality transparency

Available Data/Program: Data on coastal ecosystem is available since 2001.

Relation with Society: The area is designated as one of the tourist destinations and fishery. Because of the changes of the ecosystem, local people together with the local governments are trying to improve the ecosystems in the area.

Scientific Facility: Chulalongkorn University has a marine station in the area.