

## New Ocean Provinces for Evidence-Based Management of Marine Ecosystem Services: Five-years of progress under the transdisciplinary NEOPS science program

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The ways in which marine ecosystems and biogeochemical cycles respond to global environmental change is an increasingly important issue for today's science community. Understanding the human dimensions linked to these dynamics is crucially important to determine how the benefits that humans have been receiving from the ocean will change in the future, and how ocean management can be optimized in order to promote sustainable development. To answer these questions, we launched a five-year transdisciplinary project: NEOPS (New Ocean Paradigm on its Biogeochemistry, Ecosystem and Sustainable Use). In addition to exploring pathways to sustainable use of marine ecosystem services, an essential part of the project has been to specify new ocean provinces. Material cycling and ecosystem functions determine the boundaries of these provinces, so they provide a firm scientific base on which to build a legal and economic framework for sustainable ocean management. Longhurst (1995) proposed a single universal map of ocean provinces, but the NEOPS project is preparing around 100 maps based on physical (T, S, mixed layer, eddy, etc), chemical ( $p\text{CO}_2$ , pH, nutrients, BSi, CDOM, flux, etc), and biological (Chl, N fixation, 18S rDNA of phytoplankton, zooplankton, squid, toothed whales, etc) data. NEOPS is also planning to prepare maps of ocean provinces tailored to specific needs (e.g., ocean provinces for tuna fisheries) through the application of user-friendly tools such as Google Earth.

Keywords: ecosystem service, Pacific Ocean, sustainable use

## On Sustainability Initiative in the Marginal Seas of South and East Asia

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The South and East Asian marginal seas are vulnerable to rapid coastal population growth, overharvesting of marine biological resources, and pollution. The region's marine ecosystems have more than 30% of the world's coral reefs and produce about 40 million tons of fish and more than 80% of the world's aquaculture products. The high extraction volume of marine bioresources, rapid population growth, and far-reaching economic development increasingly test the limits of these seas to provide the ecosystem services that drive economic growth and development in the region. The conservation and management of marine resources and ecosystems, while coping with the pressures of climate change/variability and other global changes either brought about or augmented by human activities, are immense challenges that require cohesive transnational endeavours in the region and the rest of the world. The Sustainability Initiative in the Marginal Seas of South and East Asia (SIMSEA) is an international alliance of physical, ecological, and social scientists working together to meet the regional challenges of biodiversity conservation, sustainability of marine ecosystem services, and protection of human well-being in light of population pressure, environmental degradation, extreme weather events, and climate change/variability. The objectives are to: co-design an integrative program that would establish the sustainability of the marginal seas of South and East Asia; and play a catalytic role in projects and programs to facilitate scientific cooperation for the benefit of societies. The overall goal is to generate knowledge that can bring about transformative change toward sustainability in the marginal seas of South and East Asia, and contribute toward sustainability at the global level.

Keywords: Climate Change/Variability, Marginal Seas of South and East Asia, Ocean Health, SIMSEA

# Establishment of Research and Education Network on Coastal Marine Science in Southeast Asia: Scope of JSPS COMSEA-RENSEA Projects

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The Southeast Asian Region encompasses diverse coastal ecosystems, as represented by coral reefs, mangrove forests, seagrass beds, and even deep basin over 4000-m deep. These diverse environments harbor the unique and extremely high biodiversity of the region, known as the major biodiversity hotspot in the world. These waters also supply important marine resources to some 600 million people living in the region. However, the region is also under serious threat of environmental decline from various human impacts due, for example, to loads of pollutants from land and habitat destruction associated with resort development and fisheries. There are also concerns about negative impacts of global climate change, as represented by coral bleaching.

To address these issues, it is of primary importance to clarify the current status of the coastal environment and its temporal changes. There is a long history of research on the coastal environment of the region, dating back to the Challenger Expedition in the late 19th Century, resulting in a large body of knowledge accumulated to date. Novel findings and knowledge have also been provided by more recent researches conducted by countries of the region, either domestically or through international collaboration. However, still much remains to be explored on the coastal environment and biodiversity of the region. Moreover, there are large discrepancy and differences among the information obtained by different projects and researches, in terms of the objectives, sea areas, accuracy and precision of data, and forms of data publication and archive. Under this circumstance, the multilateral project “Coastal Marine Science (CMS)”, conducted with the support of the Japan Society for the Promotion of Science (JSPS) during 2001-10, has successfully established basic information on the coastal environment in the region, with collaboration among five Southeast Asian countries and Japan. Through this activity, the project also has contributed much to the education of many young scientists who are expected to lead the research and education of the region.

The CMS Project has been succeeded by the Coastal Marine Science in Southeast Asia (COMSEA: 2011–15) and the Research and Education Network on coastal ecosystems in Southeast Asia (RENSEA: 2016–2018) Projects, aiming at further expanding the research and education network on the coastal marine science of Southeast Asia, through (1) research collaboration applying new approaches and methodologies such as satellite remote sensing, molecular genetic analyses, and high-precision analyses of hazardous chemicals, (2) integrative, inter-disciplinary ecosystem researches, and (3) establishment of core of coastal marine science in each country and multilateral network. Through these activities the project aims at enhancing education of researchers who will play major roles not only in domestic but also in international activities on global issues.

Keywords: Southeast Asia, coastal marine science, multilateral network

## Meridional gap in the rate of ocean acidification between the subtropics and the tropics in the western North Pacific

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Increasing acidity of seawater as a consequence of increasing anthropogenic CO<sub>2</sub> emissions is one of the chronic stressors that is expected to have large-scale consequences for marine ecosystems and their services to human society over the coming decades. This problem, referred to as ocean acidification (OA), is one of the major concerns indicated in SDG14, stimulating research on not only the encroachment of OA and the variability of seawater acidity in space and time, but also the impacts on marine organisms. The subtropical and tropical zones in the western North Pacific constitute regions where numerous coral reef habitats with rich marine biodiversity and productivity are distributed and are severely threatened by the OA. Here we present the results of time-series measurements of oceanic CO<sub>2</sub> variables in these regions over the past three decades, and demonstrate that accumulation of excess CO<sub>2</sub> and ensuing OA are in fact occurring. In the Kuroshio-recirculation region of the subtropics, the rates of CO<sub>2</sub> increase and OA are consistent with those expected from the growth of the atmospheric CO<sub>2</sub> concentration under air-sea CO<sub>2</sub> equilibrium. However, the rates are ~40% slower in the tropics. The slower rates in the tropics are attributable to the transport of excess CO<sub>2</sub> from the surface layer of northern/eastern subtropical gyre to the thermocline of tropics through shallow meridional overturning circulation with its elapsed time of 10 - 15 years and the accelerating growth rate of atmospheric CO<sub>2</sub> concentration over the recent decade. Accordingly, it is likely that the impacts of OA on marine ecosystem and socio-economic impacts will emerge earlier in the northern subtropics than in the tropics. OA is “the other CO<sub>2</sub> problem” and can be “the other reason to act” to achieve the +1.5°C target of the Paris Agreement. This is particularly true for countries like Japan where reliance on marine resources and ecosystems for food supply is high.

Keywords: ocean acidification, western North Pacific, Sustainable Development Goal 14

# The Future of Global Ocean Management: New Findings from a Five-Year Trans-disciplinary Research under NEOPS

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The results of a five-year trans-disciplinary research by NEOPS (the New Ocean Paradigm on its Biogeochemistry, Ecosystem, and Sustainable Use), which covers oceanography, fishery science, environmental economics, and marine policy, will be presented. Particular emphasis will be dedicated to the socio-economic and policy aspects of global ocean management by introducing three research efforts. (1) Drawing on the results of three online surveys, research will be presented on people's utility of ocean ecosystem services and how this influences behavioural intentions for ocean conservation and attitudes toward ocean ecosystem services, as well as relevant factors that related to people's willingness to pay for ocean ecosystem services. Data from the 2013 survey conducted in Japan suggests that respondents perceive three distinct categories of ocean ecosystem services, which the authors named "essential benefits", "indirect benefits", and "cultural benefits". Among these, "cultural benefits" were found to have the greatest influence on behavioural intentions for ocean conservation. A 2014 survey conducted in the USA suggests that readiness to act to conserve ocean resources is highly dependent on the type of action involved. Irrespective of the type of marine ecosystem service involved, there was a very high aversion to taxation, while supporting green businesses or buying green products to support ocean conservation were less contentious. Moreover, no link was found between political persuasions and behavioural intentions or perceptions of marine ecosystem services. The most recent survey conducted in 2016 in Japan indicates that respondents unwilling to pay for ocean ecosystem services are characterized as extremely low spirit of public engagement, weak connections with other people, and a weak perception of intangible benefits. (2) NEOPS researchers have closely followed international decision-making processes related to new ocean governance measures, including the Conference of the Parties to the CBD (Convention on Biological Diversity) and the BBNJ Preparatory Committee (Preparatory Committee established by UN General Assembly resolution 69/292: Development of an international legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction). Although cultural ecosystem services have not been a major issue within these forums, the building of consensus on the need, for instance, for marine protected areas or equitable benefit-sharing mechanisms, have been crucially dependent on negotiations that take into account the diverse range of stakeholders involved as well as the different socio-cultural contexts that have shaped their positions. (3) Independent analyses by authors have also found that a number of key underlying criteria shape the decision-making landscape and heavily influence the outcomes of ocean governance negotiations. These include the number of countries involved and their respective dominance with regard to the issue under negotiation (e.g., existence of hegemons), the existence of adequate monitoring and enforcement mechanisms as well as similar levels of capacity to effectively use these mechanisms (to deter destabilizing 'balloon effects'), and other factors. Lastly, building on these research outcomes over the past five years, the future outlook for the international regime on ocean management and the role of science will be discussed.

Keywords: NEOPS, BBNJ, governance, ecosystem, biological diversity, cultural services

## Willingness to pay for conserving marine ecosystem services and character of individuals: a case study in Japan

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Marine ecosystem services are invisible in most cases. In order to make the invisible value visible and explore possible relationships between people's value of marine ecosystem services and character of individuals, multi-disciplinary approach are taken using environmental economics and social psychology. In exploring the relationships, this study takes up two distinct marine ecosystem services as representing visible and invisible ones, that is, provision of fisheries resources and absorption of carbon dioxide in the atmosphere by ocean. A nation-wide online survey was conducted to residents in Japan in 2016. Value of respective marine ecosystem services are estimated as people's willingness to pay for conserving them by conjoint analysis, whereas character of individuals are investigated with three foci, namely public spirit, connection to others both human and non-human, and locus of control based on responses to the online questionnaires from 1,891 residents in Japan. In the survey, respondents were divided into two groups, one provided with a scenario of scientific forecast of decrease of fisheries resources and increase of carbon dioxide in the atmosphere because of deterioration of absorption function by the ocean in 10 years after, and the other provided with a scenario of that in 100 years after to compare possible differences of their willingness to pay for a near future where they are still alive and a future where they are no more alive. Respondents' marginal willingness to pay for 1% prevention of decrease of fisheries resources is 17.1 Japanese yen, whereas that for 1% prevention of increase of carbon dioxide is 32.1 for a scenario for 10 years after, which can be interpreted that they would value invisible marine ecosystem services higher than visible ones. For a scenario for 100 years after, the marginal willingness to pay for both marine ecosystem services are higher than the ones for 10 years after, which would be an implication of respondents' public spirit that could be extended to others even beyond time of their living. Based on hierarchical cluster analysis, respondents are categorized into six groups with similar preferences to marine ecosystems services for both scenarios, respectively. For the scenario for 10 years after, one group composed of 180 respondents has no willingness to pay for conserving marine ecosystem services, whereas another group composed of 108 respondents has positive utility in paying for conserving marine ecosystem services. And for the scenario for 100 years after, one group with 165 respondents has no willingness to pay for conserving marine ecosystem services, whereas another group composed of 130 respondents has positive utility in paying for conserving marine ecosystem services. In total, 345 respondents which equals to 18% of respondents are free riders, whereas 238 respondents, around 13% of respondents have positive utility in paying for conserving marine ecosystem services. Groups having no willingness to pay for conserving marine ecosystem services are characterized as extremely poor public spirit with low connection to other people and low belief in the invisible. On the other hand, there are no clear relationships between locus of control and willingness to pay for conserving marine ecosystem services. The findings of this study could provide a clue in choosing measures and targets to solicit people's support to conserve marine ecosystem services.

Keywords: marine ecosystem services, value, willingness to pay, invisible, public spirit, connection