

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 CO₂ 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 CO₂ variables in these regions over the past three decades, and demonstrate that accumulation of excess CO₂ and ensuing OA are in fact occurring. In the Kuroshio-recirculation region of the subtropics, the rates of CO₂ increase and OA are consistent with those expected from the growth of the atmospheric CO₂ concentration under air-sea CO₂ equilibrium. However, the rates are ~40% slower in the tropics. The slower rates in the tropics are attributable to the transport of excess CO₂ 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 CO₂ 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 CO₂ 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% or 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

Introduction of IOC/WESTPAC - from Japanese perspective

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Followed by the high level objectives of Intergovernmental Oceanographic Commission (IOC) of UNESCO, IOC Sub-commission for the Western Pacific (WESTPAC) promotes international cooperation and coordinates programs in three areas; marine research and application, ocean observation service, and capacity building in the western Pacific and its adjacent seas.

At present WESTPAC consists of 22 member states mainly from East Asia, Southeast Asia, and south Pacific. In the area of marine research and application, twelve projects are endorsed by member states, and four projects are supported by the Japanese government (Harmful Algae Bloom, Toxic Marine Organism, Ocean Remote Sensing, and Biodiversity in coral reefs). WESTPAC also endorsed the working group activities to foster scientific and societal discussions on the regional marine science. The working group (WG) on Asian dust was the first WG in WESTPAC, led by Japanese experts, and compiled the collection of scientific papers to foster the inter-disciplinary study in WESTPAC. There are two regional Global Ocean Observing System (GOOS) projects in the area of ocean observation service. North-East Asian Regional GOOS (NEAR-GOOS) is conducted by Japan Meteorological Agency and Japan Oceanographic Data Center in cooperation with China, Korea, and Russia, to share in-situ ocean data from each country. The other one is the South East Asian Regional GOOS (SEA-GOOS), led by Thai and conducting several pilot studies from observation to forecasting experiments. Capacity development (CD) is one of key activities in WESTPAC to foster and develop capability of marine science in the region. In the case of Japan in conjunction with the marine research projects, CD has been conducted through the workshops of laboratory experiments and field surveys. In parallel to these activities, a new type of CD activities was proposed in 2008, aimed to establish the Regional Training and Research Center (RTRC) with specific research subject respectively and to develop networks among centers in sustainable manner. The first RTRC was established in China, and the efforts have been continuously made in Japan. In recent years, based on these activities, inter- and trans-disciplinary contributions are welcomed to WESTPAC. Detailed information will be introduced in the presentation.

Keywords: IOC, WESTPAC, Asia, marine science, ocean observation, capacity development

Development of information infrastructure on global warming and ocean acidification

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The oceans, which cover 70 per cent of the earth's surface, have in recent years been experiencing various changes. The small island countries dotting the oceans are of course significantly affected by such changes and are now struggling to deal with them.

We, OPRI-SPF, held international seminars with relevant organizations and discussed our new international joint policy proposal, 'For the Better Conservation and Management of Islands and their Surrounding Ocean Areas' to further materialize policy for the sustainable development of islands and their surrounding ocean areas. We participated in the International Conference on Small Island Developing States (SIDS 2014), at which we presented the above policy proposal as a contributing document, and organized a side event to launch the international collaboration network, "Islands and Oceans Net (IO Net)".

The 2nd General Meeting of IO Net was held in December 2016 with great success and significance, with 120 participants coming from 11 countries and 12 international/intergovernmental organizations. At this meeting, the Partners not only discussed the development strategy for 8 projects, based on the results of the 1st General Meeting held in May 2015 and the interactions thereafter, but also reinforced cooperation and information sharing for the implementation phases.

We proposed a project titled "Start-up of Regional Monitoring Network Platform on Ocean Acidification" as one of the 8 projects. Although it is certain that an increase in CO₂ concentration causes ocean acidification, there is still much to learn about the actual processes. Furthermore, because acidification occurs over multiple spatiotemporal scales, it is vital that both onsite and satellite observations of the oceans are used to elucidate the overall picture and establish an information infrastructure for integrating data from models of marine physics, chemistry, and biology and generating projections. In order to address the issues of ocean warming and acidification, we are developing the "Marine Crisis Watch & Action" platform based on the west Pacific region and planning to provide it to neighboring countries.

Keywords: SIDS, IO-net, Marine Crisis Watch, Ocean Acidification

High-resolution hydrographic observation with local communities in the Sanriku coastal seas, Japan

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In the Sanriku coastal seas, facing the North Pacific in the northeastern part of Japan and exchanging a large amount of seawater with the open ocean, a variety of seaweeds and shellfish are farmed without artificial feeding. After the 2011 Great East Japan Earthquake and the subsequent giant tsunami, we have built an ocean observation system to elucidate circulation patterns in the Sanriku coastal seas, not only aiming at producing globally recognized scientific results, but also putting a high priority on integrating our activities with local communities in the area. That is, practical ways were developed to carry out scientific study together with local communities.

In the study we have built a WEB site that distributes real-time-monitored marine environmental data, such as water temperature, wave height, salinity, concentration of nitrate, and meteorological conditions. The marine environmental information distributed by this system has been widely viewed and been practically utilized by the local communities including fishermen, because growth of the seaweeds and the shellfish depends greatly on the seawater circulation, which conveys nutrients into the “non-feeding” sea farming areas.

Moreover, we have held local meetings in rural fishing villages. Direct exchanges of marine information between the researchers and fishermen are very useful not only for the fishery, but also for the progress of the oceanography, because the fishermen know the sea very well. In addition, the hydrographic observation over the inshore fishery areas cannot be made safely without support from fishermen. In other words, in situ observation with local communities is essential for performing state-of-the-art coastal physical oceanography.

Keywords: Coastal Physical Oceanography,, Local Communities, The 2011 Great East Japan Earthquake, , Tohoku Ecosystem-Associated Marine Sciences



Human-Environmental Security in Asia-Pacific Ring of Fire: Water-Energy-Food Nexus

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The objectives of this research are to understand the complexity of the water-energy-food (WEF) nexus system and to create scenarios and policy options to reduce trade-offs among resources and to alleviate conflicts of resource users using scientific evidence and under assumptions of uncertainty to maximize human-environmental security. Five different interdisciplinary approaches, scales and clusters will be used in this investigation: 1) the science in/for society; 2) the water-energy nexus; 3) the water-food (e.g., fisheries resources) nexus; 4) the stakeholder analysis; and 5) the interdisciplinary study.

A primary challenge of this nexus study is to analyse the interlinkages between groundwater and fisheries production, regarding the hypothesis that the flow of nutrients from land to ocean affects the coastal ecosystem. This suggests that water use for producing and/or consuming food and/or energy on land might affect fisheries production in coastal areas. To examine this theory, we address two primary objectives; 1) to understand the complexity of the water-energy-food (WEF) nexus system since the relationships of all three resources are interrelated and interdependent; and 2) under scientific evidence and scientific uncertainty to create scenarios and policy options to solve the identified nexus problems, that is, to reduce the number of tradeoffs among three resources and to mitigate potential conflicts among these resource users through transdisciplinary approaches.

(To understand the complexity of WEF nexus system)

At the local level of WEF in Beppu, hot spring resort area, a finding of the WEF nexus shows that changes in the heat environment caused by hot spring drainage water from resorts and power generation affect river ecosystems, including non-native Tilapia habitat. As for the interlinkages between groundwater and fishery production, changes in submarine ground water (SGD) rates cause change in nutrients flux, which results to change in primary production, and finally leads to change in fishery resources. We found that there was a positive correlation between phytoplankton primary production and radon concentration, as a groundwater tracer of SGD in Obama Bay. Regarding the relationship between SDG and nutrient flux, we found nutrients supplied from the SGD have a high contribution to primary production. As a result of addressing SDG and fisheries production, we discovered that more fishes were found near SGD. We demonstrated the interlinkages between groundwater and fishery production.

(Developing methods for interdisciplinary and transdisciplinary studies)

We designed WEF nexus system integrating methods such as computer science, ontology engineering and economic tools to understand and visualize the nexus system in Beppu to contribute to scenario planning and define the academic concept of nexus. Regarding stakeholder analysis, we identified governance issues for the coexistence between hot spring energy development and hot spring resource conservation. They also visualized the social network of hot spring stakeholders, who shared same interests in Beppu. Regarding scenario planning, we identified stakeholder interests, held stakeholder meetings and expert meetings. We will provide scenarios and develop action plans by collaborating with stakeholders, and experts next year.

Keywords: water-energy-food nexus, interdisciplinary, transdisciplinary, coastal ecosystem

Biological nitrogen fixation sustains fishery production in the subtropical Pacific Ocean

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Nitrate below the euphotic layer has been generally considered as a primary nitrogen source to sustain new production which leads to fishery production in the sea. Recently nitrogen fixed by diazotrophs is gaining attention as another nitrogen input to fuel new production in the subtropical ecosystem. While a number of studies indicate that the nitrogen fixation contributes to secondary production, its role in the fishery production is still unknown. Here we present two attempts to prove the contribution of diazotrophic nitrogen to fishery production by means of the analysis of food-chain structure with carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) stable isotopic ratios. Firstly in the central Pacific, we determined the isotopic signatures in suspended particulate organic matter (POM), net-plankton and micronektonic fish from the epipelagic zone. $\delta^{15}\text{N}$ of surface POM and all biotic components was low, reflecting *in situ* N_2 fixation activity in the subtropical regions where the N_2 fixation activity was high, with a clear contrast with high $\delta^{15}\text{N}$ in the areas where the activity was low. Thus, a distinct food-chain to micronektonic fish sustained by diazotrophs existed in the subtropical Pacific. Secondly, we examined contribution of nitrogen fixation to predatory fish as indexed by the isotopic signatures in benthopelagic fish, *Beryx splendens* and their prey in the Kuroshio Current in which the diazotrophy was active. The signature of nitrogen fixation was evident in POM, net-plankton, micronektonic prey fish and *B. splendens*. Thus, diazotrophy is an important nitrogen source for fishery production in the subtropical ocean. The response of diazotrophy to the on-going climate change and the subsequent impact on higher trophic levels is the critical issue to be tackled to predict sustainability of subtropical fishery production.

Keywords: stable isotope, diazotroph, *Beryx splendens*