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Acknowledgement

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We greatly appreciate their support.

Hiroaki Saito and Ken Furuya
Symposium Conveners,

Preface

With compelling evidence for global warming, ocean acidification and other environmental threats, understanding and predicting the responses of ocean biogeochemistry and the ecosystem to environmental changes has become an urgent scientific pursuit. Since the ocean plays a critical role in sustaining human beings by providing a wide range of ecosystem services, ocean governance to maintain and manage these ecosystem services is crucial. However, our knowledge of biodiversity and material cycling in the ocean, which forms the foundation of the ecosystem services, is extremely limited.

The “New Ocean Paradigm on Its Biogeochemistry, Ecosystem and Sustainable Use (NEOPS)” research project aims to advance our understanding of ocean biogeochemistry and ecosystem dynamics in the Pacific Ocean for the sustainable use of ecosystem services, with particular attention to the high seas. The project sets the following three goals: 1) to establish ocean provinces in the Pacific Ocean based on a consistent set of pelagic biomes, 2) to evaluate ecosystem functions in each province, and 3) to propose ocean governance for maintenance and management of ecosystem functions.

This symposium aims to communicate the latest scientific knowledge related to the ocean’s ecological and biogeochemical processes, including recent findings by both NEOPS researchers and others. Building on these foundations, the symposium will provide an opportunity for fostering dialogue and gaining insight into optimal pathways to establishing new ocean provinces for the sustainable use of marine ecosystem services. The symposium will furthermore act as a platform for building or further strengthening collaborative relationships between NEOPS and other scientific programs and individual researchers in order to enhance future cooperation.

Ken Furuya
Project Leader of NEOPS

Agenda

December 3, 2015		
10:00	Ken Furuya	Opening Remarks: The new ocean paradigm on tis biogeography and ecosystem
10:10	Bo Qiu	Decadal variability, impact, and prediction of the Kuroshio Extension system
10:50	Philip Boyd, Scott Doney	A regional ocean classification to map future ecosystem change
11:30	Sachihiko Itoh, Takeshi Okunishi, Shinya Kouketsu and Hitoshi Kaneko	Mesoscale eddies and mode waters characterize new ocean ecological provinces
11:55	Lunch	
13:00	Douglas Wallace	Tracking the magnitude and distribution of the ocean carbon sink
13:40	Masao Ishii, Daisuke Sasano, Naohiro Kosugi, Yusuke Takatani, Atsushi Kojima, Yosuke Iida, Kazutaka Enyo, Toshiya Nakano	Variability and trend of oceanic CO_2 in the western North Pacific subtropical zone
14:05	Takuhei Shiozaki, Taketoshi Kodama, Shigenobu Takeda, Sachihiko Itoh, Xin Liu, Fuminori Hashihama, Ken Furuya	New ocean provinces characterized by island mass effect through nitrogen fixation
14:30	Hiroaki Saito, Fuminori Hashihama	Geography of biogenic elements in the Pacific Ocean: What form is most important?
14:55	Coffee break	
15:15	Koji Hamasaki, Shotaro Suzuki, Yoshitoshi Ogura, Tetsuya Hayashi, Hiroshi Mori, Ken Kurokawa, Wataru Arai, Hideto Takami	Diversity, community structure and functional potential of planktonic bacteria in the Pacific Ocean: insights from the NEOPS transoceanic cruises

15:40	Shoshiro Minobe, Hiromichi Ueno, James Irvine, Alexander Zavolokin, Katherine Myers, Mio Terada, Mitsuho Oe, Skip McKinnell	SST habitat and food change projections for Pacific salmon (*Oncorhynchus* spp.) in the North Pacific and adjacent seas based on CMIP5 climate models
16:05	Daisuke Tsumune, Takaki Tsubono, Kazuhiro Misumi, Takeshi Yoshimura, Michio Aoyama	Distribution of oceanic ^{137}Cs from the Fukushima Dai-ichi Nuclear Power Plant
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December 4, 2015		
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9:40	Ben A. Ward, Stephanie Dutkiewicz, C. Mark Moore, Michael J. Follows	Nutrient supply ratios define the biogeography of nitrogen fixation
10:20	Taketo Hashioka, Sanae Chiba, Maki Aita Noguchi	Biogeochemical classification of the global ocean based on phytoplankton growth limitation
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11:30	Junya Hirai, Atsushi Tsuda	Diversity and biogeography of marine planktonic copepods: Insights from metagenetic community analysis in the Pacific
11:55	Sayaka Yasunaka, Yukihiro Nojiri, Tsuneo Ono, Frank A. Whitney, Shin-ichiro Nakaoka	Seasonal to decadal variability of sea surface nutrients and DIC in the North Pacific
12:20	Lunch	
13:20	Emily Rubidge, Katie SP Gale, Janelle Curtis	Community ecological modeling as an alternative approach to physiographic classification for marine conservation planning
14:00	Takehiro Okuda, Shiroh Yonezaki, Kiyota Masashi	Regional structure and functional characteristics of large marine ecosystems in the northwestern Pacific Ocean
14:25	Yoshiki Kato, Mitsuo Sakai, Makoto Okazaki, Maki Noguchi, Hiromichi Ueno	Growth, migration and trophic interactions role of neon flying squid (*Ommastrephes bartramii*) in the North Pacific
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List of Poster Presentations

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P3	Shohei Hattori, Kazuki Kamezaki, Hiroshi Furutani, Yusuke Miki, Yoko Iwamoto, Mitsuo Uematsu, Naohiro Yoshida	Triple oxygen isotopic compositions of nitrate and sulfate in the aerosols collected for KH-13-7 cruise
P4	Yosuke Iida, Atsushi Kojima, Yusuke Takatani, Toshiya Nakano, Takashi Midorikawa, Masao Ishii	Increase in pCO_2 and its impact on the trend of oceanic CO_2 uptake for the last two decades
P5	Yoko Iwamoto, Yusuke Miki, Shintaro Yokoyama, Kazuhiko Miura, Hiroshi Furutani, Mitsuo Uematsu	Size distributions and cloud condensation nucleus activities of marine aerosols over the Pacific Ocean and its marginal seas
P6	Hyunduck Jeon, Shigeyoshi Otosaka, Hiroshi Ogawa	Study on the radiocarbon distributions of dissolved organic carbon in the central Pacific Ocean
P7	Yu Kanaji, Makoto Okazaki, Tomio Miyashita	Estimation of spatial distribution for small odontocetes using three distinct habitat models
P8	Shota Katsura, Eitarou Oka, Kanako Sato	Formation Mechanism of Barrier Layer in the Subtropical Pacific
P9	Daisuke D. Komatsu, Urumu Tsunogai, Satoko Daita, Satoru B. Ohkubo, Fumiko Nakagawa	Quantifying the mixing ratios of atmospheric nitrate in ocean surface using triple oxygen isotopes as tracers

P10	Yoshiko Kondo, Hajime Obata, Nanako Hioki, Atsushi Ooki, Shigeto Nishino, Takashi Kikuchi, Kenshi Kuma	Transport of trace metals (Mn, Fe, Ni, Zn and Cd) in the western Arctic Ocean (Chukchi Sea and Canada Basin) in summer 2012
P11	Ken-ichi Nakamura, Kazutaka Takahashi, Junya Hirai, Tsuneo Ono, Kiyotaka Hidaka, Yugo Shimizu, Yutaka Hiroe, Ken Furuya	Role of diel vertical migrant copepod *Pleuromamma abdominalis* and *P. gracilis* in nitrogen cycle in the Kuroshio Current, the subtropical Pacific Ocean
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P13	Eitarou Oka, Bo Qiu, Yusuke Takatani, Kazutaka Enyo, Daisuke Sasano, Naohiro Kosugi, Masao Ishii, Toshiya Nakano, Toshio Suga	Decadal variability of Subtropical Mode Water subduction and its impact on biogeochemistry
P14	Daisuke Sasano, Yusuke Takatani, Naohiro Kosugi, Toshiya Nakano, Takashi Midorikawa, Masao Ishii	Multidecadal trends of oxygen and their controlling factors in the western North Pacific
P15	Takuhei Shiozaki, Taketoshi Kodama, Shigenobu Takeda, Sachihiko Itoh, Xin Liu, Fuminori Hashihama, Ken Furuya	New ocean provinces characterized by island mass effect through nitrogen fixation
P16	Yusuke Takatani, Atsushi Kojima, Kazutaka Enyo, Yosuke Iida, Toshiya Nakano, Masao Ishii, Daisuke Sasano, Naohiro Kosugi, Takashi Midorikawa, Toru Suzuki	Relationships between total alkalinity in surface water and sea surface dynamic height in the Pacific Ocean
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P18	Nobuyuki Takesue, Jun Nishioka	A role of sea ice melt water on iron supply to surface water in the Chukchi Sea, the Arctic Ocean
P19	Iwao Tanita, Takuhei Shiozaki, Taketoshi Kodama, Kazutaka Takahashi, Ken Furuya	Limiting nutrient of nitrogen fixation in the Pacific Ocean
P20	Hiromichi Ueno, Moeko Otani, Mitsuho Oe, Yuxue Qin, Maki Noguchi Aita, Seokjin Yoon, Michio J. Kishi, Masahide Kaeriyama	Temporal and Spatial Variation in a Growth Factor of Pacific Salmon
P21	Tamaha Yamaguchi, Ken Furuya, Mitsuhide Sato and Kazutaka Takahashi	Phosphate release due to excess alkaline phosphatase activity of *Trichodesmium erythraeum*
P22	Tomoya Yoshimitsu, Tadashi Tokai, Shiroh Yonezaki, Masashi Kiyota, Toshie Wakabayashi, Yoshiki Kato, Mitsuo Sakai	Comparison in mesh selectivity of research driftnet between the autumn and the winter-spring cohorts of neon flying squid *Ommastrephes bartramii*

Invited Speakers

Dr. Philip W. Boyd,
Marine Biogeochemistry, Institute for Marine and Antarctic Studies (IMAS), University of Tasmania, Australia

Dr. Boyd received PhD in Marine Microbial Ecology, Queen's University of Belfast. His research has been characterized by transdisciplinary projects that bring together disparate disciplines to better understand a wide range of inextricably linked ocean processes. He has led > 20 international scientific voyages including the in situ mesoscale iron enrichments studies SOIREE (S. Ocean) and SERIES (NE Pacific), a GEOTRACES survey line (SW Pacific) and the Pacific component of Canadian JGOFS (3 voyages). Integration of the wide range of both research and policy-relevant themes has resulted in sustained innovation, major conceptual advances, and enhanced understanding across ocean- and geo-sciences. He has been served as science steering committees such as GEOTRACES and SOLAS. He is a Lead Author for IPCC Working Group II chapter on "Ocean Systems" (2008-2013). He has been received various awards, such as 2014 Hutchinson medal, 2011 New Zealand Prime Minister's Science Prize.

Dr. Patrick Lehodey,
Marine Ecosystem Department, CLS, Space oceanography Division, France

Dr. Lehodey holds a PhD in Marine Biology (1994) and HDR (2014), the highest French academic diploma for supervision of academic research. His areas of interests are broad, being highlighted by the modeling of ocean ecosystems for the management of marine resources under the combined impacts of fisheries, environmental variability and climate change. He is the main contributor to the development of a spatial environmental population dynamics model (SEAPODYM), which is driven by physical-biogeochemical ocean dynamics and integrated models of micronekton and large oceanic predators (e.g. tuna), with a quantitative approach to estimate key parameters of spatio-temporal population dynamics. SEAPODYM is widely used as an operational model for the fishery management under climate change. He has published more than 50 peer-reviewed scientific articles and book chapters, and numerous working documents for scientific committees of regional fisheries management organizations. He has attended more than 50 international conferences and workshops, 14 of which he participated as an invited speaker.

Dr. Bo Qiu
School of Ocean & Earth Science & Technology,University of Hawaii at Manoa, USA

Dr. Qiu received his PhD in Physical Oceanography from Kyoto University. His research interest focuses on the ocean circulation dynamics, especially the western boundary current system of the North Pacific, the Kuroshio and Kuroshio Extension, by means of in-situ and Argo observations, satellite remote sensing, and mathematical modeling. He is serving on various scientific committees such as NASA's Surface Topography Science Team, International CLIVAR NPOCE Program SSC, and the US Argo Implementation Panel. He is a contributing author to the IPCC 4th (2007) and 5th (2013) Assessment Reports. He was a recipient of the Okada Prize from the Oceanographic Society of Japan (OSJ) and has been serving as a Councilor of the OSJ from 1997.

Dr. Emily M. Rubidge
Institute of Ocean Sciences, Fisheries and Oceans, Canada

Dr. Rubidge received her PhD in landscape genetics and evolutionary ecology at the University of California, Berkeley. She is a conservation biologist engaged in the interdisciplinary works between science and management. She works on applied problems related to conservation planning, climate change impacts and conservation genetics. She is currently a NSERC visiting fellow with Dr. Janelle Curtis in the Conservation Biology Section, Marine Ecosystems and Aquaculture Division, at Fisheries and Oceans Canada. Her current research focuses on providing scientific support for the development of a Marine Protected Area network in the Pacific Region, Canada. This work includes developing a marine ecological classification system, identifying and mapping Ecologically and Biologically Significant Areas (EBSAs), and identifying and mapping marine ecosystem services. She is also a Research Associate at the Royal BC Museum in Victoria, BC.

Dr. Douglas W. R. Wallace
Department of Oceanography, Faculty of Science, Dalhousie University, Canada

Dr. Wallace received PhD in oceanography, Dalhousie University. His research interests are ocean carbon cycle, ocean-atmosphere exchange and ocean time-series observations. He has been engaged in various positions, such as Scientific Director, Halifax Marine Research Institute (HMRI) (2011 - current), Scientific Director, Marine Environmental Observation, Prediction and Response Network (MEOPAR) (2012 - current), Chair, International SOLAS Program (2008 – 2012), and many others. He has been received various awards, such as Nobel Peace Prize (via IPCC co-authorship) and 2014 Hutchinson medal.

Dr. Ben A. Ward
The School of Geography, University of Bristol, UK

Dr. Ward received Ph.D. in Oceanography, National Oceanography Centre, University of Southampton, UK. His research interest is understanding of biological oceanography based on approaches of ecosystem modelling and theoretical ecology. He is one of leading scientists for a new trend of trait-based ecological modelling that shows an integrated view from plankton physiology to global ecology. He participated in one of world leading projects for ecosystem modeling, the Darwin Project in Massachusetts Institute of Technology (MIT), from 2009 to 2012. He developed a core part of the Darwin model for size structured food-web model. His recent work is selected as a featured article 2014 of Journal of Plankton Research.

Abstracts (Oral Presentations)

Decadal variability, impact, and prediction of the Kuroshio Extension system

Bo Qiu[1]
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The Kuroshio Extension is an eastward-flowing, inertial jet in the subtropical western North Pacific Ocean after the Kuroshio separates from the coast of Japan. Being the extension of a wind-driven western boundary current, the KE has long been recognized as a turbulent current system rich in large-amplitude meanders and energetic pinched-off eddies. An important feature emerging from recent high-precision satellite altimeter measurements and eddy-resolving ocean model simulations, is that the KE system exhibits clearly-defined decadal modulations between a stable and an unstable dynamic state. The decadally-modulating KE dynamic state not only exerts a great impact on the regional sea surface temperature, heat content and water mass properties, it also brings about significant changes in marine ecosystems and fisheries in the western North Pacific Ocean. Here we show that the time-varying KE dynamic state can be predicted at lead times of up to 5~6 years. The long-term predictability rests on two dynamic processes: (1) the oceanic adjustment is via baroclinic Rossby waves that carry interior wind-forced anomalies westward into the KE region, and (2) the KE variability induces a negative feedback response in the overlying atmosphere that enhances the oceanic variance with a preferred timescale of ~10 years. This second process is a novel addition and is at the heart of the prolonged multi-year predictability of the KE dynamic state.

A regional ocean classification to map future ecosystem change

Philip Boyd[1], Scott Doney[2]

1 Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, 7005, Tasmania, Australia

2 Marine Chemistry & Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, MA, USA

Assessing the influence of global climate change on ocean conditions and marine life presents a major challenge for ocean scientists. In the last decade, the major advances in this field have come from global perspectives and viewpoints on climate change and its widespread effect on marine life. For example, we now have a much better picture of the magnitude and sign of changes to multiple ocean properties – such as temperature, carbon dioxide, nutrients, oxygen and irradiance - that individually and cumulatively influence ocean biota. It is now time to use the specificity of regional studies to capture in detail how the biogeography of individual oceanic provinces, and their resident biota, will be altered by changing ocean conditions. In this presentation, I will outline how a synthesis of such regional findings for oceanic provinces can be used to construct a regional classification to map future changes to ecosystem structure and function. A linked suite of model simulations, time-series observations and biological manipulation experiments can provide the details needed for such comprehensive regional appraisals, and in turn can transition our understanding of the range of shifts in biomes that might be anticipated over the coming decades across the global ocean.

Mesoscale eddies and mode waters characterize new ocean ecological provinces

Sachihiko Itoh[1], Takeshi Okunishi[2], Shinya Kouketsu[3] and Hitoshi Kaneko[1]
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Classification of ocean regions is a basis to recognize, evaluate and utilize ecosystem services. While the definition and approaches differ by target services, evaluation and governance policies and also data availability, hydrography and physical processes have been major factors to be considered. In the present study, we focus on distributions of mesoscale eddies and mode waters to update previous classifications of biomes (primary classification) and provinces (secondary classification) that might use relatively coarse-resolution observations. As for wind regimes and wind-driven gyres that were mainly considered in classical views, mesoscale eddies and mode waters could characterize ecological processes through nutrient and light availability. The classification and mapping of new biomes and provinces were conducted based on statistics of satellite and hydrographic data, and links from physics to biological productivity in newly classified provinces were examined by individual data. Analyses of satellite data and profiling float observations in the western North Pacific indicated that mesoscale eddies do not only enhance primary production through the supply of nutrients to euphotic zone, but lateral redistribution of nutrients and phytoplankton, and stabilization of water columns through lateral water exchange processes also play important roles. These processes are clearly reproduced in a lower-trophic ecosystem model that is coupled with a high-resolution ocean general circulation model. The subtropical and central mode waters in the western North Pacific were generated by the development of deep mixed layers, which were frequently observed within anticyclonic eddies. Propagations and interactions of these anticyclonic eddies are thus thought to control the distribution of these mode waters, and characterize ecological provinces. The map of ecological provinces in the present study that is based on mechanistic linkage between physics and biogeochemistry, is not the only one but to be selected from a list that includes maps from different approaches. Frameworks for visualizing and comparing maps, and assigning and evaluating attributes and ecosystem yields to each province are important next steps toward the evaluation of ecosystem services.

Tracking the magnitude and distribution of the ocean carbon sink.

Douglas W.R. Wallace
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The oceanic sink for anthropogenic carbon (C_{ant}) mitigates the impact of CO_2 emissions on global climate. Present levels of C_{ant} uptake, when combined with "carbon prices" under discussion in several countries, suggest that the ocean carbon sink is an ecosystem service worth as much as $600 billion per year. This value is offset by poorly constrained costs of ocean acidification. Both the spatial distribution of C_{ant} uptake across the air-sea interface, and its eventual storage in the ocean interior, are highly non-uniform and are inter-connected by ocean transport. The presentation will review the development of approaches, based on both observation and modelling, to diagnosing the spatial distribution of C_{ant} uptake and storage. All approaches to-date assume a steady-state, time-invariant ocean circulation and biological carbon pump. Identification of the major geographic areas or "provinces" for the uptake and storage of C_{ant} is key to the design of strategies to detect any unexpected changes to the ocean sink (e.g. due to changing ocean circulation). Such changes would, in turn, have implications for emission mitigation strategies (such as carbon pricing) aimed at controlling future atmospheric CO_2 levels. Challenges and opportunities for the detection of non-steady C_{ant} uptake involving repeat ocean surveys, moored time-series and measurements from autonomous vehicles will be discussed briefly.

Variability and trend of oceanic CO_2 in the western North Pacific subtropical zone

Masao Ishii[1], Daisuke Sasano[1], Naohiro Kosugi[1], Yusuke Takatani[2], Atsushi Kojima[2], Yosuke Iida[2], Kazutaka Enyo[2], Toshiya Nakano[2]

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Japan Meteorological Agency has been conducting high frequency oceanographic surveys in the western North Pacific including that in the meridional section of 137°E (3°N-34°N). The long-term annual or sub-annual observations in this section provide unique quasi time series data sets for the various physical and biogeochemical properties including dissolved oxygen and CO_2 system variables. In surface layer of the northern subtropics, salinity-normalized concentration of total dissolved inorganic carbon (sDIC) exhibits a substantial seasonal variation that reaches to > 30 μmol kg^{-1} in amplitude under the condition of nitrate-depletion. Shallow oxygen maximum develops in summer between the bottom of the summer mixed layer and thermocline/nitracline as a result of biological production, but its linkage to the sDIC decrease in surface layer in summer is yet to be understood. The mean rate of sDIC increase in surface layer in the past 30 years was determined for each 1º latitudinal zone by the multiple regression of sDIC as a function of temperature and the year of the measurement. In the northern subtropics (20º-34ºN), the mean rates (+1.0 to +1.2 μmol kg^{-1} yr^{-1}) were nearly consistent with the rate inferred from the rise of atmospheric CO_2 concentration. On the other hand, the mean rates were lower (+0.7 to +0.9 μmol kg^{-1} yr^{-1}) in the southern subtropical and tropical zones (3º-19ºN). The zonal difference in the rate of sDIC increase results in the zonal difference in the rate of ocean acidification; -0.0017 yr^{-1} for pH and -0.011 yr^{-1} for Ω_{arag} in the north and -0.0013 yr^{-1} for pH and -0.008 yr^{-1} for Ω_{arag} in the south. The mechanism causing these differences in the rate of CO_2 system variables are unclear, but are likely to be related to the difference in the domain of the shallow meridional overturning circulation cell in the North Pacific.

New ocean provinces characterized by island mass effect through nitrogen fixation

Takuhei Shiozaki[1], Taketoshi Kodama[2], Shigenobu Takeda[3], Sachihiko Itoh[1], Xin Liu[4], Fuminori Hashihama[5], Ken Furuya[6]

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Subtropical and tropical oligotrophic oceans have traditionally been recognized as “oceanic deserts”, where nutrient supply (especially nitrogen) is limited due to the strong stratification, and where biological production is generally low. In these oceanic deserts, enhanced primary production and rich fishery resources have identified around islands where distinctive nutrient supply occurs, and that is referred to as the island mass effect. The most well-known process of nutrient supply is upwelling in the island wake, which induces a bloom of chain-forming diatoms. Meanwhile, recent studies have demonstrated that blooms of *Trichodesmium* spp., major cyanobacterial diazotrophs, occur frequently around islands. Here we found that in the western subtropical South Pacific, *Trichodesmium* spp. thrived around islands and performed active nitrogen fixation, and that their abundance was attributable to the material supplied by land runoff. The *Trichodesmium* spp. were advected to areas remote from these islands, and as a consequence, the elevated primary production fueled by nitrogen fixation extended over a large area (up to distances of ~3500 km) around the islands. This wide expansion of high primary production was characterized by a low $\delta^{15}N$ of suspended particles and a large-scale reduction in phosphate concentrations at the surface. The occurrence of this vast ecosystem is likely triggered by terrigenous nutrient supply, suggesting its potential vulnerability to human activity on small islands. We also found that the similar phenomenon occurred around islands located along the Kuroshio Current. We demonstrated that the active nitrogen fixation in the Kuroshio is attributable to the island mass effect; *Trichodesmium* increased around islands situated along the Kuroshio, and were likely advected into the mainstream of the Kuroshio. *Trichodesmium* is a major diazotroph in the Kuroshio, and diazotrophy in the Kuroshio is considered to influence the nutrient stoichiometry in the North Pacific. Thus, our results indicate that phenomena around the islands located along the Kuroshio are important for determining the partial nitrogen inventory in the North Pacific. Our studies suggest that the region characterized by the island mass effect through nitrogen fixation generally occurs near islands in the tropical and subtropical Pacific Ocean.

Geography of biogenic elements in the Pacific Ocean: What form is most important?

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Supply and dynamics of biogenic elements such as N, P, Si are essential marine processes to consider ocean domain since they are main control factors of biological productivity ecosystem structur and biological pump. In marine ecosystems, most nutrients are supplied from deep water and the biological productivity is high in subarctic and upwelling regions. On the other hand, most part of subtropical waters are recognized as oligotrophic ecosystem with lower nutrient concentration than "detection limit" of conventional method of the analysis, e.g., <0.1 μM for NO_3. In the oligotrophic subtropical waters, it has been suggested DOM contribute significant part of nutrient supply and production, but the contribution of particulate matter is rarely studies. Recently, high-sensitive methods for nutrient measurement was developed (e.g., Hashihama et al., 2009) and found that the variations in nitrate and phosphate concentration were more than 3-order of magnitude in the western subtropical North Pacific. We developed the method of LWCC (Liquid Waveguide Capillary Cell) for nutrients into particulate forms of P and Si and also for DOP, and compared the inventory of each form in the Pacific Ocean. We found that variations in the concentrations particulate N and P were within 2-order of magnitude and less variable than nutrients (5-order of magnitude). Our study suggests that particulate forms of P and N play important role as a source of biogenic element in super-oligotrophic western subtropical gyre in the North Pacific. We will discuss contrastive biogenic elemental dynamics between subtropical and subarctic/upwelling ecosystems.

Diversity, community structure and functional potential of planktonic bacteria in the Pacific Ocean: insights from the NEOPS transoceanic cruises

Koji Hamasaki[1], Shotaro Suzuki[1], Yoshitoshi Ogura[2], Tetsuya Hayashi[2], Hiroshi Mori[3], Ken Kurokawa[3], Wataru Arai[4], Hideto Takami[4]

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We report spatial change of bacterial diversity, community structure and functional potential along transoceanic transects in the Pacific Ocean, which is fundamental to understand biogeochemical cycles and food web dynamics and evaluate ecosystem services in the ocean. We collected about 300 seawater samples during 4 cruises from 2011-2014 by R/V Hakuho-maru. Two size fractions, >3.0 μm and 0.22-3.0 μm, were obtained by filtering the seawater in order to compare particle-associated (PA) and free-living (FL) communities of bacteria. Although particle association of microbes is essential to their roles in organic matter degradation and nutrient regeneration, much less information has been known about diversity and function of PA bacteria than FL bacteria. PCR amplicon deep sequencing of the 16S rRNA gene V1V3 region was performed to obtain bacterial community profiles. PA and FL communities showed distinctive structures and interestingly the difference increased with depth. Both communities largely changed with depth from 0 m to 200 m and changed little from 200 m to the bottom. This pattern of vertical dissimilarity in bacterioplankton communities was quite reproducible in a wide latitudinal range from 40° S to 50° N. We also found that PA communities always showed higher diversity (Simpson Index) and larger spatial variability of the diversity than FL communities. The analysis of microbial community genomes were performed on 18 samples collected from surface seawater of tropical and subtropical regions. Functional potential of bacterioplankton were compared between PA and FL communities. Size-fractionated DNA samples were subjected to the MiSeq 250 bp paired-end sequencing, and 10-20 million reads per sample were obtained. KEGG orthology was assigned to each predicted gene. We evaluated metabolic potential of bacterioplankton communities by using Metabolic And Physiological potentiaL Evaluator (MAPLE), which is an automatic system for mapping genes to the KEGG module. As it was shown in the community structure analysis, PA and FL communities showed distinctive patterns of module completion and abundance. The similarity percentage analysis suggested that higher abundance of some transporters in PA than FL communities largely contributed to the dissimilarity of the functional potential between them. This study revealed that large scale patterns of diversity and community structure of bacterioplankton especially PA communities in the Pacific Ocean and also their features in the functional potential in comparison with FL communities.

SST habitat and food change projections for Pacific salmon (*Oncorhynchus spp.*) in the North Pacific and adjacent seas based on CMIP5 climate models

Shoshiro Minobe[1], Hiromichi Ueno[2], James R. Irvine[3], Alexander V. Zavolokin[4], Katherine W. Myers[5], Mio Terada[1], Mitsuho Oe[6], and Skip McKinnell[7]

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Climate change is affecting Pacific salmon (*Oncorhynchus*) species in multiple ways including the abundance and distribution of thermally suitable oceanic habitat, which can be represented by sea-surface temperature (SST) change in future. Previous studies examined habitable SST changes, and suggested shrinking of SST habitat. In this presentation, we first update SST habitat estimation based on recent and previously unpublished high seas surveys, and then examine SST habitat and food changes in the habitat for salmon species during the 21st century by analyzing outputs of CMIP5, used in the IPCC Fifth Assessment Report. The results based on RCP8.5 scenario, the high end scenario in the IPCC report, are explained in this abstract. The SST habitat changes in winter are rather gradual, but those in summer are dramatic; in the end of this century most of salmon species have to utilize Arctic Sea as a refugee from too hot SSTs prevailing over the North Pacific including its marginal seas. Also in the summer season, the largest reduction of surface zooplankton amount is found among all seasons. These results suggest that, in addition to the habitat shift and shrinking, reduction of food availability in specific seasons strongly influence Pacific salmon in future.

Distribution of oceanic ^{137}Cs from the Fukushima Dai-ichi Nuclear Power Plant

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A series of accidents at the Fukushima Dai-ichi Nuclear Power Plant (1F NPP) following the earthquake and tsunami of 11 March 2011 resulted in the release of radioactive materials to the ocean by two major pathways, direct release from the accident site and atmospheric deposition. We reconstructed spatiotemporal variability of ^{137}Cs activity in the regional ocean for four years by numerical model, such as a regional scale (horizontal resolution is about 1 km) and the North Pacific scale (horizontal resolution is about 10 km) oceanic dispersion models, an atmospheric transport model, a sediment transport model, a dynamic biological compartment model for marine biota and river runoff model.

^{137}Cs is a passive tracer in the ocean. Direct release rate of ^{137}Cs were estimated for four years after the accident by comparing simulated results and observed activities very close to the site. The estimated total amounts of directly release was 3.6±0.7 PBq. Directly release rate of ^{137}Cs was the order of magnitude of 10^{14} Bq/day and decreased exponentially with time to be the order of magnitude of 10^{9} Bq/day by the end of September 2015. Simulated ^{137}Cs activities attributable to direct release were in generally good agreement with observed activities in a regional scale. Distribution of ^{137}Cs was strongly affected by meso-scale eddies. It is still difficult to represent the observed data as point to point comparison even if model can simulate the meso-scale eddies by nudging to reanalysis data, JCOPE2.

In the North Pacific scale, ^{137}Cs activity in the intermediate water increased due to the Subtropical Mode Water (STMW) formation. ^{137}Cs is a useful tracer to detect the STMW formation. Not only the direct release but also the atmospheric deposition are essential for the distribution of ^{137}Cs activity in the North Pacific. Five-member, ensemble simulation with high resolution can represent the increase of ^{137}Cs activity in the intermediate water.

Recent advances in the modelling of oceanic higher trophic levels with SEAPODYM

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The Spatial Ecosystem And Population Dynamics Model (SEAPODYM) is a tool for predicting spatial population dynamics of exploited fish populations under the influence of environmental variability. It includes also a representation of zooplankton and several functional groups of micronekton at lower and mid-trophic levels. The model is coupled off-line to 3D physical and biogeochemical ocean models with temperature, currents, primary production, euphotic depth and dissolved oxygen being key input variables. Alternatively, these variables can be derived from satellite and operational ocean circulation models to achieve realistic mesoscale predictions and forecasts. The modeling framework includes a robust method for estimating optimal sets of parameters, an indispensable attribute when a model is designed as a tool for ecosystem and fisheries management. Through a series of examples of applications, the recent advances in the continuous development of SEAPODYM will be provided. First, the progress in modeling the mid-trophic levels groups (micronekton) using assimilation of acoustic data will be reviewed. Future perspectives will be discussed that includes the on-line coupling with biogeochemical models and the central role of these organisms in the ecosystem functioning and the carbon cycle. Then, highlights on recent results for assessing the impact of fishing, environmental variability and climate change on tuna and other exploited species will be presented. The last optimal solutions allowing reconstructing the past history of these species since the 1950s were obtained and validated both with fishing and tagging data datasets. These solutions are then used to design a global operational model providing open boundary conditions to regional high resolution models.

Nutrient supply ratios define the biogeography of nitrogen fixation

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A conceptual model describing competition between nitrogen-fixing (i.e. diazotrophic) and non-nitrogen-fixing plankton suggests that the ocean can be divided into six observable biogeochemical provinces in terms of surface nutrient concentrations and phytoplankton community structure. The boundaries between these provinces are set by the ratios in which N, P, and Fe are delivered to the surface ocean, and manifest in the surface concentrations of limiting and non-limiting nutrients. Strong empirical support for the model predictions is found in global-scale observations of surface nutrient concentrations and diazotroph abundance, and Fe:N and P:N supply ratios are thus identified as key determinates of plankton community structure. Observed spatial and temporal variability in the Fe:N supply ratio suggests that future changes in these variables may impact the structure and function of marine communities, a possibility that is supported by experimental simulations in an Earth system model.

Biogeochemical provinces in the global ocean based on phytoplankton growth limitation

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The biogeochemical province is one of the useful concepts for the comprehensive understanding of regional differences of the marine ecosystem. Various biogeochemical provinces for lower-trophic level ecosystem have been proposed using a similarity-based classification of seasonal variations of chl-a concentration typified by Longhurst 1995 and 2006. Such categorizations well capture the regional differences of seasonality as "total phytoplankton". However, background biogeochemical mechanism to characterize the province boundary is not clear. Namely, the dominant phytoplankton group is different among regions and seasons, and their physiological characteristics are significantly different among groups. Recently some pieces of new biogeochemical information are available. One is an estimation of phytoplankton community structure from satellite observation, and it makes clear the key phytoplankton type in each region. Another is an estimation of limitation factors for phytoplankton growth (e.g., nutrients, temperature, light) in each region from modeling studies. In this study, we propose new biogeochemical provinces as a combination between the dominance of phytoplankton (i.e., diatoms, nano-, pico-phytoplankton or coexistence of two/three types) and their growth limitation factors (particularly we focused on nutrient limitation; N, P, Si or Fe). In this combination, we classified the global ocean into 23 biogeochemical provinces. The result suggests that even if the same type of phytoplankton dominates, the background mechanism could be different among regions. On the contrary, even if the regions geographically separate, the background mechanism could be similar among regions. This is important to understand that region/boundary does respond to environmental change. This biogeochemical province is useful for identification of key areas for future observation.

A sub-polar marginal sea controls oceanic biogeochemical cycles in the North Pacific - West to East dissolved Fe distribution -

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The subarctic North Pacific is known to have High Nutrient Low Chlorophyll (HNLC) areas, where nutrients concentration are not depleted through all season and the phytoplankton growth is broadly limited by iron (Fe) availability. Simultaneously, the western subarctic gyre in the North Pacific has greater seasonal variability in biogeochemical parameters than that of the Alaskan gyre. To investigate Fe sources for controlling seasonal amplitude of biogeochemical parameter in each gyre, latitudinal transect Fe distribution with high resolution is required. To reveal the detailed spatial variation of the west-east distribution and the controlling processes of dissolved Fe in the entire subarctic Pacific, vertical section observations were conducted as a part of the Japanese GEOTRACES program. The sections displays high dissolved Fe concentrations below the surface to water as deep as ~3000 m in the western subarctic, suggesting Fe-rich intermediate water was transported laterally. The section data also indicate that the influence of the western Fe-rich intermediate water does not reach the Alaskan gyre intermediate layer. These Fe distributions were well explained by the known sedimentary Fe sources and the water transport systems from the sub-polar marginal sea and the continental margin. Calculated Fe flux from the intermediate water to the euphotic zone in the western subarctic gyre is significantly higher than that on the eastern side, and can quantitatively explain the differences in surface macro-nutrient consumption between the western and eastern subarctic, as well as the formation of the HNLC region. These results are consistent with the previous studies that the western subarctic gyre has greater seasonal variability in lower trophic levels than the eastern subarctic Pacific, even with the Fe limitation.

Diversity and biogeography of marine planktonic copepods: Insights from metagenetic community analysis in the Pacific

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Planktonic copepods are among the most important zooplankton in marine food webs and biogeochemical cycles, and their community structures have a pronounced effect on global marine ecosystems. To further reveal copepod diversity and biogeography, the community structures of epipelagic and mesopelagic copepods were investigated in the Pacific (40ºS–68ºN) using metagenetic community analysis of nuclear large subunit ribosomal DNA. This method is taxonomically comprehensive, avoids time-consuming morphological classification, and provides genetic information on DNA sequences. Latitudinal community and diversity gradients were evident in the epipelagic layer, and these gradients were clearly correlated with environmental changes in water temperature and chlorophyll *a* concentration in particular. High diversity was observed in the tropical and subtropical areas, with a peak in the North Pacific subtropical gyre. This pattern was also observed in the mesopelagic layer within relatively stable water environments, suggesting the influence of epipelagic ecosystems on mesopelagic communities. Although diversity was higher in the mesopelagic layer than in the epipelagic layer, the epipelagic community was composed of various taxonomic groups with high genetic diversity. Specific taxonomic groups were diverse in the mesopelagic layer, indicating that different mechanisms maintain diversity within each layer. Distribution patterns were clearly different between low-latitude (tropical and subtropical zones) and high-latitude (transition, subarctic, and arctic zones) groups. Phylogenetic analysis revealed recent divergence of the high-latitude group, suggesting that a relatively short evolutional history is a factor underlying the low diversity at high latitudes. These results indicate that both environmental and evolutionary factors have determined the current diversity and biogeography of planktonic copepods.

Seasonal to decadal variability of sea surface nutrients and DIC in the North Pacific

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National Institute for Environmental Studies (NIES, Japan) and Institute of Ocean Sciences (IOS, Canada) has carried out ship of opportunity measurements of nutrients (phosphate, nitrate, and silicate) and partial pressure of CO2 since late 1980s. Using the ship of opportunity data and others, seasonal to decadal variability of sea surface nutrients and dissolved inorganic carbon (DIC) in the North Pacific were clarified. Nutrient and DIC concentrations were high in the subarctic in winter and low in the subtropics. In the summer, substantial amount of nutrients remained unutilized in subarctic and the northern part of the subarctic-subtropical boundary region. In the subtropics, nutrients were almost entirely depleted throughout the year, while DIC concentrations showed a north-south gradient and significant seasonal change. Nutrients and DIC showed a large seasonal drawdown in the western subarctic region, while the drawdown in the eastern subarctic region was weaker, especially for silicate. The subarctic-subtropical boundary region also showed a large seasonal drawdown, which was most prominent for DIC and less obvious for nitrate and silicate. In the interannual time scale, the Pacific Decadal Oscillation was related to a nutrients and DIC seesaw pattern between the subarctic-subtropical boundary region and the Alaskan Gyre through the changes in horizontal advection, vertical mixing and biological production. When the North Pacific Gyre Oscillation was in the positive phase, nutrient concentrations in the subarctic were higher than the mean states. Trends of phosphate and silicate averaged over the North Pacific were negative, while nitrate trend was insignificant.

Community ecological modeling as an alternative approach to physiographic classification for marine conservation planning.

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Accurate mapping of marine species and habitats is an important yet challenging component of establishing networks of representative marine protected areas. Due to limited biological data, marine classifications based on abiotic data are often used as surrogates to represent biological patterns. We tested the surrogacy of an existing physiographic marine classification, the British Columbia Marine Ecological Classification System (BCMEC), using non-metric multidimensional scaling (nMDS) and a permutational analysis of variance (PERMANOVA) to test if species composition was significantly different among Ecosections defined by BCMEC. We then present an alternative approach that incorporates both biological and environmental data in a community modeling framework. We use data on 174 species of demersal fish and benthic invertebrates to identify broad-scale biological assemblages in a 100,000 km^2 study area in the northeast Pacific Ocean. We identified assemblages using cluster analysis then used a random forest model with 14 environmental variables to identify potential drivers of changes in assemblages across space. Using the model, we predicted which biological assemblage was most likely to be present based on the environmental conditions, and delineated this prediction into ecological units called "Biomes". Our community modelling approach resulted in five major geographically coherent biological assemblages that were best explained by changes in depth, temperature range and summer salinity. Our model showed high predictive performance (AUC = 0.93) delineating the Slope, Shelf, Dogfish Bank, Other Banks and Troughs Biomes. A comparison of the two classifications showed that the community approach represents significantly more distinct and Biome-specific species assemblages than those delineated by the BCMEC Ecosection boundaries. An examination of uncertainty in our random forest model prediction highlighted reduced model performance in transition zones at Biome boundaries. The ability to map the underlying uncertainty is a strength of our analytical classification approach, in contrast with rule-based classifications where underlying uncertainty, particularly at boundaries, is lost. The output of this study provides a biotic driven classification that can be used to better achieve ecological representativity in the MPA planning process.

Regional structure and functional characteristics of pelagic marine ecosystems in the western North Pacific Ocean

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The Ecosystem Approach to Fisheries (EAF) and the Ecosystem Based Fishery Management (EBFM) are becoming the important concept for managing fisheries and implementing the principles of sustainable development. Both concepts emphasize fisheries and also include other components of marine ecosystem like as marine mammal, protected species, and non-target species. For sustainable utilization of fishery resources and maintenance of marine ecosystem function and biodiversity, the crucial issue is understanding the structure and function of marine ecosystems. Higher trophic level (HTL) organisms are key components of the open ocean ecosystems through top-down control, and tend to become main target of high sea fishery. HTL organisms are widely distributed over the open ocean and migrate according to the life history and ecological traits of each species. The distribution of HTL species influenced by spatio-temporal variation of oceanic environments construct diagnostic and dynamic ecosystems. We delineate the spatial structure of open ocean communities based on the HTL species composition using long-term survey data and figure out the ecosystem properties of each community through food web analysis. This approach allows us to evaluate the interactions between highly migratory species (e.g., salmons, and neon flying squid) and the productivity of regional ecosystems through food webs. To understand the spatial structure of HTL communities in the western North Pacific Ocean, we analyzed the long-term driftnet survey data. We applied the dissimilarity (Bray-Curtis index) analysis and the clustering algorisms (ward's method) to the species composition data of individual sampling locations, and divided the western North Pacific Ocean into several subareas. We next analyzed the characteristics of food webs in these subareas; i) species composition in weight and number, ii) stomach contents analyses, and iii) stable isotope analyses. Based on the information about ecosystem components and their interactions, we construct Ecopath models, which are mass-balance food web models appropriate for looking over trophic structure of marine ecosystems, for distinctive subareas. With these models, we can compare the structure and function of the regional ecosystems in the western North Pacific Ocean and evaluate the ecological function and interaction of migratory HTL species in each subarea.

Growth, migration and trophic interactions role of neon flying squid (*Ommastrephes bartramii)* in the North Pacific

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The neon flying squid, *Ommastrephes bartramii* iswidespreadin subtropical and temperate regions. This economically important oceanic squid species has been harvested commercially by Japan since 1974, and subsequently by Korea and China. It is revealed from field observations that *O. bartramii* has one-year lifespan. It is also observed that it migrates between its spawning grounds (30-35°N) and feeding grounds (40-45°N). The North Pacific population is comprised of two spawning cohorts; the autumn cohort and winter-spring cohort. It is interesting to see, despite their apparent contiguous hatching periods, there is a marked difference in the mantle length of both cohorts.

O. bartramii is getting a significant amount of attention not only due to commercial fisheries stock but also a keystone species in food web in the North Pacific. However, their feeding ecology has been mostly examined by traditional methods. Nowadays, stable isotopes of nitrogen and carbon have proven to be a valuable tool in numerous studies on food webs and trophic relationships. In case of cephalopods study, stable isotope profiles along the gladius made of chitinous shell have been recently analyzed and seem to be a promising tool to produce a chronological record of dietary information over their lifetime. In this study, δ13C and δ15N values were measured along the gladius to reconstruct *O. bartramii* feeding variations.

Stable isotope profiles along the gladius (internal chitinous shell) have been recently analyzed and form a promising tool to back-calculate a chronological record of changes in the diet and habitat. In this study, $\delta^{13}C$ and $\delta^{15}N$ values were measured along the gladius to reconstruct the feeding variations and habitat of the autumn cohort during ontogeny. The results of $\delta^{13}C$ values support previous studies which inferred differences in migratory behavior between males and females. These differences occurred from 260 mm mantle length.

Based on this result, we are trying to develop a bioenergetics model for this species. Our model was based on NEMURO.FISH, using respiration and consumption terms and assumed that SST and prey zooplankton density are the determining factors of the reduction of body size. SST and prey zooplankton density are obtained from the result of NEMURO embedded in 3-D physical model, along the migration route of *O. bartramii.*

Toward the effective global ecological and biogeochemical observation planning - recommendation from the study on new ocean provinces

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With an increasing demand for better understanding of climate change impacts on the marine ecosystem and biogeochemical cycle, the international ocean science community has been seeking the best way to establish the global ecological and biogeochemical observation systems. Different from physical oceanography which parameters are globally measurable by already established methods, the bottleneck is how we could measure the complex ecological and biogeochemical parameters in basin to global scales in cost-effective ways. Our paper is to present an idea for designing the effective global ecological and biogeochemical observation plans based on the ocean provinces, which were newly developed through the NEOPS project. We analyzed seasonality of biogeochemical properties (nutrients and pCO_2) and phytoplankton abundance using VOS (Voluntary Observing Ship) data and satellite ocean colour data, respectively, which have been collected over 10 years since 2000. Then we divided the North Pacific into c.a. 10~15 ocean provinces based on the similarity in seasonal variations of the respective properties. Since we defined the provinces with the “dynamic” rather than “static” boundaries, locations of the boundaries between the provinces interannually varied both in the biogeochemical and phytoplankton province maps. Interannual shifts of the boundaries were detected in a larger extent in some regions, e.g. along the Kuroshio Extension and around the Gulf of Alaska, indicating that phenological changes in biogeochemical and ecological processes are particularly susceptible to climatic control in those regions. We also found high interannual variation in zooplankton community structure in the same regions. We expect the NEOPS new ocean provinces might be useful to propose the focal regions that should be intensively observed with relatively high temporal and spatial resolutions.

Surface distributions of dissolved and particulate phosphorus pools in subtropical Pacific Ocean

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Phosphate concentrations vary greatly from sub-nanomolar to sub-micromolar levels in surface waters of the subtropical Pacific Ocean. In the vast area, there are regions where phosphate concentrations are depleted below 10 nM, as seen in western subtropical North Pacific (WSNP). In the phosphate-depleted regions, it is supposed that microorganisms utilize labile dissolved organic phosphorus (DOP) instead of phosphate to maintain their growth. Total particulate P (TPP) of microorganisms consists of particulate organic phosphorus (POP) such as phospholipids and nucleic acids, and particulate inorganic phosphorus (PIP) existed as intracellular storage (phosphate, pyrophosphate, and polyphosphate) or surface-adsorbed P. Under P stress condition, microorganisms generally decrease cell P quota such as substitution of non-phosphorus lipids for phospholipids and/or they store excess P as polyphosphate. To understand the strategy of P acquirement in the subtropical Pacific, it is important to elucidate the distributions of organic and inorganic pools of dissolved and particulate P. Four trans-Pacific NEOPS cruises and application of the sensitive analytical technique enabled us to reveal surface distributions of each P pools. Our finding shows that the WSNP was the region of the lowest dissolved P. Mean concentrations of phosphate, labile DOP, and total DOP in the WSNP were 5 ± 3, 6 ± 4, and 141 ± 28 nM, and were significantly lower than those in other subtropical Pacific (105 ± 88, 14 ± 17, and 172 ± 48 nM, respectively). However, mean concentrations of TPP, POP, and PIP were not significantly different between the WSNP (13.4 ± 2.6, 10.9 ± 2.5, 2.5 ± 0.6 nM, respectively) and the other regions (14.6 ± 5.7, 12.3 ± 5.0, 2.3 ± 1.3 nM, respectively). No significant correlation of particulate P forms (TPP, POP, and PIP) and phosphate were found over the subtropical regions. The ratios of particulate P forms to particulate organic carbon (POC) also showed no significant correlation with phosphate. Based on these results, the lowest dissolved P in the WSNP could not lead to a significant decrease in cell P quota of microorganisms. Maintenance of cell P quota under the phosphate-depleted condition might be associated with DOP utilization and/or PIP accumulation.

Triple oxygen isotopic compositions of nitrate and sulfate in the aerosols collected for KH-13-7 cruise

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Atmospheric boundary layer of the ocean is one of the most optically active places in the Earth's atmosphere, because of high amount of solar radiation and humidity throughout the year. The changes in the oxidation process of the atmosphere caused by the generation and disappearance of ozone in the atmospheric boundary layer are not fully understood. Triple oxygen isotopic compositions ($\Delta^{17}O = \delta^{17}O - 0.52 \times \delta^{18}O$) nitrate ($NO_3^-$) and sulfate ($SO_4^{2-}$) in the atmosphere, enable us to understand the chemistry in the atmosphere through the stable isotope composition. In this study, we present $\Delta^{17}O(NO_3^-)$ and $\Delta^{17}O(SO_4^{2-})$ values of atmospheric aerosols collected in the Pacific Ocean by KH-13-7 cruise. The $\Delta^{17}O(NO_3^-)$ values were widely distributed and 21-32 ‰, while $\Delta^{17}O(SO_4^{2-})$ does not varied and ranged from 0 to 1.5‰. In this presentation, based on the results, we discuss the atmospheric oxidative capacity in the atmosphere in the atmospheric boundary layer of the South Pacific.

Increase in pCO_2 and its impact on the trend of oceanic CO_2 uptake for the last two decades

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To determine the rate of oceanic partial pressure of carbon dioxide in surface seawater (pCO_2) increase is critical in reconstructing the fields of pCO_2 and sea-air CO_2 flux over the decades. In this study, we have analyzed the rate of pCO_2 increase for the past decades, ranging from +1.21 μatm·year^{-1} in the western equatorial Pacific to +2.00 μatm·year^{-1} in the Southern Ocean, and developed algorithms to reconstruct pCO_2 fields in global monthly pCO_2 fields for the period of 1990-2013 on the basis of quality-controlled database Surface Ocean CO_2 Atlas (SOCAT) version 2 using the multiple regression technique. The root mean square error between estimated and observed pCO_2 is ±16.3 μatm. The mean annual sea-air CO_2 flux over the global ocean for the years 1990−2013 was estimated to be −1.78 PgC·year^{-1} (contemporary flux; a negative value indicates oceanic uptake) on the average and showed a trend of increasing CO_2 uptake of −0.20 (PgC·year^{-1})·decade^{-1} with large contributions by the Pacific and the Atlantic. The uncertainty in this estimate is calculated to be 0.78 PgC·year^{-1} (44%), i.e., 0.09 PgC·year^{-1} from our empirical method to interpolate/extrapolate pCO_2, 0.67 PgC·year^{-1} from determination of the rates of pCO_2 increase and the rest from gas transfer processes including wind speed (0.27 PgC·year^{-1}) and a scaling factor of piston velocity (0.27 PgC·year^{-1}). The uncertainty in the pCO_2 increasing rate resulted in the largest uncertainty in the sea-air CO_2 flux and is needed to be reduced largely through the continued pCO_2 measurements.

Size distributions and cloud condensation nucleus activities of marine aerosols over the Pacific Ocean and its marginal seas

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Atmospheric aerosols play an important role in controlling radiative properties and lifetime of clouds by acting as cloud condensation nuclei (CCN). Given that the ocean covers about 70% of the Earth's surface, oceanic aerosols contribute significantly to the CCN budget in the marine environment. Marine particulate organics and precursor gases generated by marine biota may affect concentrations, size and chemical composition of the oceanic aerosols. Thus, it is important to understand the relationship between marine primary productivity and aerosol properties related to CCN activities over the open ocean. In this study, size distributions and CCN activities of aerosols over the Pacific Ocean and its marginal seas are characterized, and factors controlling the spatial variation of the aerosol characteristics are investigated.

Atmospheric measurements were conducted during R/V Hakuho-maru KH-13-7 and leg 2 of KH-14-3 cruises. Ambient air was sampled continuously through the inlets via silicon tubing and then dried with a diffusion dryer. The dried air samples were introduced to a scanning mobility particle sizer (Model 3034 or Model 3936L25, TSI Inc.) to measure number size distributions of ambient aerosols. CCN concentrations were measured with a continuous flow thermal gradient CCN counter (CCN-100, DMT Inc.) during the leg 2 of KH-14-3. Concentrations of atmospheric trace gases (O_3 and CO) and radon (^{222}Rn), those can be tracers for anthropogenic or land-origin air masses, were also measured continuously along the cruise tracks.

The observed aerosols had apparent bi-modal size distributions with a minimum around 100 nm in most of the ocean regions except for the arctic region. The bi-modal size distribution is often observed in open ocean and can be due to cloud processing. The contributions of each size mode to the total number concentrations varied with ocean regions: aitken-mode particles (less than ~100 nm) contributed largely in the pristine maritime air masses, while number concentrations of aitken- and accumulation-mode (larger than ~100nm) particles were almost same in the ocean region affected by land-origin air masses. In the arctic region, a spontaneous enhancement of aerosols with diameter of ~100 nm was observed. Because there are not major anthropogenic sources of pollutants around the arctic region, the enhanced particles might be come from biogenic sources. Analysis based on CCN activation ratio suggests that these increased fine particles were rich in organics.

Study on the radiocarbon distributions of dissolved organic carbon in the central Pacific Ocean

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Radiocarbon content of marine dissolved organic carbon ($DO^{14}C$) can provide useful information on how organic carbon is produced, transported, and ultimately sequestered in the ocean interior. So far the studies about concentrations and spatiotemporal variations of $DO^{14}C$ tended to be largely coastal environments, and provided limited information about single point profiles at anchor points along the postulated route of global thermohaline circulation. But it is hard to apply such results to the entire ocean because of the mixture of water mass that have different end-member values. We conducted research to present the first set of full-depth profiles for $DO^{14}C$ along a transect from the central South Pacific Ocean to Chukchi Sea (40°S - 170°W, 68°N - 168°W), where $DO^{14}C$ were not reported until now. And besides, we aim to verify previous results based on detailed survey data acquired by this study, and to closely investigate the character of distribution and how they are affected by biotic and abiotic factors. In order to measure radiocarbon contents of seawater samples, they should be treated with a specific preparation system composed of the custom quartz reactor, dedicated vacuum line and UV lamp. It is crucial to secure the enough recovery in the process of sample preparation, so we have been working since last April to find ideal condition for a high degree of confidence in data. We present here not only how the system is progressing but also what radiocarbon study in the central Pacific Ocean means for better understanding of oceanic carbon cycle.

Estimation of spatial distribution for small odontocetes using three distinct habitat models

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The spatial distributions of four small odontocete species, Dall's porpoise, Pacific white-sided dolphin, short-beaked common dolphin, and pantropical spotted dolphin were estimated using generalized linear model (GLM), Ecological Niche Factor Analysis (ENFA), and Maximum Entropy modeling (MaxEnt). GLM compares presence/absence of the focal animals, while MaxEnt and ENFA contrast the species distribution with the background environment in the whole survey area. The National Research Institute of Far Seas Fisheries (NRIFSF) has conducted dedicated sighting surveys since 1980s. The four species included in the study has been frequently encountered during these surveys. The sighting data collected during summers between1983 and 2006 was pooled and used to model species' distribution in relation to the environmental variables (temperature at surface, 100 and 200 m deep, bottom depth, distance to coast, slope, chlorophyll-a concentration, and net primary production). Performance of distinct modeling approaches were compared using the area under the receiver operating characteristic curve (ROC/AUC) and the Boyce index (BI). ROC/AUC and BI values were larger than 0.90 for the results of GLM and MaxEnt for the four species without few exceptions, while ROC/AUC and BI values were relatively smaller for the results of ENFA. Thus it was considered that GLM and MaxEnt more accurately estimated the habitat suitability of the four odontocete species. GLM and MaxEnt showed the similar habitat suitability maps. The core habitat of Dall's porpoise was in the subarctic region north of 42°N. Pacific white-sided dolphin and short-beaked common dolphin showed zonal distribution patterns extending from the Japanese coast to close to the west coast of North America between 40–45°N and 37–40°N, which corresponded with the transitional domain and the transition zone, respectively. Suitable areas for pantropical spotted dolphin were detected in the tropical and subtropical regions south of 37°N. Our results indicated that the four odontocete species separated their habitats in association with wide-scale oceanographic structures in the North Pacific.

Formation Mechanism of Barrier Layer in the Subtropical Pacific

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Seasonal and interannual variations of barrier layer (BL) and its formation mechanism in the subtropical North and South Pacific were investigated by using raw and gridded Argo profiling float data and various surface flux data in 2003−12 and hydrographic section data from the World Ocean Circulation Experiment Hydrographic Programme. BLs detected by raw Argo profiles, which existed within the sea surface salinity (SSS) front located on the equator side of SSS maxima, were thickest and most frequent in winter and had a temporal scale shorter than 10 days, indicating their transient nature. Surface and subsurface processes for the BL formation suggested by previous studies were evaluated. Poleward Ekman advection of fresher water was dominant as the surface freshening, but cannot explain the observed seasonal variations of BL. Subsurface equatorward intrusion of high-salinity tropical water was too deep to produce salinity stratification within isothermal layers. These results strongly suggest that BLs in the subtropical Pacific are formed mainly through tilting of the SSS front due to the poleward Ekman flow near the sea surface and the equatorward geostrophic flow in the subsurface. This idea is supported by dominant contribution of the meridional SSS gradient to the meridional sea surface density gradient within the SSS front and the correspondence between the seasonal variations of BL and isothermal layer depth. On interannual time scale, the winter BL thickness in the North and South Pacific was related to the Pacific Decadal Oscillation and the El Niño-Southern Oscillation, respectively, through the intensity of trade winds controlling isothermal layer depth.

Quantifying the mixing ratios of atmospheric nitrate in ocean surface using triple oxygen isotopes as tracers

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While general remineralized nitrate (NO_3^-) shows mass-dependent relative variations in both ^{17}O and ^{18}O ($\delta^{17}O = 0.52\delta^{18}O$), atmospheric NO_3^- displays an anomalous enrichment in ^{17}O ($\delta^{17}O > 0.52\delta^{18}O$) (Michalski et al., 2003). Thus, the triple oxygen isotopic compositions ($\Delta^{17}O = \delta^{17}O - 0.52\delta^{18}O$) of NO_3^- in a water mass can be a useful tracer to quantify the contribution of depositional atmospheric NO_3^- to total NO_3^- in the water mass, because oxygen isotope exchange reaction is minimum at the range of pH and NO_3^- concentration in natural water environment. In this study, we applied the $\Delta^{17}O$ tracer method to determine NO_3^- cycles in western marginal area of north Pacific. Surface (mixed layer) seawater (0-10m) are taken at open ocean area on Okhotsk sea, Bering sea, and western North Pacific. Both sub-surface seawater (30-50m) and deep seawater are taken as well in the area for comparison.

To determine $\Delta^{17}O$ in oceanic nitrate, we developed a rapid and sensitive online analytical system to determine the triple oxygen isotopic compositions of NO_3^- in nmol quantities using continuous-flow IRMS (CF-IRMS) without the cumbersome and time-consuming pretreatments. The system is based on the isotopic analysis of N_2O, which is quantitatively converted from NO_3^- using the simple reactions using spongy cadmium and sodium azide in an acetic acid buffer, and then purified by PoraPLOT capillary column. Addition to the direct N_2O isotopic analysis at the masses 44, 45, and 46, we determine the isotopic composition of O_2 which is quantitatively produced in a gold tube at 780 °C to determine $\delta^{15}N$, $\delta^{18}O$ and $\delta^{17}O$ for NO_3^-. By using the method, 20 nmol of NO_3^- give a 1 σ uncertainty of 0.1 ‰ for $\delta^{18}O$ and 0.1-0.3 ‰ for $\Delta^{17}O$.

Most of the deep water samples exhibit little anomaly in $\Delta^{17}O$. The absence of a significant ^{17}O anomaly in the deep waters suggests that a minor contribution of atmospheric NO_3^- inputs in the deep sea environments, in line with general understandings that most NO_3^- in deep sea water have been remineralized from sinking organic nitrogen. On the other hand, surface seawater in both Okhotsk sea and Bering sea exhibit small but definite ^{17}O anomaly up to +1.2 ‰. The average $\Delta^{17}O$ is +0.9±0.3 ‰ in the area, except for the upwelling region in Bering sea, where $\Delta^{17}O$ is less than +0.5 ‰ in usual. Assuming that the $\Delta^{17}O$ value is +26 ‰ for $NO_3^-{}_{atm}$, the we estimate that $NO_3^-{}_{atm}$ fraction is ca. 4±1 % in the area. These values are basically consistent with the independent estimates on their nitrogen budgets. By determining the distribution of more $\Delta^{17}O$ values of NO_3^- in ocean surface, as well as precise NO_3^- assimilation rates (= primary production rates), we can estimate more precise deposition rates of $NO_3^-{}_{atm}$, as well as their temporal variations.

Transport of trace metals (Mn, Fe, Ni, Zn and Cd) in the western Arctic Ocean (Chukchi Sea and Canada Basin) in summer 2012

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Trace metals such as Fe, Mn, Ni, Zn and Cd are involved in numerous processes in the metabolisms for phytoplankton growth. In the Arctic Ocean, the sea shelf area comprises roughly one-third and accounts for one-fourth of that of the global ocean. Previous studies have revealed that the maximum of Fe concentration existed in the halocline waters like as nutrients and dissolved organic matters, suggesting that both the brain water originated from the Pacific Ocean and the input from the continental shelf play the significant roles for Fe transport (e.g., Hioki et al., 2014). On the contrary, there are only few data about the distributions of Zn, Cd, Ni and Mn in the western Arctic Ocean. In this study, distributions of dissolved and total dissolvable trace metals (Fe, Mn, Ni, Zn and Cd) were investigated in the western Arctic Ocean (Chukchi Sea and Canada Basin) in 2012 September to elucidate the mechanism of the transport of these elements in this region. In the western Arctic Ocean, not only Fe, but also the other trace metals had maxima in the halocline and/or near bottom waters with respect to both dissolved and total dissolvable fractions in the western Arctic Ocean. The distribution patterns were generally similar between dissolved and total dissolvable fractions except for Fe and Mn; especially high concentration was observed in the near bottom water in the Chukchi Sea shelf with respect to Fe and Mn. In this study area, the shelf sediments, river discharge and melting sea-ice are expected as the sources of trace metals as well as remineralization of organic matters. Among these potential sources, the remineralization is the common source for all elements measured in this study. On the contrary, extra input such as sediments could be important for Fe and Mn. The relationship between the distance from sea-shelf and concentrations of dissolved trace metals showed that Fe and Mn in the halocline waters decreased with distance logarithmically, suggesting that distributions of dissolved Fe and Mn were basically controlled by sedimentary input and scavenging effect. Distributions of Zn and Cd were correlated well with phosphate concentration, suggesting that remineralization mainly controlled the distribution of these elements. These results suggested the importance of the halocline water for the transport of Mn, Ni, Zn and Cd as well as Fe in the western Arctic during summer.

Role of diel vertical migrant copepod *Pleuromamma abdominalis* and *P. gracilis* in nitrogen cycle in the Kuroshio Current, the subtropical Pacific Ocean

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The ecosystem in the subtropical ocean where nutrients are depleted at the surface due to intense stratification is sustained by regenerated production in which primary production is principally driven by ammonium excreted by heterotrophic organisms like mesozooplankton. On the other hand, in the subtropical ocean, emphasis has also been placed on the role of mesozooplankton in removing nitrogen from the mixing layer through diel vertical migration, nocturnal grazing at the surface and diurnal releasing of nitrogen beneath a permanent pycnocline. However, little is known about this surface level nitrogen release process or quantitative differences between day and night. To clarify their functional roles in the nitrogen cycle in the subtropical pelagic ecosystems, we investigated temporal change of nitrogen releases of diel vertical migrating mesozooplankton, using two dominant copepods *Pleuromamma abdominalis* and *P. gracilis.* Vertical distribution and ammonium excretion rate were assessed during day and at night in the Kuroshio Current from winter to spring (in January, March, and May 2015). Abundances of *P. abdominalis* and *P. gracilis* within the top 200 m of surface waters demonstrated a notable increase at night across all samplings, but their diel vertical migration patterns changed seasonally. While *P. abdominalis* were mainly found below 50 m at night in January and March, they actively migrated to the upper 50 m at night in May. *P. gracilis* were also mainly distributed below 50 m at night in January, and began to emerge into the depth of 50 m in March and May. On average, ammonium excretion rates of *P. abdominalis* were higher at night than those during the day in all samplings. Overall, the total amount of nitrogen released by *P. abdominalis* population at the surface (above 200 m) was 1.6–1.7 times higher than that at the lower depth (below 200 m). Meanwhile, the *P. gracilis* population excreted ammonia at almost the same rate during the day and night across all the sampling months ($P > 0.05$) except March ($P < 0.05$), when mean released nitrogen at the lower depth (below 200 m) became 1.8 times higher than that at the surface (above 200 m). These results indicate the relative importance in roles of nitrogen removal and regeneration in the mixing layer differs between the two species, and *P abdominalis* contribute more to nitrogen regeneration at the surface than *P. gracilis.*

Regional variability of the spring bloom formation in the vicinity of the Kuroshio Extension

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The Kuroshio Extension (KE) flows eastwards, meandering off the main island of Japan and transporting larvae of small migratory fishes, particularly from the winter to spring. The spring bloom formation is thought to affect the survival of these fishes by providing advantageous feeding conditions, but the characteristics of the spring bloom in KE have not yet been investigated in detail. In this study, size-fractionated primary production and phytoplankton composition were investigated in relation to the environmental variables during winter-spring period.
Primary production was relatively low (82–492 mgC m^{-2} d^{-1}) and the main primary producers were generally small (< 10 μm) in the KE region during the spring bloom, probably due to the low nitrate (1.5±0.83 μM) and silicic acid concentrations (2.3±1.5 μM) in the mixed layer during winter. The spring bloom formation in the KE region was classified into three patterns with respect to the location in the KE as follows: 1) In the northern edge and around the axis of the first ridge of the KE, primary production and the contribution of large phytoplankton to the total production was high, and the bloom formation is possibly caused by shoaling of the mixed layer through the intrusion of the warmer water from the south. Diatoms (*Rhizosoleniaceae*) dominated the comparatively shallow mixed layer at the northern edge, while chlorophytes and cryptophytes were dominant around the axis. 2) In the south of the KE axis of the first ridge, the enhancement of both the total primary production and the production by large phytoplankton occurs at a comparable level to those in the northern edge and around the axis of the first ridge despite the deeper mixed layer. Weak stratification near the surface, which may have occurred after the passage of a low-pressure system that replenished nutrients in the euphotic zone through turbulent mixing, was attributable to the enhanced productivity, and the most dominant group was chlorophytes. 3) To the east of the first ridge, primary production as well as the contribution of large phytoplankton to the total production tended to be lower than those of the above two areas. Primary productivity is largely affected by the advection along the meander of the KE, and cryptophytes and prasinophytes were dominant at the northern edges. Production at the northern edge of the first trough was limited by depletion of nitrate, while factors other than nitrate and silicic acid depletion restricted the productivity at the northern edge of the second ridge.

Decadal variability of Subtropical Mode Water subduction and its impact on biogeochemistry

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Temperature and salinity data from Argo profiling floats during 2005−2014 were analyzed to examine the decadal variability of the North Pacific Subtropical Mode Water (STMW) in relation to that of the Kuroshio Extension (KE) system. The formation volume of STMW in the southern recirculation gyre of KE in the cooling season was larger during the stable KE period after 2010 than the unstable KE period of 2006−2009 by 50%. As a result, the volume and spatial extent of STMW increased (decreased) in the formation region during the stable (unstable) KE period, as well as in the southern, downstream region with a time lag of 1−2 years. The decadal expansion and contraction of STMW were also detected by shipboard observations conducted routinely in the most downstream region near the western boundary, in terms of not only physical but also biogeochemical parameters. After 2010, enhanced subduction of STMW consistently increased dissolved oxygen, pH, and aragonite saturation state and decreased potential vorticity, apparent oxygen utilization, nitrate, and dissolved inorganic carbon, among which changes of dissolved inorganic carbon, pH, and aragonite saturation state were against their long-term trends. These results indicate a new mechanism consisting of westward sea surface height anomaly propagation, the KE state transition, and the STMW formation and subduction, by which the climate variability affects physical and biogeochemical structures in the ocean's interior and potentially impacts the surface ocean acidification trend and biological production.

Multidecadal trends of oxygen and their controlling factors in the western North Pacific

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The rate of change of dissolved oxygen (O_2) concentrations was analyzed over 1987–2011 for the high-frequency repeat section along 165°E in the western North Pacific. Significant trends toward decreasing O_2 were detected in the northern subtropical to subtropical-subarctic transition zones over a broad range of isopycnal horizons. On 25.3σ_θ between 25°N and 30°N in North Pacific Subtropical Mode Water, the rate of O_2 decrease reached -0.45 ± 0.16 μmol kg^{-1} yr^{-1}. It is largely attributed to a deepening of isopycnal horizons and to a reduction in oxygen solubility associated with ocean warming. In North Pacific Intermediate Water, the rate of O_2 decrease was elevated (-0.44 ± 0.14 μmol kg^{-1} yr^{-1} on 26.8σ_θ) and was associated with net increases in apparent oxygen utilization in the source waters. On 27.3σ_θ in the subtropical Oxygen Minimum Layer (OML) between 32.5°N and 35°N, the rate of O_2 decrease was significant (-0.22 ± 0.05 μmol kg^{-1} yr^{-1}). It was likely due to the increases in westward transport of low-oxygen water. These various drivers controlling changes in O_2 along the 165°E section are the same as those acting along 137°E (Takatani et al., 2012) and also account for the differences in the rate of O_2 decrease between these sections. Additionally, in the tropical OML near 26.8σ_θ between 5°N and 10°N, significant trends toward increasing O_2 were detected in both sections (+0.36 ± 0.04 μmol kg^{-1} yr^{-1} in the 165°E section). These results demonstrate that warming and circulation changes are causing multidecadal changes in dissolved O_2 over wide expanses of the western North Pacific.

New ocean provinces characterized by island mass effect through nitrogen fixation

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Subtropical and tropical oligotrophic oceans have traditionally been recognized as “oceanic deserts”, where nutrient supply (especially nitrogen) is limited due to the strong stratification, and where biological production is generally low. In these oceanic deserts, enhanced primary production and rich fishery resources have identified around islands where distinctive nutrient supply occurs, and that is referred to as the island mass effect. The most well-known process of nutrient supply is upwelling in the island wake, which induces a bloom of chain-forming diatoms. Meanwhile, recent studies have demonstrated that blooms of *Trichodesmium* spp., major cyanobacterial diazotrophs, occur frequently around islands. Here we found that in the western subtropical South Pacific, *Trichodesmium* spp. thrived around islands and performed active nitrogen fixation, and that their abundance was attributable to the material supplied by land runoff. The *Trichodesmium* spp. were advected to areas remote from these islands, and as a consequence, the elevated primary production fueled by nitrogen fixation extended over a large area (up to distances of ~3500 km) around the islands. This wide expansion of high primary production was characterized by a low $\delta^{15}N$ of suspended particles and a large-scale reduction in phosphate concentrations at the surface. The occurrence of this vast ecosystem is likely triggered by terrigenous nutrient supply, suggesting its potential vulnerability to human activity on small islands. We also found that the similar phenomenon occurred around islands located along the Kuroshio Current. We demonstrated that the active nitrogen fixation in the Kuroshio is attributable to the island mass effect; *Trichodesmium* increased around islands situated along the Kuroshio, and were likely advected into the mainstream of the Kuroshio. *Trichodesmium* is a major diazotroph in the Kuroshio, and diazotrophy in the Kuroshio is considered to influence the nutrient stoichiometry in the North Pacific. Thus, our results indicate that phenomena around the islands located along the Kuroshio are important for determining the partial nitrogen inventory in the North Pacific. Our studies suggest that the region characterized by the island mass effect through nitrogen fixation generally occurs near islands in the tropical and subtropical Pacific Ocean.

Relationships between total alkalinity in surface water and sea surface dynamic height in the Pacific Ocean

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Improved spatial and temporal representation of total alkalinity (TA) is expected to be an important component in monitoring changes in the oceanic carbon cycle and acidification over the coming decade. However, it is difficult to successfully represent in the region such as the North Pacific by previous empirical relationships based on temperature and salinity for TA in the surface ocean. Here we propose new empirical equations for TA in surface waters over the Pacific Ocean that were derived from PACIFICA (PACIFic ocean Interior CArbon) database. The most unique feature of the new equations is that sea surface dynamic height (SSDH) has been used as one of the explanatory variables. The variability in SSDH derived from satellite altimeter observations are known to be useful in describing seasonal and interannual variations in wind-driven circulation and eddies. On the basis of the relationship between deseasonalized SSDH and salinity-normalized TA (NTA), we divided the Pacific Ocean into five domains. We derived the empirical equations of TA for each of five domains by using the variables of SSDH and salinity. The root mean square error of the fittings of these equations to the measured TA is 7.8 □mol kg^{-1}. Comparing with previous equations, the SSDH-based empirical equations are especially improved to represent the TA distribution in the North Pacific subtropical-subarctic frontal zone where NTA shows large spatio-temporal variability due to the path states of the Kuroshio Extension and north-south shift of frontal position.

Growth response of phytoplankton assemblage to additions of subsurface water in the central North Pacific

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Recent findings on the role of trace metals as a factor controlling primary productivity and biogeochemical processes in the oceanic waters emphasized the need for better understandings of interaction between macro- and micronutrients. In the subtropical North Pacific, both trace metals and dissolved inorganic nitrogen is in extremely low concentrations in the surface waters and thus inputs of macro- and micronutrients from the subsurface layer could be one of the mechanisms regulating composition and productivity of phytoplankton assemblage. In the subarctic North Pacific, availability of iron could be the fundamental limiting nutrient in the high-nitrate, low-chlorophyll (HNLC) waters, and the iron supply from atmospheric dust or continental shelf sediments may have strong influences on the distinct productivity. In this study, we examined the effects of macro- and micronutrients supplies from the subsurface layer on the growth of phytoplankton assemblages in the upper and lower euphotic zone by onboard bottle incubation experiments conducted along a 170ºW transect in the North Pacific. Addition of filtered subsurface seawater (SSW) to the 10 m phytoplankton assemblage resulted in an increase in chlorophyll biomass and cell density of *Synechococcus* relative to the controls at 10, 20 and 35ºN, probably due to the supply of limiting macro-nutrients such as nitrate. A station at 50ºN was under the HNLC condition, but SSW treatment showed some increase in chlorophyll *a* concentration, suggesting that dissolved iron in the subsurface water relieved iron-limitation to some extent. Further stimulations of phytoplankton growth were observed by the simultaneous additions of the subsurface seawater and 1 nmol/L Fe (SSW+Fe) at 10, 35 and 50ºN. It seems that concentrations of dissolved iron in the subsurface water were not high enough to support the complete utilization of the amended macro-nutrients in the incubation bottles. The SSW+Fe treatment using phytoplankton assemblage from the subsurface chlorophyll maximum layer also showed higher chlorophyll biomass relative to the SSW treatment at the end of the experiment at 20, 35 and 50ºN. These results suggest that growth of phytoplankton near the bottom of the euphotic zone can be limited by iron deficiency similar to that of the surface phytoplankton assemblage at 35 and 50ºN. Therefore, a vertical mixing of water column in the northern part of the central North Pacific may promote the development of iron-limited waters.

A role of sea ice melt water on iron supply to surface water in the Chukchi Sea, the Arctic Ocean

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Nitrate depletion in the surface layer in summer in the Arctic ocean indicating biological utilization and sufficient supply of bioavailable iron into surface water. To reveal iron supply processes in the Arctic ocean in the early stage of biological increase, we investigated a roles of sea ice melt water on iron supply to surface phytoplankton community. We conducted surface towed fish clean sampling from the Bering sea shelf area, through the Bering strait, and around sea ice edge in the Chukchi Sea. Alkalinity was measured as tracer which can be used for classify the sources of fresh water, river discharge or sea ice melting. Judging from the potential alkalinity, sea ice melt water was clearly distributed around edge of the sea ice. Dissolved iron and total dissolvable iron concentration well correlated with a fraction of sea ice melt water, and iron concentration increased with increasing of the fraction. On the other hand, area of Alaskan coastal current (ACC), west coast of Alaska, both of river water and sea ice melt water existed and iron concentrations correlated with fraction of sum of river water and sea ice melt waters. Our estimate from the slope of the correlation indicate that the sea ice melt water have comparable impact on iron supply as river discharge. Additionally, our study indicates that iron supply from sea ice melt water influence to more wide area than river discharge in the Arctic ocean surface.

Limiting nutrients for nitrogen fixation in the Pacific Ocean

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Nitrogen fixation provides an important source of nitrogen source for new production in the oligotrophic ocean. However, there have been regional limitations on knowledge about the distribution of diazotrophs and the influence of nutrients such as iron and phosphorus on nitrogen fixation in the Pacific Ocean. Thus, we used field observations to analyze the relationship among the abundance of four major diazotroph groups (*nifH* abundance of *Trichodesmium* spp., UCYN-A, *Crocosphaera watsonii* and γ-proteobacteria 24774A11, and filament abundance of *Richelia intracellularis*), nitrogen fixation rate, and environmental factors (temperature, nitrate+nitrite, phosphate, dissolved iron (DFe), aerosol deposition estimated by a numerical model) in the western and central North Pacific as well as the eastern South Pacific. Simultaneously, we assessed nutrient limitations on nitrogen fixation ($^{15}N_2$ bubble method; Montoya et al. 1996) by conducting two-day, on-board incubation experiments with 2 nM $FeSO_4$ and/or 200 nM KH_2PO_4 enrichment. *Trichodesmium* spp., *C. watsonii*, γ-proteobacteria 24774A11, and *R. intracellularis* were primarily distributed in the western and central North Pacific and were absent in the eastern South Pacific, while UCYN-A was distributed both in North and South Pacific subtropical gyres. In the western North Pacific, *Trichodesmium* spp. and γ-proteobacteria 24774A11 were abundant in the western subtropical area, while UCYN-A and *C. watsonii* were abundant in the high-latitude (35° N) and low-latitude (10−25° N) North Pacific, respectively. Temperature can be used to explain the distribution of each group, as the temperature ranges of these distributions were similar to those reported previously. Additionally, high DFe in the western area probably resulted in the high recorded abundance of γ-proteobacteria 24774A11 and *Trichodesmium* spp.. There was a particularly significant relation between the abundance of γ-proteobacteria 24774A11 and DFe or aerosol deposition. On the other hand, the distribution of *C. watsonii*, which was abundant in the low-latitude North Pacific, seems to be attributable to this group's low iron requirements, because DFe and aerosol deposition were low in this area. The results of incubation experiments indicated that the limiting nutrients for nitrogen fixation were both iron and phosphorus in the western North Pacific, and iron in the upwelling area of the eastern South Pacific. In the western North Pacific, the limiting nutrient was iron in the western and high-latitude area and phosphorus in the low-latitude area, which coincided with the spatial variation of diazotroph composition, implying that diazotroph community in highly iron supplied area could increase nitrogen fixation in response to heterogeneous nutrient supply over a short timescale.

Temporal and Spatial Variation in a Growth Factor of Pacific Salmon

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Temporal and spatial variation in a growth factor of Pacific salmon (*Oncorhynchus spp.*) was investigated from a bioenergetics perspective using the prey-density function for consumption as the growth factor. In terms of the estimation of prey density, we used zooplankton density obtained from an ecosystem model, NEMURO embedded in a 3-D physical model. This study focused on the three species of Pacific salmon (chum (*O. keta*), pink (*O. gorbuscha*), and sockeye (*O. nerka*)), all of which are zooplankton feeders whose biomass accounts for more than 90% of all Pacific salmon. Empirical orthogonal function (EOF) analysis was conducted for the growth factor in the subarctic North Pacific during 1948–2007. The growth factor of Pacific salmon varies on a decadal timescale. The EOF first mode for the growth factor was related to the Pacific Decadal Oscillation (PDO). The variation in the growth factor in the Bering Sea, the western subarctic gyre, and the eastern central subarctic North Pacific were consistent with the variation of the carrying capacity of chum, pink, and sockeye salmon, suggesting that these areas are the key areas connecting climate change and the carrying capacity from the perspective of prey condition.

Phosphate release due to excess alkaline phosphatase activity of *Trichodesmium erythraeum*

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The dependence of alkaline phosphatase activity (APA) on water temperature and light intensity was investigated under various culture conditions using a major marine diazotroph (*Trichodesmium erythraeum*) isolated from the Kuroshio Current (nonaxenic strain ECS0305). In contrast to poor APA detected in cultures grown under P-replete condition, APA was well expressed in cultures grown in P-limited medium with no added phosphate. Under P-limitation, APA steadily increased with increasing temperature and light intensity in the ranges from 22-30°C, and from 40-260 μmol m^{-2} s^{-1}, respectively. Based on measured chlorophyll *a* and APA values determined during the late exponential growth of *T. erythraeum*, the mean hydrolyzing time required to double its cellular P quota (T_h) was estimated. T_h was compared with the reported P-specific doubling time of other *T. erythraeum* strains and was found to be 9.7 (0.68) times faster under P-limited (P-replete) conditions. This result strongly suggests that APA of the *Trichodesmium*-bacteria consortium of strain ECS0305 was excessively active in regard to its cellular P requirement under P-limitation. Furthermore, under P limitation, intense bacterial aggregations were observed around trichomes sympatrically with visualized APA using fluorescent substrate under a fluorescence microscope. This implies the enhancement of bacterial growth by surplus phosphate supply due to excess APA of *T. erythraeum* as mentioned above, or by possible release of dissolved organic matters from *T. erythraeum*. Therefore, the present study suggests an important role of *T. erythraeum* not only as a nitrogen fixer, but also as a phosphate supplier to other organisms in P-limited oligotrophic ocean.

Comparison in mesh selectivity of research driftnet between the autumn and the winter-spring cohorts of neon flying squid *Ommastrephes bartramii*

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Neon flying squid *Ommastrephes bartramii* is one of commercially important species for squid jigging fishery. Research driftnet combined with driftnets of different mesh size have been used to investigate the neon flying squid stocks in the Northwest Pacific Ocean in summer. Meanwhile, it is well known that driftnets have mesh selectivity and that squid body size and condition as well as mesh size are factors affecting mesh selectivity. The mesh selectivity should therefore be taken into account in analyses of the mantle length data from the stock survey with using research driftnet. Neon flying squid stock comprises two cohorts: autumn cohort and winter-spring cohort. The two cohorts have different geographic distribution, hatch season and thus different body size (and maybe body shape and/or body proportion) in mantle length (ML) composition of the squid caught in summer survey season. This study estimated selection curve parameters of driftnet mesh for the two cohorts.

Selection curves of driftnet were estimated from the ML data which were obtained from the surveys in the Northwest Pacific with using driftnets of different mesh sizes conducted during 1999-2012 by the National Research Institute of Far Seas Fisheries and in 2013 by the Tohoku National Fisheries Research Institute. A series of research driftnets used in the surveys comprised driftnets of 14 different mesh sizes. This study estimated selection curve for each cohort, on the assumption that of the squid caught in the survey, individuals of ML below 350 mm belonged to the autumn cohort and the other to the winter-spring cohort. Slight difference was found in mesh selectivity for the neon flying squids between the autumn and the winter-spring cohorts. For mesh size of which optimum length was around 35mm ML, e.g. 93mm mesh size, optimum mantle length was smaller in the winter-spring cohort than that in the autumn cohort. As a result of comparison in body shape between the two cohorts, significant difference in the regression coefficients of maximum girth to mantle length was detected (ANCOVA, $P < 0.001$). Mantle length of squid with a given body girth are slightly larger in the autumn cohort than in the winter-spring cohort. This may be a possible explanation of the difference in optimum length of mesh selectivity between the two cohorts.