Poster presentations

Developing the suitable operation prediction model of neon flying squid in the central North Pacific using Satellite images and VMS
Yang Liu, Sei-Ichi Saitoh, Hiroki Takegawa and Toru Hirawake

Effect of 3-D physical structures on spatial distributions of Japanese common squid in the coastal waters of southwestern Hokkaido, Japan
Xun Zhang, Sei-Ichi Saitoh, Toru Hirawake, Satoshi Nakada, Koji Koyamada, Toshiyuki Awaji, Yoichi Ishikawa and Hiromichi Igarashi

Habitat model development of Japanese common squid in Japan Sea using satellite remotely sensed data
Mariko Dehara, Sei-Ichi Saitoh and Toru Hirawake

Predicting the potential invasion in Korean waters of the saltmarsh grass Spartina alterniflora from China – A joint proposal by KIOST and Nanjing University
Keun-Hyung Choi and Changyong Wang

BIO/MEQ Topic Session (S3)

Tipping points: defining reference points for ecological indicators of multiple stressors in coastal and marine ecosystem

Co-sponsored by the International Council for the Exploration of the Sea (ICES) and Integrated Marine Biogeochemistry and Ecosystem Research (IMBER)

Co-Convenors: *Rebecca G. Martone (USA), Ian Perry (Canada), Jameal Samhouri (USA), Motomitsu Takahashi (Japan), Maciej Tomczak (Poland / ICES), Chang Ik Zhang (Korea)*

Invited Speakers:
Phil Levin (NNOAANW Fisheries Science Center, USA)
Tetsuo Yanagi (Research Institute for Applied Mechanics, Kyushu University, Japan)

Background

Many coastal and marine ecosystems, ranging from reefs to estuaries to pelagic systems, are exposed to multiple stressors, which can lead to rapid changes with significant, long-term consequences that are often difficult to reverse. Changes in ocean climate, the abundance of key species, nutrients, and other factors drive these shifts, which affect ocean food webs, habitats, and ecosystem functions and people's livelihoods and well-being. Determining indicators of ecological changes due to multiple stressors and defining reference points for those indicators are key steps for managers to avoid ecological degradation and loss of keys goods and services. Setting ecological reference points in ecological systems presents a challenge to resource managers because (a) reference points are often difficult to determine due to the complexity of natural systems, including the presence of thresholds, tipping points, and non-linearities; (b) the paucity of theoretical modeling and empirical understanding needed to address these complexities, identify ecological thresholds and develop early warning indicators means that managers must make decisions based on high levels of uncertainty; and, (c) many institutional and governance structures do not allow managers the necessary flexibility to take up this information and react within relevant timeframes. The aim of this session was to address these pressing challenges, and explore promising approaches to tackling them with the goal of catalyzing new research and management innovation. In particular, the convenors sought presentations that (i) define the conceptual basis for reference points and management objectives surrounding reference points; (ii) use theoretical, modeling and observational approaches to identify potential reference points for indicators of changes in marine ecosystems; (iii) incorporate risk and sources of error (measurement, model, process) in such analyses; (iv) discuss how reference points may be used in helping to manage marine ecosystems, specifically in relation to the decision-making process related to evaluating and deciding on acceptable levels of risk. Discussions were guided by the FUTURE science themes, with special attention to examining climate and anthropogenic drivers of ecological change, and identifying early warning indicators to enable forecasting

to avoid crossing ecological thresholds. The outcomes are expected to contribute to the work of PICES Working Group 28 on *Development of Ecosystem Indicators to Characterize Ecosystem Responses to Multiple Stressors.*

Summary of presentations

The session provided a very interesting overview of how tipping points pertain to marine species and ecosystems. It was well-attended and there was a great diversity of presentations, featuring many different geographies and at many different scales – from ecosystem-wide changes in response to tipping points to threshold responses of individual animals and fisheries stocks.

In his Invited Presentation, Dr. Phillip Levin addressed the important topic of how to respond to regime shifts in social-ecological systems. He focused on the importance of integrated ecosystem assessments (IEAs), and how they can be applied to counteract regime shifts. He suggested that the first question to answer as part of an IEA is whether the existing regime is desired, and then further broke this question down into 3 parts. First, do people see the world the same way? Dr. Levin illustrated that people do not necessarily view the world the same way using a folk taxonomy example, and suggested that regime shifts are likely not to be perceived the same way either. Second, Dr. Levin posed the question: does anyone care if a regime shifts? Using the example of regime shifts from kelp forests to sea urchin barrens and back again, he illustrated how different groups of people are likely to have different preferences for each regime. The third question Dr. Levin addressed focused on defining the target regime. Via the lens of eelgrass restoration, Dr. Levin described a novel approach for determining public preferences for different ecosystem configurations. Overall, he argued that portfolios of indicators need to be accompanied by portfolios of reference points that reflect people's preferences for alternative ecosystem configurations.

Dr. Jake Rice asserted that the one thing managers should avoid is to make a tipping point a target. This argument stems from the fact that rapid changes in the ecosystem happen near tipping points, and those changes may not be desirable. However, Dr. Rice showed that identifying tipping points is analytically challenging. Nonetheless, he made a strong case for managers to: avoid tipping points with high probability, emphasize that objective even more so than an objective of achieving targets, and avoid optimizing along a single ecosystem dimension (*e.g.*, a single fishery).

Dr. Rebecca Martone provided an overview of a multi-institutional collaborative project called "Ocean Tipping Points." The project includes scientists and lawyers from universities, government agencies, and NGOs and consists of synthesis and application components. The synthesis component includes compilation of a global database of marine ecosystem shifts (n > 100 studies, few from the western Pacific), a meta-analysis of nonlinear relationships in pelagic systems, a law review that demonstrated that regulations incorporating thresholds yield better environmental outcomes, and a management review of 50 case studies of current management contexts showing that explicit use of tipping points in management yields improved environmental outcomes. The application components focus on coral reefs in Hawaii, USA, and the herring food web in Haida Gwaii, BC, Canada.

Dr. Maciej Tomczak described an impressive body of work showing that overexploitation, changes in climate, and nutrient loading combined to cause a shift from a cod-dominated to a sprat-dominated Baltic ecosystem. Dr Tomczak defined this phenomenon as a regime shift, *i.e.*, a food web reorganization and redirection of energy flow pathways. He used a network indicator called Redundancy to suggest that resilience has declined in the Baltic over time, in response to an overall forcing index (inclusive of changes in climate, fishing, *etc*.).

Dr. Takahashi and colleagues presented the results from an expert judgment survey to determine relative risks of coastal and marine habitats in the Eastern, Central and Western Regions of the Seto Inland Sea. Results indicate regional variation within the Seto Inland Sea to a suite of stressors. Coastal engineering and development affects strongly all ecosystems across the regions. Commercial activities, including fishing, have stronger impacts in the eastern waters. Nutrient input and HABs have higher risk in the central and eastern

areas. Dr. Takahashi presented spatially explicit temporal data that corroborate many of the outcomes from the expert judgment survey. For example, tidal flats and seagrass beds have decreased in areas of the Seto Inland Sea. Stressor-specific risk scores indicate regional variability linked to population density and geographical features in the Seto Inland Sea. Future comparisons with results from global models and other regional models will help identify gaps and biases in expert judgement. These results can help identify priorities for research and management of cumulative impacts to ecosystems at regional spatial scales.

Dr. Ian Perry presented work in the Salish Sea examining the drivers of change acting on the Strait of Georgia in the Salish Sea, British Columbia. Using redundancy analysis, Dr. Perry identified regime-like transitions of the Strait of Georgia since 1970. Dr. Perry then presented an examination of potential predictors for typical system behaviours prior to significant shifts in the system, including variance, autocorrelation at lag-1, and conditional heteroskedasticity. Standard deviation and the autocorrelation are not correlated with the regime shifts and thus do not act as good predictors. Interestingly, conditional hetero-skedasticity of SST and North Pacific Gyre Oscillation within the moving window of 37 months was well-correlated with the regime shift and possibly could be used as an early warning indicator. Dr. Perry described some of the challenges associated with choosing which indicators, which predictors for early warnings of regime shifts, choice of time period (*e.g.*, moving windows), and how to identify significance. Early warning indicators appear promising, but the real world is more messy than simulated data. Several indicators are likely necessary, particularly lower trophic level biological variables, and combining these in a probability approach might be good way forward.

Dr. Bill Sydeman focused on the importance of understanding how changes in community structure relate to changes in ecosystem functions and processes, with emphasis on tipping points of mid-trophic level invertebrates and fishes and meso-predators. Meso-predators may serve as indicators of variability in ecosystem function as they may be the most responsive to the forage fish community variability. Dr. Sydeman showed that there are many non-linear responses of ecosystems to changes in mid trophic level (MTL) fish, (*e.g.*, changes in breeding success of seabirds) and that shapes of the relationships can be used to determine which indicators might be more sensitive to ecosystem changes. The global model for seabird breeding success indicates a threshold that around the mean long-term trend. Dr. Sydeman then explored whether there is variability in the threshold numerical response between forage fish abundance and seabirds, either among predator species, prey species or the parameter examined. Interestingly, among some predator and prey species the threshold holds but for other species there are different relationships, but despite this variation North Pacific seabird threshold range is similar to the global model. Furthermore, the threshold tends to hold for different parameters; however, there is high uncertainty associated with this because of data limitations. Ultimately, predator-prey threshold relationships may provide insight to ecosystem state shifts. Future work on population-level responses, multi-species predator–prey numerical responses, and how differences in mean abundance or life history characteristics (*e.g.*, diet specialization) might affect the threshold, will be useful to understand threshold responses in ecosystem indicators.

Dr. Wen Yu presented on the effects of acute gamma radiation on the survival and physiological indices of the Chinese black sleeper. Existing studies from UNSCEAR (2008) indicate that fish are the most sensitive species based on LD50 reference points but few focus on data from marine fish and there are no data in China. By examining the Chinese black sleeper, Dr. Yu's study fills important gaps in our understanding of the response of marine species to radiation, particularly as it may be more susceptible to pollution and is economically important. Dr. Yu presented the results of a dose-response experiment that examined 5 irradiated groups and a control groups, with 60 individuals per group. Preliminary results indicate that with the 3 higher levels of irradiation, 100% mortality occurred within a few days, while the lowest level of radiation was similar to the controls. The calculated LD_{50} was 7.1 (6.3–7.9) Gy, which is lower than the 10–25 Gy summarized from UNSCEAR. Future research will include additional experiments to confirm these results, along with research on other local species and tests of the effects of chronic radiation.

Mr. Kyung-Su Kim described his research on the combined effects of elevated CO_2 and temperature on the physiological conditions of olive flounder larvae, *Paralichthys olivaceus*. Using a MFC controller and mixing chambers Mr. Kim described the experimental settings, including 3 different CO_2 concentrations, based on

current day 2100 mild and strong emissions based on IPCC predictions and 2 temperatures, optimum and high temperature. Both total length and wet weight increased with CO_2 at lower temperatures, but variable responses occurred when CO_2 was combined higher temperatures. Skeleton malformation occurred more frequently with higher CO_2 conditions, and bone density decreased with increasing CO_2 conditions. Results from histomorphology did not show any malformation in tissues under higher CO_2 conditions. Dr. Kim's study illustrated that CO_2 and temperature have variable interactive effects on growth (positive) and bone density (negative), suggest that these types of studies are necessary to tease apart the multiple effects of stressors on condition, which may have implications for population dynamics and ecosystems.

For his invited presentation Dr. Tetsuo Yanagi described eutrophic and oligotrophic processes in the Seto Inland Sea and their relation to the Satoumi concept. Eutrophication (TN:TP) in recent years has decreased in the Seto Inland Sea and fish stocks have also seen similar declines, suggesting regime shifts related to changes in productivity driven by nutrient inputs. Dr. Yanagi explored models of phytoplankton population dynamics using relationships with different strengths of non-linearity for a variety of parameters. The relation between fish catch and nutrient concentration is non linear and there is hysteresis due to sediment pollution. Oligotrophic conditions may lead to changes in stratification and ability of fish to eat sinking phytoplankton, leading to hypoxia and possibly a new regime. Dr. Yanagi then suggested that there is a possibility to move from oligotrophic conditions back to eutrophic conditions with higher productivity, which is the preferred state, and introduced the Satoumi concept. The Satoumi concept developed by Dr. Yanagi supports the idea that coastal seas can have high biodiversity and productivity under human interactions, where both over and under- use can lead to low biodiversity and productivity. For example, decreases of eelgrass beds in the Seto Inland Sea led to decrease of fish catch by set nets, which in turn led local fishermen to create eelgrass beds. Now both eelgrass beds and fish catches by set nets are increasing. Currently Dr. Yanagi has a new project supported by the Ministry of the Environment to develop coastal management method to realize the sustainable coastal sea, in which physical, biological, social sciences, and governance will support integrated, community-based management, to realize clean, rich and prosperous seas.

Dr. Kazumi Wakita presented research on the diversity of perceptions and utility of marine ecosystem services. With an online survey of 1100 residents of japan, Dr. Wakita examined people's perceptions of different ecosystem services and the utility or satisfaction experienced by different people could be used as a basis for decision making. In addition, she explored the how utility that residents derive from marine ecosystem services affect their behavioural intentions for marine conservation, assuming that where there is higher the perceived indispensability, the greater the utility, and the higher the indispensability the greater its influence on enhancing behavioural intensions for marine conservation. Using factor analysis and structural equation modeling to determine the causal relationships between perceived value and their intensions of behaviour for conservation of marine biodiversity, Dr. Wakita uncovered 3 hidden factors including (1) Essential Benefits, including food, life satisfaction, health, *etc*.; (2) Indirect Benefits, which was primarily composed of provisioning services and regulating services; and, (3) Cultural Benefits. Dr. Wakita found that cultural benefits were most important in driving behavioural intentions for marine conservation. Essential benefits also contributed to behaviour assessments, whereas indirect benefits were not significant. Essential benefits had highest indispensability, followed by indirect benefits, while cultural benefits scored lower on indispensability. These results indicate that indispensability does not correlate with conservation behaviors. Focusing on the landlocked Nagano residents, Dr. Wakita also performed factor analysis to examine the scarcity principle. The same 3 factors were identified, but their contents were different. Perception of marine ecosystem could vary reflecting scarcity of the services in their place of residents, which will be different for different communities. Dr. Wakita's talk emphasizes the need for more attention for cultural aspects of marine ecosystem services.

Dr. Christopher Aura assessed the magnitude and interrelationships of seasonal phytoplankton bloom occurrence at the Japanese scallop farming area of Okhotsk Sea, Hokkaido Japan. To define tipping points, Dr. Aura and colleagues defined different bloom types, including the spring bloom, ice bloom, and open water bloom, using time series data sources including chla, sea ice, surface wind stress. By identifying the mechanism of bloom occurrence, Dr. Aura was able to identify that a decline of wind stress leads to increased ice edge blooming and decreased open water bloom variability. In addition, using PCA and Pearson correlation

matrices, he found that there are distinct relationships between scallop landings, sea ice cover, and bloom variability. Where there is a strong negative relationship between sea ice days and open water bloom, while open water blooms are positively correlated with scallop landings. Thus, tipping points can be described by wind stress and solar radiation.

Dr. Jameal Samhouri and colleagues explore what has happened once a tipping point has been crossed, where multiple pressures shift systems over ecological thresholds and lead to different ecosystem states.. Dr. Samhouri described how examining systems that have crossed tipping points may help guide the recovery of ecosystems, specifically working toward the development of theory to reassemble marine systems. Dr. Samhouri examined what types of ecosystem reassembly strategies are currently in use, what strategies are likely to be the most effective using a theoretical model, and finally, determined if and where the most effective strategies that have been identified from models are being used. Dr. Samhouri identified three main reassembly strategies, where lower trophic levels recover first, higher trophic levels recover first, or simultaneous recovery occurs. Using a theoretical toy model of a generalist predator and multiple prey species, Dr. Samhouri asked whether who goes first matters in terms of ecosystem reassembly, specifically examining these three strategies. Simultaneous recovery (to equilibrium) of both predator and prey is fastest while predator first is the slowest, but predator first is the most direct in terms of amplification volume, without noisy transient dynamics. From the literature, the least common strategy is where highest trophic level recovery first, suggesting that the most effective strategies, specifically simultaneous reassembly and lower trophic level first, are the most common. Additional future work examining stochastic dynamics and multiple trophic levels in the system may help identify how regimes shift and the possibility of priority effects under more realistic scenarios.

Dr. Kulik presented work examining potential reference points for mean trophic level of macrofauna in the Sea of Okhotsk. Trophic level, a common indicator of fisheries status, can be determined by stable isotope ratio of nitrogen, but this depends both on seasonal delivery of nitrogen with spring blooms and on the age of the consumer. To address this variability, Dr. Kulik used an adjusted mean weighted average trophic level (muTL) of every catch, using information on weight at length from fishery data and stable isotope ratio information from data of species in the benthic-pelagic zone. Using trophic level of 67 fish, 6 squid and 5 decapod species and 148 species from Fishbase, Dr. Kulik and colleagues estimated muTL from 9926 trawls in pelagic waters from 1984–2013 and from 6321 bottom trawls from 1977–2010. Dr. Kulik examined spatial and temporal variation of muTL using Generalized Additive Models with splines for coordinates, horizon of trawling, years and months. Dr. Kulik's results indicate that there is deviation from the global mean of muTL in pelagic waters over time in the Sea of Okhotsk, and during the period of 2003–2013, he estimated that the linear rate of increase in muTL of catches was 0.007 per year. Spatial variation also occurs in muTL, with deeper pelagic waters showing lower than average muTL in the pelagic fisheries, but for bottom trawls, the deeper pelagic waters demonstrate higher than average muTL. This research illustrates the need to understand spatial and temporal variation in reference points of indicators in order to understand ecosystem shifts.

Dr. Yusheng Zhang and colleagues described the fate and potential impacts from radionuclides in the NW Pacific following the Fukushima Nuclear Disaster (FND). Transfer of radionuclides can occur from water to fish through the food web and directly through contact with water. On a series of cruises beginning in June 2011, Dr. Zhang and colleagues collected tissue samples from 3 species - squid, saury, and dolphin fish. They used these samples to analyze radionuclide concentrations of ^{134}Cs, ^{137}Cs, and ^{110m}Ag, using the gamma spectrometry method. All radionuclides were detected in all 3 collected species of marine animals, including ^{134}Cs and ^{110m}Ag, which are important indicators of nuclear accident pollution and aren't usually seen. Squid showed higher concentrations than saury and dolphinfish, though radionuclide contents varied among tissue types. Dr. Zhang also developed spatial maps of exposure, indicating where the nuclide samples were found and their magnitudes, and examined temporal patterns in radionuclide concentrations in tissues. Concentrations of most radionuclides in squid peaked in November 2011, and dropped precipitously, except for ^{90}Sr, which showed a very different temporal pattern. Dolphin fish radionuclide concentrations also exhibited declines over time. Dr. Zhang indicated that though radionuclide concentrations in marine animals increased following FND, they were lower than the limit reference point for seafood safety.

Dr. Hyeong-gi Kim presented work regarding thermal influence on nematodes, the most numerous metazoans worldwide and a potentially informative indicator group because of their abundance, occurrence in a wide range of habitats, habitat specificity, and a broad range of feeding types and generation times. Dr. Kim focused on the effects of thermal discharge from nuclear power plants on nematode communities in Gori coastal waters of the southern East Sea / Sea of Japan. The nematode community consisted of 6 dominant species, but a much larger number of species were extremely rare. Most nematodes were non-selective deposit feeders, and sediment type was a dominant factor determining nematode community composition. Interestingly, bottom temperature was not significantly correlated with the abundance of most nematodes.

Mr. Delvan Neville from Oregon State University discussed reference points in the context of radioecology. In this field, reference points are referred to as Derived Consideration Reference Level. Mr. Neville determined distribution of radionucleotides in the bodies of several Northern California Current marine species including *Thunnus aluluna* (albacore tuna). Concentrations were generally low, such that only a 10,000-fold increase in ^{137}Cs would exceed safe limits. Pink shrimp and several other species exhibited much larger responses than those seen in tuna.

Some overall comments:

- Tipping points are an integrative concept for social-ecological systems and pertain to many issues of strong interest to PICES, including climatic shifts, changes in top predator abundances, ecosystem responses to multiple pressures, and more.
- However, a clear definition is challenged by this same feature. It seemed that the implicit and most general definition that emerged in S3 focused on the existence of a nonlinear change in a dynamical system. Defined this way, tipping points can occur in individual animals in response to environmental challenges (eg, radiation, CO2), to harvested fish stocks because of spawner-recruit relationships, and to entire food webs and ecological communities because of nonlinear predator-prey and competitive interactions.
- Early warning indicators of tipping points may be difficult to identify and anticipating or forecasting tipping points may not be possible. However, retrospective analysis and modeling can illustrate general lessons and rules of thumb, as well as help identify potential trajectories of recovery and guide management actions.
- Tipping points are inherent to social-ecological systems, but do not in and of themselves tell us anything about objectives and targets. Rather, knowledge of tipping points can help guide decisions about objectives and targets.
- While desired states of the social ecological system are important to consider for decision making, it is the biophysical system that defines what states are possible. Thus while it is important to define desired states within the tipping points framework, it is important to manage expectations about what is possible to achieve.

We are seeing an increasing amount of integration of social-ecological effects within ecosystems PICES activities across the North Pacific. This is a good sign for the FUTURE program.

List of papers

Oral presentations

Marine ecosystem regime shifts: Challenges and opportunities for Ecosystem-Based Management (Invited)
Phil Levin

Tipping points and decision-making: Why they matter, why they are hard, and practical things to do
Jake Rice

Embedding the science of tipping points into ocean management
Rebecca Martone, Carrie Kappel, Courtney Scarborough, Mary Hunsicker, Ben Halpern, Kimberly Selkoe, Phil Levin, Jameal F. Samhouri, Crow White, Ashley Erickson, Ryan Kelly, Lindley Mease, Margaret Caldwell, Larry Crowder and Rod Fujita

Ecological network indicators of ecosystem status and change in the Baltic Sea
Maciej T. Tomczak, Johanna J. Heymans, Johanna Yletyinen, Susa Niiranen, Saskia A. Otto and Thorsten Blenckner

Regional variations in ecosystem responses to anthropogenic activities and natural stressors in the Seto Inland Sea
Motomitsu Takahashi, Sachihiko Itoh, Naoki Yoshie and Kazuhiko Mochida

Potential early warning indicators of marine ecosystem changes in coastal British Columbia, Canada
R. Ian Perry

Seabird indicators and "tipping points" in North Pacific marine ecosystems
William J. Sydeman, Sarah Ann Thompson, Julie A. Thayer, Marisol Garcia-Reyes, Heather Renner, John F. Piatt, Stephanie Zador and Yutaka Watanuki

The effects of acute gamma irradiation on the survival and the physiological and biochemical indexes of Chinese black sleeper, Bostrichthys sinensis
Wen Yu, Tao Yu, Yusheng Zhang and Feng Lin

The combined effects of elevated CO2 and temperature on the physiological condition of the olive flounder larvae Paralichthys olivaceus
Kyung-Su Kim, JeongHee Shim and Suam Kim

Eutrophication and oligotrophication processes in the Seto Inland Sea and their relationships to the Satoumi concept (Invited)
Tetsuo Yanagi

Diversity of perceptions and utility of marine ecosystem services
Kazumi Wakita, Zhonghua Shen, Taro Oishi, Nobuyuki Yagi, Hisashi Kurokura and Ken Furuya

Assessment of the magnitude and interrelationship of seasonal phytoplankton bloom occurrence at the Japanese scallop (*Mizuhopecten yessoensis*) farming area of Okhotsk Sea, Hokkaido, Japan
Christopher Mulanda Aura, Sei-Ichi Saitoh, Yang Liu and Toru Hirawake

Ordered re-assembly of marine ecosystems
Jameal F. Samhouri, Adrian C. Stier and Phil Levin

Potential reference points for mean trophic level of macrofauna in the Sea of Okhotsk
Konstantin M. Gorbatenko, Vladimir V. Kulik and Artem E. Lazshentsev

The bioconcentration of artificial radionuclides by marine animals after the Fukushima nuclear accident in the Northwest Pacific
Wu Men, Jianhua He, Wen Yu, Fenfen Wang, Wuhui Lin and Yusheng Zhang

Seasonal and spatial variations in nematode assemblages affected by thermal influence of a nuclear power plant in Korea (East Sea, Pacific Ocean)
Hyeong-gi Kim, Hyun soo Rho and Chul-woong Oh

Characterization of absorbed dose from natural and anthropogenic radionuclides for the purpose of establishing reference points within the marine environment
Delvan R. Neville and Kathryn A. Higley

Poster presentations

DNA damage (Comet Assay) as biomarker of Cd exposure in bivalve mollusks *Modiolus kurilensi* and *Corbicula japonica*
Valentina V. Slobodskova, Sergey P. Kukla, Viktor P. Chelomin and Elena V. Zhuravel

Sulfonamide antibiotics in the Northern yellow Sea are related to resistant bacteria: Implications for antibiotic resistance genes
Guangshui Na, Hui Gao, Ruijin Li, Jinqiu Du, Ziwei Yao and Chuanlin Huo

Growth rate comparison of Pacific oyster, Crassostrea gigas, reared in situ in a high-CO_2 mesocosm environment
JeongHee Shim, Hakbin Hwang, Jae-Hyun Lim, Sang-Jun Lee and Jung-no Kwon

Valuation of ecosystem diversity maintenance service in marine protected areas: Shandong case
Shang Chen, Shengjie Tu, Tao Xia, Zhengxiang Gao and Tao Zhang