45th Scientific Symposium of the UJNR Aquaculture Panel

Potential of aquaculture to mitigate impacts of environmental change

International Conference Center Hiroshima
1-5 Nakajima-cho, Naka-ku, Hiroshima-shi, Hiroshima, 730-0811, Japan

October 16th and 17th, 2017

Photo credit: Hiroshima Bay from the top of the mount by FEIS, FRA

Aim of the Symposium

Environmental change impacts fisheries and aquaculture in many ways. Nutrient pollution is driving eutrophication and dead zones; ocean acidification is changing water chemistry, and climate change is already influencing our food supply, fresh water availability, weather and way of life. Aquaculture will be impacted by, and can also impact, these environmental changes over various time and spatial scales. Aquaculture of finfish, shellfish and seaweed have different threats, benefits and opportunities related to environmental change. Understanding the global and regional trend of climate change, effects of environmental change on ecosystem and aquaculture, technical improvement of aquaculture, and aquaculture industrial adaptation to climate change are all research priorities of the National Ocean and Atmospheric Administration (NOAA), the United States Department of Agriculture (USDA) and the Japan Fisheries Research and Education Agency (FRA). The primary focus of this symposium will be on the potential of aquaculture to mitigate impacts of environmental change, such as sequestering carbon, bio-extraction of nutrients and CO_2, and ocean acidification. We hope to exchange ideas and discussion which will be beneficial in exploring science and technology that will enable aquaculture to sustain in a changing environment and be used to mitigate the anthropogenic impacts on environment. We also hope the exchanged ideas will be developed into our collaborative research efforts to resolve key issues and assist strengthening of aquaculture industry in the United States and Japan.

Program

Monday, October 16, 2017

Registration 13:00-13:30

Opening Session and Keynote Presentation
Welcome Remarks
Fuminari Ito, Japan Panel Chair, Executive Director,
Headquarters, FRA 13:30-13:40

Aim of the Symposium
Takuro Shibuno, Director,
National Research Institute of Aquaculture, FRA 13:40-13:50

Keynote Presentation and Introduction of NOAA grants
(Moderators: Paul Olin and Junya Higano)

New direction of management policies in the Seto Inland Sea, Japan in the changing environment
Osamu Matsuda, Professor Emeritus, Hiroshima University 13:50-14:30

Break 14:30-14:50

Marine aquaculture's role in providing nutritional security in a changing environment
Mike Rust, US Panel Chair, NOAA Fisheries Office of Aquaculture 14:50-15:30

An overview of NOAA grants on aquaculture and the environment
Shiyu Rachel Wang, Knauss Fellow, NOAA Headquarters,
Office of Aquaculture 15:30-15:55

Environmental Change
(Moderators: Takuro Shibuno and Mathew Poach)

Oligotrophication and its measures in the Seto Inland Sea, Japan
Katsuyuki Abo, National Research Institute of Fisheries and Environment of Inland Sea, FRA 15:55-16:20

Assessment and future prediction of climate shift impacts on the macroalgal ecosystem and cultivation in the Seto Inland Sea
Goro Yoshida, National Research Institute of Fisheries and Environment of Inland Sea, FRA 16:20-16:45

Poster session 16:45-17:30

Symposium Reception 17:30-19:30

Tuesday, October 17, 2017

Environmental Remediation
(Moderators: Natsuki Hasegawa and Darien Mizuta)

Coastal management using oyster-seagrass interactions for sustainable aquaculture, fisheries and environment
Masakazu Hori, National Research Institute of Fisheries and Environment of Inland Sea, FRA 9:00-9:25

Marine sediment conservation using benthic organisms
Katsutoshi Ito, National Research Institute of Fisheries and Environment of Inland Sea, FRA 9:25-9:50

Break 9:50-10:10

Biological Response to Environmental Change
(Moderators: Satoshi Watanabe and Brett Dumbauld)

Coastal acidification amplifiers along the US East coast: concerns for shellfish production
Matt Poach, NOAA, Northeast Fisheries Science Center 10:10-10:35

Growth variation in long blades kelp *Saccharina longissima* in eastern Hokkaido, Japan
Natsuki Hasegawa, National Research Institute of Aquaculture, FRA 10:35-11:00

Harmful algal blooms and shellfish aquaculture in a changing environment
Leila Basti, Tokyo University of Marine Science and Technology 11:00-11:25

Lunch Break 11:25-13:00

Ecosystem Approach to Aquaculture Part 1
(Moderators: Masakazu Hori and Cheng Sheng Lee)

Ecosystem approach to marine aquaculture
Kay McGraw, NOAA, Office of Habitat Conservation 13:00-13:25

Spatial Planning for Shellfish Aquaculture and Seagrasses in US West Coast Estuaries: Considerations for Adapting to an Uncertain Climate
Brett Dumbauld, U.S. Department of Agriculture,
Agricultural Research Service 13:25-13:50

Offshore mussel aquaculture: strategies for farming in the changing environment of NE Atlantic EEZ
Darien Mizuta, NOAA, Northeast Fisheries Science Center 13:50-14:15

Ecosystem Approach to Aquaculture Part 2
(Moderators: Katsuyuki Abo and Kay McGraw)

Nutrient environment in Gokasho Bay, effects of fish aquaculture on inorganic nutrient levels
Satoshi Watanabe, National Research Institute of Aquaculture, FRA 14:15-14:40

Challenges and opportunities of IMTA in Hawaii and beyond
Cheng Sheng Lee, Director, Center for Tropical and Subtropical Aquaculture, U.S. Department of Agriculture 14:40-15:05

Break 15:05-15:25

Open Discussion: Development of collaborative research projects
Moderators: Fuminari Ito and Mike Rust 15:25-15:50

Science Symposium Closing
Mike Rust, US Panel Chair, NOAA Fisheries Office of Aquaculture 15:50-16:00

List of Participants

Abo, Katsuyuki	FRA, FEIS
Basti, Leila	TUMSAT
Bayne, Christopher	FRA, FEIS
Boyce, Delan	NOAA
Dumbauld, Brett	USDA, Agricultural Research Service
Fujii, Tetsuo	JIRCAS
Hasegawa, Natsuki	NRIA, FRA
Higano, Junya	FRA, FEIS
Hirose, Taro	FRA, FEIS
Hori, Masakazu	FRA, FEIS
Ikuta, Kazumasa	FRA, FEIS
Ito, Fuminari	FRA, Headquarters
Ito, Katsutoshi	FRA, FEIS
Katamachi, Daisuke	FRA, FEIS
Lee, Cheng Sheng	USDA, Center for Tropical and Subtropical Aquaculture
Matsuda, Osamu	Hiroshima University
McGraw, Kay	NOAA, Office of Habitat Conservation
Mizuta, Darien	NOAA, Northeast Fisheries Science Center
Nakajima, Kazuhiro	FRA, FEIS
Ohkubo, Nobuyuki	FRA, FEIS
Ohseko, Norihisa	FRA, NRIA
Okumura, Takuji	FRA NRIA,
Olin, Paul	California Sea Grant
Otoshi, Clete	NOAA Headquarters
Ozaki, Akiyuki	FRA NRIA,
Poach, Matt	NOAA, Northeast Fisheries Science Center
Rust, Mike	NOAA, Headquarters
Shibuno, Takuro	FRA, NRIA
Shigeta, Toshihiro	FRA, FEIS
Shimada, Yukinori	FRA, NRIA
Takano, Masatsugu	FRA Headquarters
Tezuka, Naoaki	FRA, FEIS
Tokoro, Tatsuki	FRA, FEIS
Uchida, Motoharu	FRA, FEIS
Wang, Shiyu Rachel	NOAA, Headquarters
Watanabe, Satoshi	FRA, NRIA
Yoshida, Goro	FRA, FEIS

FEIS: National Research Institute of Fisheries and Environment of Inland Sea
FRA: Japan Fisheries Research and Education Agency
NOAA: National Ocean and Atmospheric Administration
NRIA: National Research Institute of Aquaculture
TUMSAT: Tokyo University of Marine Science and Technology
USDA: U.S. Department of Agriculture

Symposium Abstracts

1. *New direction of management policies in the Seto Inland Sea, Japan in the changing environment*

Osamu Matsuda

Hiroshima University (Professor Emeritus), Higashi-Hiroshima, 739-8528, Japan, *Email: matsuda036 at go3.enjoy.ne.jp*

Abstract
The Seto Inland Sea, the largest enclosed coastal sea in Japan, covers an area of 23,000 km^2 and was originally renowned for productive fishing and aquaculture ground with its scenic beauty. However, since the coastal basin within its watershed around the sea are home to 30 million people, impact of human activities on the sea has been very strong. During Japan's period of rapid economic growth in the mid-1960s to mid-1970s, industrialization of the coastal area, increase of the number of factories and expansion of landfills in water front areas caused a rapid increase in water pollution with a reduction of shallow water area and destruction of the marine environment. In order to conserve the environment of the region, the Law on Temporary Measures for the Environment Conservation of the Seto Inland Sea was enacted in 1973. This law was made permanent in 1978 as the Law on Special Measures for the Environment Conservation of the Seto Inland Sea ("The Seto Inland Sea Law"). More than 40 years have passed since the enactment of the legal system in 1973. During the time, changes of both natural and socio-economic environment around the sea were remarkable, and recently, 2015 became the year for a particularly important change of direction for management because major revisions of both "The Seto Inland Sea Law" and the governmental Basic Program based on the law were made in this year. In the newly revised Basic Program, two major aims of the previous Basic Program (1. conservation of water quality, 2. conservation of natural landscape) were reformed to four new major aims (1. conservation and restoration of coastal environment, 2. conservation and appropriate management of water quality, 3. conservation of natural and cultural landscapes, 4. sustainable utilization of fish resources). These recent changes indicate that not only passive conservation but also positive conservation such as restoration of coastal environment became very important target nowadays. The new direction of the management reflects the changing environment of the Seto Inland Sea after WWII in which the first major target was water pollution control including toxic substances, and then target turned to red tide due to eutrophication and recently major targets are changing to lowered biological productivity and diversity due to oligotrophication and deteriorated habitat. Therefore, main approaches of the management also changed from water quality control by restrictive measures to restoration of habitat such as tidal flat and sea grass bed by promotion of participatory creative activities. New direction is also supported by the concept of *Satoumi* which includes restoration of biodiversity, biological productivity, habitat and well-balanced nutrient cycle by the intervention of positive human activities. These recent shifts of the management policies are expected to contribute to recovering productive fishing and aquaculture grounds in the Seto Inland Sea.

Annotated Bibliography of Key Works
Okaichi, T. and Yanagi, T. ed. 1997., Sustainable *Development in the Seto Inland Sea Japan-From the Viewpoint of Fisheries*, 329 pp., Tera Scientific Publishing Company.
This book provides valuable information on the Seto Inland Sea until 1990s.

Stickney, R. R. and McVey, J.P. ed. 2002. *Responsible Marine Aquaculture*, 391 pp., CABI Publishing.
This is a milestone work on the development of sustainable and responsible marine aquaculture.

Okaichi, T. ed. 2003. *Red Tides*, 439 pp., Tera Scientific Publishing Company.
This book provides comprehensive aspects of red tides such as phenomena, organism, ecological problems, environmental relevance and mechanism of outbreaks.

Yanagi, T. 2007. Sato-Umi: *A New Concept of Coastal Sea Management*, Terra Scientific Publishing Company, Tokyo.
This book was written by the first proposer of the concept of Sato-Umi (*Satoumi*).

Matsuda, O. 2008. Eutrophication and its Cause/Consequence: The Case of the Seto Inland Sea, p78-92, in Nobuo Mimura ed. "*Asia-Pacific Coasts and Their Management*", Springer.
This is a case study on the management of the eutrophic Seto Inland Sea.

Secretariat of the Convention on Biological Diversity (CBD). 2011. Biological and Cultural Diversity in Coastal Communities – Exploring the Potential of *Satoumi* for Implementing the Ecosystem Approach in the Japanese Archipelago, *CBD Technical Series No. 61*, 118pp., Montreal.
This volume of CBD Technical Series provides relevance of *Satoumi* to biodiversity issue and case studies of *Satoumi* activities from Hokkaido northernmost area to Okinawa southernmost area of Japan.

Matsuda, O. et al. 2012. Western Japan cluster: Seto Inland Sea as *satoumi*, p381-402, in Anantha Kumar Duraiappah et al. ed. "*Satoyama-Satoumi Ecosystems and Human Well-Beings*", United Nations University Press.
This is a comprehensive reference of the Seto Inland Sea and also a part of the result of Sub-Global Assessment on Japanese *Satoyama* and *Satoumi*.

Matsuda, O. 2012. Combining Activities of *Sato-Umi* and *Sato-Yama* in Japan: Towards a New Type of Integrated Coastal and Watershed Management, in M. Taniguchi and T. Shiraiwa ed. "*The Dilemma of Boundaries-Toward a New Concept of Catchment*", Springer.
This paper describes the possibility of integrated coastal management by connecting *Sato-Umi* and *Sato-Yama.*

Berque, J. and Matsuda, O. 2013. Coastal Biodiversity Management in Japanese Satoumi. *Marine Policy* 39: 191-200.
This paper refers to relevance of *Satoumi* to biodiversity management.

Matsuda, O. 2014. Predicting and promoting the future state of coastal seas with special emphasis on *Satoumi*, p209-221, in Natsuki Shimizu et al. ed. "*Connectivity of Hills, Humans and Oceans, Challenge to Improvement of Watershed and Coastal Environments*", Kyoto University Press.
Some aspects of future perspective of *Satoumi* were described in this paper.

2. *Marine aquaculture's role in providing nutritional security in a changing environment*

Michael B. Rust
NOAA Office of Aquaculture, 1315 East-West Highway, Silver Spring MD. 20910, USA,
Email: mike.rust at noaa.gov

Abstract
The world produces less than 2% of its food, fiber and biofuel from the sea despite the fact that oceans cover 70% of the earth and receive 70% of its solar energy. Instead we use 70% of available freshwater and 40% of our land through agriculture to feed and clothe ourselves. Future world food security plans developed by governments and international agencies often focus mainly on improving agriculture with an occasional nod toward fisheries, but rarely consider what aquaculture, especially marine aquaculture could provide. Marine aquaculture represents a food production approach that uses less freshwater, feed and land resources than agriculture, is more energy efficient and emits fewer greenhouse gasses than agriculture. In addition, marine aquaculture is relatively buffered from some aspects of climate change. For example, marine aquaculture does not suffer from droughts or floods, and is buffered from extreme storm events and temperature changes. Properly sited and managed, marine aquaculture can provide ecosystem services that help wild stocks persist under changing environmental conditions. Finally, the nutritional quality of aquaculture products is high relative to terrestrial products, increasing the nutritional quality of the diet for society. Marine aquaculture needs to articulate the advantages it represents to world nutritional security so discussions and planning for future food security under a changing climate can be informed.

Annotated Bibliography of Key Works

U.S. Department of Health and Human Services and U.S. Department of Agriculture. *2015 – 2020 Dietary Guidelines for Americans. 8th Edition*. December 2015. Available at http://health.gov/dietaryguidelines/2015/guidelines/.
Every five years the US government reviews current nutritional research and analyzes US food consumption patterns to develop guidelines. Seafood is chronically under consumed by all age groups and both sexes. This has real impacts on human health and results in increased heart disease, stroke and dementia in the US population. Americans consume about half of what is recommended for optimal human health.

Forster, J. and R. Radulovich, 2015. Chapter 11 - Seaweed and food security. In: *Tiwari and Declan, Seaweed Sustainability*, Academic Press, San Diego, pp 289- 313.
Makes the case for a marine agronomy based on seaweeds analogous to terrestrial agronomy that currently provides the majority of our food and fiber.

Hall, S.J., A. Delaporte, M. J. Phillips, M. Beveridge and M. O'Keefe. 2011. *Blue Frontiers: Managing the Environmental Costs of Aquaculture*. The WorldFish Center, Penang, Malaysia.
Provides a comparison between aquaculture and terrestrial production from an environmental perspective.

3. *An overview of NOAA grants on aquaculture and the environment*

Shiyu Rachel Wang
NOAA Headquarters, Office of Aquaculture,1315 East-West Highway, Silver Spring MD. USA 20910, *Email: shiyu.wang at noaa.gov.*

Abstract
NOAA funds extramural research on aquaculture and environmental change through three major competitive grants: Small Business Innovation Research (SBIR) Program, Saltonstall-Kennedy (SK) Grant Program and Sea Grant Program. From 2002 to 2016, NOAA has spent

$9.2 million U.S. dollars on research projects focus on the interactions between aquaculture and the environment, with $6.5 million federal funds and $2.7 million matching funds. Annual spending fluctuated with a maximum of $1.3 million in 2005 and a minimum of $0.14 million USD in 2002 and zero spending in 2009. Out of the three major funding programs, Sea Grant funded 75% of the entire spending. A total of 43 projects on aquaculture and related topics including nutrient removal, carbon fixation, ocean acidification, waste treatment and related topics were completed. Analysis of the impact of these projects is planned. An understanding of NOAA's spending can help identify research gaps, evaluate impact, inform policy and allocate budget related to aquaculture in a changing environment.

Annotated Bibliography of Key Works

Love, D.C., Gorski, I. and Fry, J.P., 2017. An Analysis of Nearly One Billion Dollars of Aquaculture Grants Made by the US Federal Government from 1990 to 2015. *Journal of the World Aquaculture Society*.

The authors conducted a study on U.S. federal spending for aquaculture by tracking 2957 federal research grants awarded through different agencies from 1990 to 2015. For the past quarter century, 1.04 billion US dollars were spent on aquaculture research with about 90% of federal funds and 10% matching funds. Aquaculture production sciences received the most funding (27%) out of 13 major disciplines in aquaculture, followed by aquatic animal health and disease (17%). Environment related aquaculture topics including water and waste management and environmental interactions received 7% of the total federal funding across all related agencies. Comparing the U.S. domestic aquaculture production with the federal spending, the authors concluded a 37-fold return in federal government investments in aquaculture since 2000. This study can be used as a framework to track and assess federal agencies' spending on different topics of aquaculture, identify research gaps and inform policy making and grant allocation.

4. *Oligotrophication and its measures in the Seto Inland Sea, Japan*

Katsuyuki Abo[1*] and Tamiji Yamamoto[2]

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[2]Hiroshima University, Kagamiyama, Higashi-Hiroshima, Hiroshima 739-8511, Japan

Abstract

The Seto Inland Sea had been known as a beautiful and bountiful sea with rich ecosystem. However, during the period of high economic growth, eutrophication progressed and fishery damage caused by harmful algal bloom became frequent. Since the Interim Measures Law concerning Conservation of the Environment of the Seto Inland Sea (later the Special Measures Law) was enacted in 1973, the water quality of the Seto Inland Sea has improved by a series of measures such as reduction of inflow load. On the other hand, however, oligotrophication has become a problem in recent years, and it caused decrease in Nori (*Pyropia yezoensis*) production due to bleaching of leaves because of nutrient depletion. In addition, it is also pointed out that the decrease in fisheries production, such as small pelagic fish and demersal fish, is related to nutrient reduction. Here we describe the changes and current situation in the water quality of the Seto Inland Sea and discuss the influence of the load reduction on the lower trophic ecosystem and the fishery production. We also introduce nutrient supply methods such as fertilizer application, additional discharge of dams, nutrient management operation of

sewage treatment plants, etc. which are experimentally conducted as countermeasures for bleaching Nori. In addition, we mention future subject to restore the bountiful Seto Inland Sea.

Annotated Bibliography of Key Works

Abo, K., S. Akiyama, K. Harada, Y. Nakaji, H. Hayashi, K. Murata, A. Wanishi, Y. Ishikawa, T. Masui, S. Nishikawa, K. Yamada, M. Noda and S. Tokumitsu, (accepted) Long-term variations in water quality and causal factors in the Seto Inland Sea, Japan. Bulletin on Coastal Oceanography, 55

The long-term variations in water quality in the Seto Inland Sea were investigated based on the routine observation data of the local fisheries experimental stations. The water temperature increased due to the global warming and the nutrient decreased due to oligotrophication. The reduction of DIN and DIP concentrations were largely affected by land load reduction.

Abo, K., K. Tarutani, K. Harada, K. Miyahara, A. Nakayama and H. Yagi, 2012. Effects of nutrient discharge on Nori aquaculture area in Kako River estuary, J. JSCE, Ser.B2, *Coastal engineering*, 68, 1_1116-1_1120.

Effects of nutrient discharge on Nori aquaculture area were investigated. The Nori production in the winter season were sustained by nutrient discharge from the river, sewage treatment plant and industrial effluent. A numerical simulation evaluated the effects of nutrient control operation of the sewage treatment plant on the nutrient environments of the aquaculture area.

Yamamoto, T., 2002. The Seto Inland Sea—eutrophic or oligotrophic? *Marine Pollution Bulletin*, 47, 37-42.

This was the first study showing the Seto Inland Sea was in the state of ‘cultural oligotrophication’ caused by the reduction of nutrient loading. This study indicated that the measures to reduce phosphorus had caused a change in phytoplankton species composition, thereby altering the food web structure, suggesting that this might be the major cause of the reduction of fishery production.

Yamamoto, T. and G. Hatta, 2004. Pulsed nutrient supply as a factor inducing phytoplankton diversity. *Ecol. Model.*, 171, 247-270.

A numerical model was constructed to elucidate whether phytoplankton species diversity could be increased by an environmental fluctuation such as a pulsed nutrient supply. Diatom showed large fluctuations in cell density in response to pulses of nutrients, while dinoflagellate showed preference for continuous nutrient supply mode. Dam construction, which is one of the causes of oligotrophication, usually flattens variability in the freshwater discharge, hence lead to dinoflagellate dominancy.

Yamamoto, T., S. Tateno, K. Hata, K. Mizushima, Y. Goda, S. Takahashi, K. Tarutani, H. Saito and T. Tanimoto, 2017. Designing an effective action plan for sustainable local resources and the coastal environment: A case study of Mitsu Bay, Hiroshima, Japan. Proceedings of International Conference "*Managing risks to coastal regions and communities in a changing world*" (EMECS'11 - SeaCoasts XXVI, St. Petersburg, 22-27.08.2016). Moscow, RIOR Publ., ISBN978-5-369-01628-2, DOI: 10.21610/conferencearticle_58b43157871ef

This study proposed measures for sustainable fishery production in an oligotrophic bay (Mitsu Bay). Water quality was extremely good (oligotrophic), therefore improvement of sediment quality was necessary. As oyster cultivation was popular in this bay, improvement of sediment quality using oyster shells could contribute to the formation of a recycling-oriented society.

5. *Assessment and future prediction of climate shift impacts on the macroalgal ecosystem and cultivation in the Seto Inland Sea*

Goro Yoshida[1*], Hiromori Shimabukuro[1], Setsuo Kiyomoto[2], Tatsuru Kadota[2], Taku Yoshimura[2], Noboru Murase[3], Mikio Noda[3], Yoshimi Kono[4], Shoichi Takenaka[4], Toshiharu Tamura[5], Norio Tanada[6], Xiaojie Yu[7], Naoki Yoshie[7] and Xinyu Guo[7]

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[2] Seikai National Fisheries Research Institute, FRA, Taira-machi, Nagasaki, Nagasaki 851-2213, Japan
[3]National Fisheries University, FRA, Nagata-honmachi, Shimonoseki, Yamaguchi 759-6595, Japan
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[5]Ehime Prefectural Government, Ichiban-cho, Matsuyama, Ehime 790-8570, Japan
[6]Fisheries Research Division, Tokushima Prefectural Agriculture, Forestry and Fisheries Technology Support Center, Minami-cho, Kaifu-gun, Tokushima 779-2304, Japan
[7]Center for Marine Environmental Studies, Ehime University, *Bunkyo-cho, Matsuyama,* Ehime 790-8577, Japan

Abstract

Seto Inland Sea is the largest semi-enclosed sea area, which is interposed to Pacific Ocean by Bungo and Kii Channels. In the Seto Inland Sea, macroalgal beds are important grounds as nursery of many important fishes and for small scale fisheries such as gill-net or set-net fisheries. Also, aquaculture of edible macroalgae such as *Nori* (laver) and *Wakame* (sea mustard), as well as aquaculture of bivalves, is an important industry in the Seto Inland Sea. However, coastal water temperature on the increase trend in past several decades has been greatly affecting macroalgal ecosystems and cultivation in western Japan. Abrupt and unsteady degradation or extinction of macroalgal beds (*Isoyake*) has been spreading around Japanese coast, and the phenomena are remarkable along the coasts facing to the open seas (Pacific Ocean and East China Sea) influenced environmentally by warm currents. Though serious *Isoyake* has not still occurred in the Seto Inland Sea, it is also predicted to expand within the sea area in near future as the water temperature continues to rise. In case of aquaculture, production of *Wakame* in the Seto Inland Sea has been already tremendously decreasing due to failure in steady growth of seedlings. All these negative conditions of macroalgae are considered to be attributable to physiological unsuitability and conspicuous increase of grazing activities of herbivorous animals against the background of water temperature increase. We have been conducting 1) field monitoring and surveys to detect influences of water temperature increase on macroalgal ecosystems and cultivation, 2) experiments of impacts of water temperature rise on eco-physiological situations of key species, 3) a construction of an original high resolution numerical model to reproduce and forecast the coastal water temperature changes in the past and future, 4) application of the outputs of the model, to relate past events to temperature conditions at those times for understanding of the mechanisms and to predict future conditions according to the global warming scenarios, 5) development of practical technologies in macroalgal ecosystem conservation and cultivation for adaptation to changing environments. In the presentation, we will introduce current situations of macroalgal ecosystems and cultivation in and around the Seto Inland Sea, and some of the results of the studies described above.

Annotated Bibliography of Key Works

Tanaka, K., Taino, S., Haraguchi, H., Prendergast, G. and Hiraoka,. M. 2012. Warming off southwestern Japan linked to distributional shifts of subtidal canopy-forming seaweeds. *Ecology and Evolution*, 2 (11): 2854-2865.

Along the coast of Kochi Prefecture, southwestern Japan, macroalgal bed of temperate kelp (*Ecklonia cava*) has been tremendously decreasing and it has serious impact on abalone fishery. In addition, the authors clarified by field surveys that temperate *Sargassum* species which are also important constitutes of macroalgal beds have been replaced by tropical species, *S. ilicifolium*. Behind these events, the coastal water temperature has been increasing since the 1970s at the rate of 0.3 ℃/ decade in the annual mean.

Takao, S., Kumagai, N.H, Yamano, H., Fujii, M. and Yamanaka, Y. 2015. Projecting the impacts of rising seawater temperatures on the distribution of seaweeds around Japan under multiple climate change scenarios. *Ecology and Evolution* 5 (1): 213-223.

Authors predicted the future distribution of seaweed (temperate kelp, *Ecklonia cava*) along the Japanese coast based on water temperature increase prediction output in the most recent multiple climate projection models and emission scenarios (RCP scenarios). They suggested that continued warming may cause in a pole-ward shift of the distribution of *E. cava*, but the results were different according to the scenarios. In the highest emission scenario (RCP8.5), E. cava would disappear from the Japanese coast due to both of physiological damages and grazing pressures by herbivorous animals.

Tanada, N. 2016. Development of a practical method for mass seedling production using free-living gametophytes and a new cultivar tolerant to warm waters for early harvesting of Undaria pinnatifida (Harvey) Suringar. *Aquabiology* 38 (4): 464-471. (in Japanese with English abstract)

The production of Wakame, *Undaria pinnatifida* in cultivation in Tokushima, which is one of the largest producing area in Japan, has been decreasing seriously after the 1990s. The decrease is supposed to be due to water temperature increase, especially during autumn when seedlings of Wakame are started to be cultured in the sea, because the seedlings are sensitive to high temperature conditions at that stage. Authors developed new techniques in mass seedling production and its control, and it can enable to make new cultivars of Wakame which can have tolerance to high temperatures.

6. *Coastal management using oyster-seagrass interactions for sustainable aquaculture, fisheries and environment*

Masakazu Hori[1*], Franck Lagarde[2], Masami Hamaguchi[1] and Mitsutaku Makino[3]

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[2]Station de Sete, IFREMER, Sete 34203, France
[3]National Research Institute of Fisheries Science, Yokohama, Kanagawa 236-8648, Japan

Abstract

Coastal environments of the world have been exposed to eutrophication for several decades. Recently the quality of coastal waters has been gradually and successfully improved, however this improvement has caused another issue in coastal ecosystem services, namely, oligotrophication. While oligotrophication, with higher water transparency, has recovered

benthic macrophyte vegetation which have been depressed by phytoplankton derived from eutrophication, local stakeholders have suggested that oligotrophication reduces pelagic productivity and therefore fishery production in coastal ecosystems. In contrast, oligotrophication with high transparency has recovered benthic primary productivity including seagrass vegetation. Seagrasses are quite important for climate change mitigation and adaptation such as carbon storage, acidification mitigation, and protection from sea-level rise and storm surges, which has been welcomed by other stakeholders. Therefore, harmonizing coastal fishery with environmental conservation goals is now essential for the sustainable use of ecosystem services. Here, we present the scope of our study based on an interdisciplinary approach including ecological actions, socio-economical actions and psychological actions. We chose to focus on the interaction between oyster aquaculture and seagrass vegetation as a typical ecological action. Coastal organisms have adapted their traits to the environment over a long period of time, so that restoration of mixed coastal habitats represents reconstruction of the original process of coastal production. Subtidal seagrass vegetation with intertidal oyster reefs is the original mixed habitats in Japan, which would be expected to enhance coastal production by improving the production efficiency without adding nutrients. A simple field experiment with carbon and nitrogen contents and the stable isotope analyses revealed that oyster spats cultivated on a tidal flat adjacent to seagrass beds had higher nitrogen contents and higher δ13C ratios than spats cultivated in an offshore area using only pelagic production. This result suggests that utilization of the traditional mixed habitats, which enables oysters to use both pelagic and various benthic production, has potential to sustain food provisioning service for humans even in oligotrophic environment.

Annotated Bibliography of Key Works

Pernet, F, N Malet, A Pastoureaud, A Vaquer, C Quere, and L Dubrica. 2012. Marine diatoms sustain growth of bivalves in a Mediterranean lagoon. *J Sea Res,* 68: 20-32.
Carbon stable isotopes and fatty acids were measured in the suspended particulate organic matter (POM) of the Thau lagoon to study its qualitative temporal changes in relation to environmental factors and to identify the food sources of bivalves over a one-yr-cycle in relation to their growth. Reciprocally, the impact of shellfish farming on POM was also studied. Oysters and mussels were sampled and measured for biometry, stable isotopes and fatty acid composition. Water samples were collected at two sites, both inside and outside of the shellfish farming area, to determine concentrations in POM, chlorophyll a (Chl *a*) and stable isotopes. Carbon isotopes and fatty acids in bivalves reflected seasonal changes in food sources, which varied consistently with the environment. Seasonal changes in δ13C and fatty acids in the bivalves suggested that dietary phytoplankton contribution varied according to season. Terrestrial organic matter and bacteria can contribute to the diet of bivalves during non-bloom periods. Mussels seemed to rely more on diatoms and less on terrestrial organic matter and bacteria than oysters did, particularly when phytoplankton biomass was low during the summer. Although one- and two-yr-old oysters showed similar $\delta^{13}C$, their fatty acid dynamics differed slightly. Periods of high growth rate in bivalves were mainly fuel led by diatoms, thus highlighting the importance of seasonal blooms of micro phytoplankton during the critical period of bivalve growth and gamete production. Although there was no significant effect of shellfish farms on Chl *a* and POM$\delta^{13}C$, consistent differences indicate that stable isotopes could be used successfully to investigate the effects of bivalve aquaculture.

Morimoto, N, Y Umezawa, ML San Diego-McGlone, A Watanabe, FP Slringan, Y Tanaka, GL Regino, and T Miyajima. 2017. Spatial dietary shift in bivalves from embayment with river discharge and mariculture activities to outer seagrass beds in northwestern Philippines. *Mar Biol.*164: 84.

To investigate the spatial variation in bivalve food sources along a pollution gradient and assess bivalve contribution to biogeochemical cycles in tropical coastal ecosystems, the $\delta^{13}C$ and $\delta^{15}N$ values of bivalves and their potential food sources were studied in northwestern Philippines. In a semi-enclosed embayment affected by river discharge and mariculture activities, bivalves depended primarily on ^{13}C-depleted suspended particulate organic matter such as phytoplankton and/or fish feeds. However, toward the relatively oligotrophic seagrass beds, the bivalve food source gradually shifted to more ^{13}C-enriched re-suspended and/or settled particles. Furthermore, in the outer seagrass beds exposed to the open ocean, bivalves mainly relied on similar food sources, such as detritus of microalgae, regardless of the distance from the embayment. These trends appear to reflect the ready availability of the food sources. Especially in the outer seagrass beds, a semi-closed material cycle within the vicinity of the sea bottom likely emerged between bivalves and algae, but not between the phytoplankton in the overlying water column. This resulted in a relatively weak benthic-pelagic coupling for bivalves. These cycles would need to be taken into account when estimating the biogeochemical cycles in eutrophicated coastal areas.

Duarte, CM, IJ Losada, IE Hendriks, I Mazarrasa, and N Marba. 2013. The role of coastal plant communities for climate change mitigation and adaptation. *Nature Climate Change* 3: 961-968.

Marine vegetated habitats (seagrasses, salt-marshes, macroalgae and mangroves) occupy 0.2% of the ocean surface, but contribute 50% of carbon burial in marine sediments. Their canopies dissipate wave energy and high burial rates raise the seafloor, buffering the impacts of rising sea level and wave action that are associated with climate change. The loss of a third of the global cover of these ecosystems involves a loss of CO_2 sinks and the emission of 1 Pg CO_2 annually. The conservation, restoration and use of vegetated coastal habitats in eco-engineering solutions for coastal protection provide a promising strategy, delivering significant capacity for climate change mitigation and adaption.

7. *Marine sediment conservation using benthic organisms*

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Abstract

Estuaries and coastal zones used as fish aquaculture are often polluted by organic contaminants and anthropogenic chemicals. Bioremediation has been recognized as an efficient technology to clean up environmental pollutants. The authors have studied environmental remediation using benthic organisms, and have shown that some annelids are adaptable to polluted environment. For example, *Capitella* cf. *teleta* (Annelida, Polychaeta), inhabits in bottom sediment beneath a fish farm, has high protease activity, whereas *Perinereis nuntia* (Annelida, Polychaeta), inhabits in an estuary has high cellulase activity. Furthermore, *Thalassodrilides* cf. *briani* (Annelida, Oligochaeta) can survive highly hypoxic and sulfidic sediments contaminated with various pollutants, and have shown to biotransform 1-nitronaphthalene, a toxic and carcinogenic chemical, into substances that are nontoxic to fish. In another study,

when the three benthic species were maintained in polluted sediments, the polychaetes *P. nuntia* and *C*. cf. *teleta* markedly increase redox potential (Eh) level and decrease acid volatile sulfides (AVS) level compared with those of the oligochaete *T* cf. *briani*. Furthermore, concentration of polycyclic aromatic hydrocarbons (PAHs), incomplete combustion products of fossil fuels, in the sediment were significantly lower than the initial level. Especially, *T* cf. *briani* showed a marked ability to degrade the PAHs in the sediment. These results indicate that benthic organisms have species-specific remediation properties and ecological functions in organically polluted sediments. Currently, we are working on the development of a real-time measuring device of the Eh in the sediment under fish farms. The Eh is a comprehensive parameter to monitor the degree of eutrophication of the sediment under fish farm. We also introduce our on-going research progress on this topic.

Annotated Bibliography of Key Works

Ito, K., Nozaki, M., Ohta, T., Miura, C., Tozawa, Y., Miura, T. 2011. Differences of two polychaete species reflected in enzyme activities. *Marine Biology* 158 (6): 1211-1221.
Polychaetes constitute most of the benthic macroinvertebrates in estuarine and coastal environments. We investigated the utilization of organic matter in two polychaete species, *Capitella* sp. I and *Perinereis nuntia brevicirris*, living in different coastal habitats. The protease activity of *Capitella* sp. I (89.7 μg/mg) was about 10 times that of *P. nuntia brevicirris* (8.0 μg/mg). High cellulase (endo-β-1,4-glucanase) activity was detected in *P. nuntia brevicirris* (3.2 μg/mg), whereas scarcely any was detected in *Capitella* sp. I. We isolated cDNA clones of protease mRNA from *Capitella* sp. I and of cellulase mRNA from *P. nuntia brevicirris*. The high protease activity of *Capitella* sp. I enabled it to survive in the sediment under a fish farm, where it degrades organic matter. In contrast, the high cellulase activity of the estuary-dwelling *P. nuntia brevicirris* allowed it to degrade organic matter originating from terrestrial areas.

Ito K, Ito M, Onduka T, Ohta K, Torii T, Hano T, Mochida K, Ohkubo N, Miura T, Fujii K. 2016. Differences in the ability of two marine annelid species, *Thalassodrilides* sp. and *Perinereis nuntia*, to detoxify 1-nitronaphthalene. *Chemosphere* 151: 339-44
Bioremediation is a promising method for remediating environmentally polluted water. We investigated the abilities of two benthic annelid species to biotransform 1-nitronaphthalene, a nitrated polycyclic aromatic hydrocarbon. We used an oligochaete, *Thalassodrilides* sp. (Naididae), collected from the sediment beneath a fish farm and a polychaete, *Perinereis nuntia*, which was obtained from a commercial source. Populations of both organisms were exposed to 1400 μg L(-1) of 1-nitronaphthalene in seawater for 3 days in the dark at 20 °C. The concentration of the pollutant decreased to 12 μg L(-1) in the seawater containing the Thalassodrilides sp. and to 560 μg L(-1) in the seawater containing *P. nuntia*. The 1-nitronaphthalene concentration in the bodies of the animals increased from 12 to 94 μg kg(-1) in *Thalassodrilides* sp. and from 0.90 μg kg(-1) to 38,000 μg kg(-1) in *P. nuntia*. After 3 days, 99% and 40% of the 1-nitronaphthalene had been biotransformed in the *Thalassodrilides* sp. and *P. nuntia* experimental groups, respectively. We then tested the acute toxicity of residual 1-nitronaphthalene from the same water using mummichog (fish) larvae. After the larvae had been exposed for 96 h, the percentage of apparently unaffected larvae remaining was 83.3% in *Thalassodrilides* sp. group but only 16.7% in the *P. nuntia* group. Clearly, of the two species we studied, *Thalassodrilides* sp. had a superior ability to convert 1-nitronaphthalene into substances that were nontoxic to mummichog larvae. Therefore, we recommend the use of this species for bioremediation of chemically polluted sediments.

Ito M, Ito K, Ohta K, Hano T, Onduka T, Mochida K, Fujii K. 2016. Evaluation of bioremediation potential of three benthic annelids in organically polluted marine sediment. *Chemosphere* 16: 3392-9.
This study aimed to evaluate the possible remedial effects of three marine benthic annelids on organically polluted sediments from the waters of Hatsukaichi Marina, Hiroshima, Japan. Two polychaetes, *Perinereis nuntia* and *Capitella* cf. *teleta*, and an oligochaete, *Thalassodrilides* sp., were incubated in sediments for 50 days. Their effects on physicochemical properties such as organic matter (loss on ignition), redox potential (Eh), acid volatile sulfides (AVS), and degradation of polycyclic aromatic hydrocarbons (PAHs) were assessed. The polychaetes *P. nuntia* and *C*. cf. *teleta* significantly increased Eh level and decreased AVS level compared with the oligochaete *Thalassodrilides* sp. and control (without benthic organisms). Total PAH concentration significantly decreased from the initial level with all three groups; *Thalassodrilides* sp. had a marked ability to reduce PAHs in sediment. These results indicate that benthic organisms have species-specific remediation properties and ecological functions in organically polluted sediments.

8. *Coastal acidification amplifiers along the US East coast: concerns for shellfish production*

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Abstract
In coastal systems endangered by acidified water, it becomes paramount to understand the link between acidification and its environmental drivers. Bays along the US Mid-Atlantic coast are particularly vulnerable to local amplification of ocean acidification due to highly eutrophic conditions, low alkalinity freshwater input, and episodic upwelling of acidified water. To better understand these drivers two research studies were conducted along the NJ coast. The first study was conducted during the summers of 2014 and 2015 at the Aquaculture Innovation Center (AIC) of Rutgers University located in Cape May, NJ. The AIC is an important research hatchery that currently supports the New Jersey oyster aquaculture industry through the production of disease resistant and triploid seed oysters. The second study, which began in the summer of 2017, focuses on elucidating the range of pH and aragonite saturation (Ωarag) conditions experienced at the inlet to Little Egg Harbor Bay, NJ, an important shellfish location. During the summers of 2014 and 2015, temperature, salinity, dissolved oxygen (DO), turbidity and pH were continuously monitored at the AIC's intake pipe located in the Cape May Canal. Periodic duplicate grab samples were also collected at the intake and at locations within the facility. One of each duplicate grab samples was preserved and analyzed for pH and dissolved inorganic carbon (DIC), whilst the other was preserved for analysis of the planktonic community. The DIC and pH were used to calculate the aragonite saturation state of the sampled water. The pH at the intake showed diurnal variations that tended to mirror the DO signal. The largest drop in pH was measured in July of 2014 and again in July of 2015. These pH drops were decoupled from the DO signal. Likewise, grab samples showed that water of

low pH and aragonite saturation was entering the facility. The occurrence of consistent Southwesterly winds and cooler surface water temperatures along the coast during both time frames indicated that upwelling was occurring. A spike in plankton numbers was recorded in samples collected immediately after the 2014 upwelling event. These results show that hatcheries along the NJ coast need to be aware that upwelling may bring reduced shellfish production conditions, and highlights the need for continued monitoring. Starting in May of 2017, temperature, salinity, DO, turbidity, pH and carbon dioxide partial pressure (pCO_2) were continuously monitored at one station in Little Egg Harbor off Beach Haven. Periodic grab samples were collected from near the sensors, preserved, and analyzed for pH and DIC. Results from the grab samples were used to validate sensor readings. Sensor temperature, salinity, pH and pCO_2 data were used to calculate Ω_{arag}. Relationships between pH and DO will be highlighted as well as indications of periodic upwelling events. Results will be used to determine the relative contribution of eutrophication, freshwater inflow, and coastal upwelling as acidity amplifiers as well as estimate past pH and Ω_{arag} levels from legacy data collected in nearby Barnegat and Great Bays.

Annotated Bibliography of Key Works

Barton, A., B. Hales, G.G. Waldbusser, C. Langdon, and R.A. Feely. 2012. The Pacific oyster, *Crassostrea gigas*, shows negative correlation to naturally elevated carbon dioxide levels: Implications for near-term ocean acidification effects. *Limnology and Oceanography*, Vol 57: 3. Pp 698–710.

The authors report results of a monitoring study designed to evaluate the response of Pacific oyster (*Crassostrea gigas*) larvae, grown at a commercial hatchery on the Oregon coast, to natural changes in carbonate chemistry associated with periodic seasonal upwelling during the summer of 2009. During the study, the intake waters experienced aragonite saturation states from 0.8 to 3.2 and pH from 7.6 to 8.2. They observed significant negative relationships between aragonite saturation states at the time of spawning and subsequent growth and production of larvae over the size range of 120 to 150-mm shell length. This was one of the first studies to link failures in seed oyster production to more corrosive water from coastal upwelling.

Booth, J.A.T., E.E. McPhee-Shaw, P. Chua, et al. 2012. Natural intrusions of hypoxic, low pH water into nearshore marine environments on the California coast. *Continental Shelf Research*, Vol 45: 15. Pp 108–115.

The authors reviewed a decade-long data set to examine oxygen and pH variability on the inner shelf off of Central California. Results show regular inundation of cold, hypoxic and low pH water. The source-water for these periodic intrusions originates in the offshore, midwater environment above the local OMZ, generally between 50–100 m but occasionally deeper. Pulses of the greatest intensity arose at the onset of the spring upwelling season, and fluctuations were strongly semidiurnal and diurnal. Arrival of cold, hypoxic water on the inner shelf appears to be driven by tidal-frequency internal waves pushing deep, upwelled water into nearshore habitats. These observations are consistent with the interpretation that hypoxic water is advected shoreward from the deep, offshore environment where water masses experience a general decline of temperature, oxygen and pH with depth.

Ekstrom, J.A., L. Suatoni, S.R. Cooley, et al. 2015. Vulnerability and adaptation of US shellfisheries to ocean acidification. *Nature Climate Change*, Vol 5: 3. Pp 207–214.

Authors present a spatially explicit, multidisciplinary analysis of the vulnerability of coastal human communities in the United States to ocean acidification. Their results highlight US regions most vulnerable to ocean acidification, reasons for that vulnerability, important knowledge and information gaps, and opportunities to adapt through local actions. Results

indicated that 16 of the 23 bioregions around the United States are exposed to rapid OA (reaching Ω_{Ar} 1.5 by 2050) or at least one amplifier; 10 regions are exposed to two or more threats of acidification. The marine ecosystems and shelled molluscs around the Pacific Northwest and Southern Alaska are expected to be exposed soonest to rising global OA, followed by the north-central West Coast and the Gulf of Maine in the northeast United States. Communities highly reliant on shelled molluscs in these bioregions are at risk from OA either now or in the coming decades. In addition, pockets of marine ecosystems along the East and Gulf Coasts will experience acidification earlier than global projections indicate, owing to the presence of local amplifiers such as coastal eutrophication and discharge of low-Ω_{Ar} river water. This analysis can be used to help prioritize societal responses to ocean acidification.

Gobler, C.J. and H. Baumann. 2016. Hypoxia and acidification in ocean ecosystems: coupled dynamics and effects on marine life. Biological Letters, Vol 12: 5. Pp 1-8.
As climate change progresses, the effects of atmospheric CO_2 on coastal acidification will intensify; and, while hypoxia is a much-studied stressor for coastal organisms, the combined effect of hypoxia and acidification has only recently become a focus for scientists. The authors conduct a meta-analysis of published research that studied the combined effects of pH and dissolved oxygen variability on marine organisms. The authors conclude that low DO is a greater stressor to most marine organisms than low pH conditions, although worse effects can occur through the synergistic interaction of the two. While most traits under concurrent low DO and low pH appeared to be additively affected, every study reviewed also found synergistic interactions in at least one instance. They also conclude that neither the occurrence nor the strength of these synergistic impacts is currently predictable, and therefore, the true threat of concurrent acidification and hypoxia to marine food webs and fisheries is still not fully understood. Addressing this knowledge gap will require an expansion of multi-stressor approaches in experimental and field studies.

Wallace, R.B., H. Baumann, J.S. Grear, R.C. Aller, and C.J. Gobler. 2014. Coastal ocean acidification: The other eutrophication problem. Estuarine, Coastal and Shelf Science, Vol 148: 5. Pp. 1-13.
To assess the potential for acidification in eutrophic estuaries, the authors characterized the spatial and temporal patterns of DO, pH, pCO_2, and $\Omega_{Aragonite}$ in four, semi-enclosed estuarine system across the Northeast US: Narragansett Bay, Long Island Sound, Jamaica Bay, and Hempstead Bay. Multi-year monitoring datasets were assessed to define seasonal patterns in pH and DO while cruises were conducted to vertically and horizontally resolve spatial patterns of acidification during the seasonal onset, peak, and decline of hypoxia in these estuaries. They utilized three approaches for this study: 1) The analysis of monthly monitoring data across Long Island Sound; 2) Vertical measurements of water column conditions across Narragansett Bay, Long Island Sound, and Jamaica Bay; and 3) Continuous, horizontal mapping of conditions across Jamaica Bay and Hempstead Bay. Low pH conditions (<7.4) were detected in all systems during summer and fall months concurrent with the decline in DO concentrations. While hypoxic waters and/or regions in close proximity to sewage discharge had extremely high levels of pCO_2, (>3000 μatm), were acidic pH (<7.0), and were under-saturated with regard to aragonite ($\Omega_{Ar} < 1$), even near-normoxic but eutrophic regions of these estuaries were often relatively acidified (pH < 7.7) during late summer and/or early fall. This study revealed that acidification is an annual feature of eutrophic estuaries across the Northeast US that co-occurs with seasonally low oxygen. The spatial and temporal dynamics of DO, pH, pCO_2, and $\Omega_{Aragonite}$ suggest that they are all ultimately driven by high rates of microbial respiration. The degree of acidification observed

in these systems during summer are within ranges that have been shown to adversely impact a wide range of marine life.

9. *Growth variation in long blades kelp Saccharina longissima in eastern Hokkaido, Japan*

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Abstract
Saccharina longissima (Naga-konbu in Japanese) is one of commercially important Laminariacean kelp species, which grows to more than 10 m in blade length. The kelp is distributed in shallow Pacific coastal areas from eastern Hokkaido (Kushiro and Nemuro) to the Chishima island. Its distribution area is under the influence of the cold Oyashio current, and the water temperature varies seasonally from sub-zero to 20°C. This kelp is the main harvested species in eastern Hokkaido, mostly used for tsukuda-ni (preserved food cooked with sweetened soy sauce) and kelp rolls making use of its soft texture, whereas other kelp species with harder blades are widely used for broth. Its annual production is around 10 thousand tons in dry weight with a gradual decreasing trend in recent years. Fisheries cooperative association of Habomai in Nemuro has been monitoring the blade size of the kelp in its harvested grounds along the coastal line of more than 15 km (43.30°N, 145.67°E - 43.39°N, 145.82°E) in May and June. We analyzed the variations in the blade size of the kelp (Age 1+) in this area between 2000 and 2014. *S. longissima* is a perennial kelp species, and the kelp over Age 1+ is targeted for fisheries harvesting using long handle gears between June and October. Effects of locational environmental factors on the blade weight in May and June were estimated using correlation analysis and generalized linear regression model (GLM). In GLM analysis of weight in May, monthly average water temperature in Kushiro, monthly average daylight hours and wind speed in Nemuro for the previous two years and longitudes at sampling points were used as explanation variables. In GLM analysis of weight in June, monthly average environmental parameters in May and June were used as explanation and the average blade weight in each point in May as both explanation and offset variables. The monitoring data showed that the blade size varied among years, and the blade growth was good in 2002 and 2009. On the other hand, 2003, 2011 and 2013 had a poor-growth of the blade. Correlation analysis revealed that only correlation coefficients between the blade weight in May and water temperature had regular trends: negative during the previous year and positive during the present year. GLM analysis of the blade weight in May also revealed that the models including only temperatures and longitudes had small AIC values of 6,346 although AICs of Null and best model including all parameters were 6,513 and 6,306 (smallest), respectively. GLM analysis of the blade weight in June revealed that the average blade weight at each study point remarkably contributed to predict the weight in June. These results suggested that the growth of *S. longissima* is affected by the water temperature. High water temperature in the previous autumn and extremely low temperature in the present winter to spring reduce the growth of the kelp. The increasing trends of water temperature in recent years, may be one of the factors decreasing the fisheries production of the kelp in eastern Hokkaido.

Annotated Bibliography of Key Works

Sasaki Shigeru. 1973. Studies on the life history of *Laminaria angustata* var. *longissima* (M.) Miyabe. Hokkaido Kushiro Fisheries Experimental Station, Kushiro. Pp141.
This paper was published in 1970s when this species increasingly became of high fisheries importance around eastern Hokkaido, Japan. The author summarized the life history of *Laminaria angustata* var. *longissima* (M.) Miyabe., which has been recently renamed as *Saccharina longissima.* This paper includes the studies about the life history of two seasonal germinal groups in winter and summer to provide information for stock enhancements, the importance of suspended culture, reviewing position of the S. *longissima* in Japanese kelp fisheries with evaluating the factors affecting its fisheries production such as the floating ice. Some parts of these studies were published in Journal of Hokkaido Fisheries Experimental Station in Japanese. Although the marine and social environments for *S. longissima* fisheries have markedly changed since 1970s, intensive studies such as one done by Sasaki (1973) have not been conducted since then.

Yotsukura Norishige. 2010. The hierarchy of Laminariales in Japan. Algal Resources, 3:193-198.
This paper reviews the hierarchy of laminarialean algae which has been proposed by molecular phylogenetic analyses. There is a variety of laminarialean species in Japan's coastal areas where some species including *Saccharina longissima* are harvested or cultured on a large scale. These species have been classified based on morphological characteristics although there are variations in its morphology among its growth stages and environmental conditions. Author enumerated 37 laminarialean species belonging to 7 families in Japan.

10. *Harmful algal blooms and shellfish aquaculture in a changing environment*

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Abstract
Shellfish aquaculture is mainly carried out in sheltered coastal areas that are affected by several anthropogenic stressors including eutrophication, pollution, biofouling, invasive species, expanding diseases, and harmful algal blooms. In particular, harmful algal blooms (HAB) have been known to cause fish and shellfish kills, contamination of fish but mainly shellfish with potent toxins that cause mild to severe poisonings in humans, and in many cases alteration of ecosystem function. In shellfish, notably in bivalve molluscs, in addition to mass mortalities, HAB are known to cause acute to chronic physiological and pathological alterations that lead to impediments to aquaculture farms via reduction of their fitness or following closure of production due to long-term contamination with toxins detrimental to human health. The frequency, magnitude, duration and in several cases the geographic distribution of HAB have been increasing putting shellfish aquaculture farms under further stress. Several factors have been attributed to such increase in HAB, including climate change, with recent reports of range expansion of some cosmopolitan HAB species across the North Atlantic and North Pacific

associated with warming ocean temperature and with projected range expansion of some other cosmopolitan HAB species across the North Western European Shelf-Baltic Sea system and North East and South East Asia associated with increased nutrient loads under projected climate change scenario A1B of the IPCC, IPSL-CM4. Warming water temperature driven by climate change is also expected to induce thermodynamic changes in physiological functions of shellfish with potential shifts in their thermal sensitivity and performance, as it is also expected to alter the responses of bivalves to HAB. In the present study, the effects of warming temperature and several HAB species of major concern to shellfish aquaculture farms both in Japan and around the world, on the economically-important bivalve species Manila clam (*Ruditapes philippinarum*), Mediterranean mussel (*Mytilus galloprovincialis*), Pacific oyster (*Crassostrea gigas*), Japanese pearl oyster (*Pinctada fucata martensii*), Japanese scallop (*Mizuhopecten yessoensis*) and noble scallop (*Mimachlamys nobilis*), are presented. The effects of warming temperature and the HAB species *Heterocapsa circularisquama* (shellfish-kills), *Alexandrium catenella* (paralytic shellfish poisoning, PSP) and A. affine (uncharacterized allelochemicals), *Chattonella marin*a, *Chattonella antiqua* and *Heterosigma akashiwo* (ichthyotoxic, fish- and shellfish-kills), *Karenia mikimotoi* and *K. papilionacea* (Fish- and shellfish-kills), and *Dinophysis acuminata* and *D. caudata* (diarrheic shellfish poisoning DSP, and other lipophilic toxins) have been examined. The results of several experimental sets on behavior, feeding, respiration, absorption efficiency, scope for growth, organ integrity, oxidative stress, and survivorship of adult bivalves are presented. In addition, the effects on gametes (oocytes and spermatozoa) and early-life developmental stages (fertilization, fertilized eggs, embryos, several larval stages) are also presented and discussed. The combined effects of HAB and ocean warming – and other climate driven stressors, notably ocean acidification – on these important cultured shellfish species will be discussed in light of the finding of the present study and other relevant studies reported in the literature.

Annotated Bibliography of Key Works

Glibert, P.M., Allen, J.I., Artioli, Y., Beusen, A., Bouwan, L., Harle, J., Holmes, R., Hotl, J., 2014. Vulnerability of coastal ecosystems to changes in harmful algal bloom distribution in response to climate change: projections based on model analysis. *Global Change Biol.* 20: 3845–3858.

Using a global modeling approach, the effects of nutrient loading and climate change on the projected distributions of two genera of harmful algae in coastal ecosystems of three regions of the globe were examined. Range expansions and retractions were found for the two genera suggesting future shifts in the vulnerability of coastal ecosystems to HAB events, increased regional HAB impacts on aquaculture leading to increase in the risks to human health and ecosystem services and associated economic consequences.

Basti, L., Endo, M., Segawa, S., Shumway, S.E., Tanaka, Y., Nagai, S., 2015. Prevalence and intensity of pathology induced by the toxic dinoflagellate, *Heterocapsa circularisquama*, in the Mediterranean mussel, *Mytilus galloprovincialis*. *Aquat. Toxicol.* 163: 37–50.

The study examines the effects of temperature on the pathologies induced by the shellfish-killing harmful alga, *Heterocapsa circularisquama*, in the Mediterranean mussel, *Mytilus galloprovincilias*. The study shows that increased temperature leads to increased prevalence and intensity of pathologies in the mussels in several vital organs, including gills and intestines. The study shows that warming temperature may increase the effects of the harmful alga on mussels even at low cell density, possibly reducing the overall health of the mussels. It also shows that the range expansion of the harmful alga associated with increased winter water temperature may put bivalve aquaculture farms under further risks of mass mortalities and production failure.

Filgueira, R., Guyondet, T., Comeau, L.A., Tremblay, R., 2016. Bivalve aquaculture-environment interactions in the context of climate change. *Global Change Biol.* 22: 3901–3913.
The study examines the interactions between bivalve aquaculture and the environment (bay geomorphic type, freshwater input), in the context of climate change (sea level rise, temperature, precipitation). Based on a factorial deign of 336 scenarios, the modeling showed that temperature is the strongest climate change driver to affect bivalve aquaculture as it can influence their metabolism. Differences in thermal tolerance of the cultured bivalve species would determine "winners" from "losers".

Gobler, J.C., Dohrty, O.M., Hattenrath-Lehmann, T.K., Griffith, A.W., Kang, Y., Litaker, R.W., 2017. Ocean warming since 1982 has expanded the niche of toxic algal blooms in the North Atlantic and North Pacific oceans. *P. Natl. Acad. Sci. USA* 114: 4975–4980.
The study models the trends in growth rates and duration of bloom seasons of two species of the most toxic and widespread harmful algal blooms in the North Atlantic and North Pacific oceans using high-resolution SST (sea surface temperature) over the past three decades. Increasing water temperature associated with climate change have expanded the niches of these toxic algae (*Dinophysis auminata* and *Alexandrium fundeyense*) and might contribute to an expansion of the associated human health threat via the consumption of shellfish contaminated with diarrheic shellfish poisoning (DSP) and paralytic shellfish poisoning (PSP).

11. *Ecosystem approach to marine aquaculture*

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Abstract
The increase in world population, along with increased demand for seafood as a source of human nutrition, and stagnant wild fisheries catches, will necessitate the growth and diversification of marine aquaculture globally. However, marine aquaculture development in many countries, including the United States, lags behind that of freshwater aquaculture. The United States, despite having the world's largest Exclusive Economic Zone (EEZ), imports about 90 percent of the seafood consumed domestically (by value). One solution to the seafood import deficit is to pursue the development of offshore aquaculture in the EEZ, or federal waters. Various laws and regulations give the National Oceanic and Atmospheric Administration (NOAA) oversight of fisheries in federal waters. NOAA's national Marine Fisheries Service (NOAA Fisheries) has long recognized the importance of implementing ecosystem-based aquaculture management in order to explicitly account for environmental changes and make trade-off decisions for actions that affect multiple species. If marine aquaculture is to grow in an environmentally and economically sustainable way, there need to be guidelines and a framework for this effort, just as there are for offshore capture fisheries. The concept of an ecosystem approach to aquaculture management embodies these principles. In order to provide a framework for offshore aquaculture in the United States, the NOAA Office of Aquaculture is developing an Ecosystem Approach to Aquaculture (EAA), which will serve as the first step in designing a more detailed, comprehensive plan for implementation of ecosystem-based management of offshore aquaculture. Similar to NOAA Fisheries' definition for ecosystem-based fisheries management, the NOAA Office of Aquaculture

defines EAA as: "*a systematic approach to aquaculture management in a geographically specified area that contributes to the resilience and sustainability of the ecosystem; recognizes the physical, biological, economic, and social interactions among the affected aquaculture-related components of the ecosystem, including humans; and seeks to optimize benefits among a diverse set of societal goals."* The purpose of the EAA is to enable the development of sustainable marine aquaculture within the context of the National Oceanic and Atmospheric Administration's (NOAA) multiple stewardship missions and broader social and economic goals. Meeting this objective will require NOAA to integrate environmental, social, and economic considerations in management decisions concerning aquaculture. The EAA will also serve to reaffirm that aquaculture is an important component of NOAA's efforts to maintain healthy and productive marine and coastal ecosystems. This includes protecting special marine areas, rebuilding overfished wild stocks, restoring populations of endangered species, and restoring and conserving marine and coastal habitats. Implementation of the EAA involves balancing competing uses of the marine environment, creating employment and business opportunities in coastal communities, and enabling the production of safe and sustainable seafood. This presentation will provide an overview of NOAA's Ecosystem Approach to Aquaculture, including a definition of EAA, rationale for development of the document, and some of the benefits of EAA.

Annotated Bibliography of Key Works

Soto, D., Aguilar-Manjarrez, J., Hishamunda, N. (eds). Building an ecosystem approach to aquaculture. FAO/Universitat de les Illes Balears Expert Workshop. 7–11 May 2007, Palma de Mallorca, Spain. FAO Fisheries and Aquaculture Proceedings. No. 14. Rome, FAO. 2008. 221 pp.

This FAO report summarizes findings from a workshop co-organized with the Universitat de les Illes Balears that took place from 7–11 May 2007 in Palma de Mallorca, Spain on "Building and ecosystem approach to aquaculture" (EAA). Participants defined the phrase "ecosystem approach to aquaculture" and several main principles that should guide the sustainable development of aquaculture. These included the development of aquaculture consistent with resilience of ecosystem functions; improving human wellbeing; and consideration of other relevant sectors (social, technical, economic, and political). They state that EAA should address the many needs and desires of societies without compromising ecological integrity. The workshop participants also agreed on various ecosystem approaches for different scales (e.g., small or "farm", regional or zone, and global) and that regulations should focus more on the recipient body of water (e.g., stream, estuary, large marine ecosystems) rather than the scale and intensity of production.

Aguilar-Manjarrez, J., Soto, D. and Brummett, R. 2017. Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Full document. Report ACS113536. Rome, FAO, and World Bank Group, Washington, DC. 395 pp.

The Food and Agricultural Organization of the United Nations and the World Bank Group convened an expert workshop on Site Selection and Carrying Capacities for Inland and Coastal Aquaculture in December 2010 in Northern Ireland. Spatial planning is becoming increasingly important in the growth of aquaculture and the issues involved require an ecosystem approach to management that addresses larger spatial units than just the individual farm or site. The main purpose of the workshop was development of a guide or handbook for aquaculture site selection and carrying capacity estimation within an ecosystem approach to aquaculture that can be used by a broad range of stakeholders. The publication provides useful and practical information and guidance for managers, policy-makers, technical staff, and aquaculturists about zoning, siting, and management based on experiences and examples

from ten case studies in countries around the world. They identify relevant processes and activities for various users on different spatial scales in a systematic fashion.

National Oceanic and Atmospheric Administration. 2016. Ecosystem-based fisheries management policy of the National Marine Fisheries Service. National Marine Fisheries Service Policy Directive 01-120. May 23, 2016. 8 pp.

Several national laws or mandates require the National Oceanic and Atmospheric Administration (NOAA) to manage the nation's living marine resources, including fisheries in a sustainable manner. In order to enable better decision-making among various groups and concerns, (e.g., commercial, recreational, and subsistence fisheries), aquaculture, protected species, biodiversity, and habitats, NOAA is implementing Ecosystem-Based Fisheries Management (EBFM). The policy directive issued in May 2016 is a framework for an ecosystem approach to fisheries, which defines EBFM; describes the benefits of EBFM; discusses how EBFM relates to existing legal authorities and requirements; and establishes a framework of guiding principles for implementing EBFM within NOAA Fisheries. It builds on the NOAA's past progress and commitment to integrating its management programs for living marine resources and considering interactions among fisheries, protected species, aquaculture, habitats, and other ecosystem components, including human communities in decision-making. The policy defines EBFM as "a systematic approach to fisheries management in a geographically specified area that contributes to the resilience and sustainability of the ecosystem; recognizes the physical, biological, economic, and social interactions among the affected fishery-related components of the ecosystem, including humans; and seeks to optimize benefits among a diverse set of societal goals." The EBFM policy document specifically mentions aquaculture as an ecosystem component, and NOAA includes aquaculture in the term "fisheries". Therefore, this document although mostly intended for commercial fisheries, forms the basis for the development of a separate Ecosystem Approach to Aquaculture (EAA) which recognizes the similarities, but also the distinct differences, between "capture" or "wild" fisheries and aquaculture. Although the EBFM directive focuses on "capture" or "wild" fisheries, the language and concepts in it are also directly applicable to aquaculture and, in most instances, the phrase "ecosystem approach to aquaculture", or EAA could easily be substituted for "ecosystem-based fishery management" (EBFM), and the word "aquaculture" substituted for "fisheries".

Since there are distinct and important differences between capture fisheries and aquaculture, the NOAA Office of Aquaculture is developing a separate Ecosystem Approach to Aquaculture (EAA). An EAA is the first step or level along a continuum toward a more complex and detailed plan for implementing ecosystem-based management of aquaculture.

National Oceanic and Atmospheric Administration. 2011. Marine Aquaculture Policy. NOAA Office of Aquaculture. Issued June 2011.

The NOAA Office of Aquaculture developed a Marine Aquaculture Policy in 2011 to enable the development of sustainable marine aquaculture within the context of NOAA's multiple stewardship missions and legal mandates. The document defines aquaculture as "the propagation and rearing of aquatic organisms for any commercial, recreational, or public purpose". It includes production for food, wild stock replenishment or restoration (for finfish as well as shellfish and other marine organisms), and rebuilding populations of threatened or endangered species. It contains specific goals with regard to aquaculture development and management, and provides the basis for the policy and some background information. The policy also describes the benefits and challenges of sustainable aquaculture in the U.S. and sets forth NOAA aquaculture priorities and actions for implementing the policy in terms of regulations, interactions with various agencies and groups in the U.S., and cooperation with other nations. One of the stated goals in the policy is ecosystem compatibility; that is to say,

aquaculture development in federal waters should be compatible with the functioning of healthy, productive, and resilient marine ecosystem. In keeping with this goal, aquaculture operators should be held accountable for protecting the species and environment in which they are working. Other goals include compatibility of aquaculture facilities with other authorized uses of marine waters and basing management decisions on the best available science and information.

12. *Spatial Planning for shellfish aquaculture and seagrasses in US west coast estuaries: considerations for adapting to an uncertain climate*

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Abstract
Shellfish aquaculture has been an important contributor to the local economy of several communities along the US West Coast for almost 100 years and in most of the estuaries where it occurs it has coexisted with the native seagrass (eelgrass, *Zostera marina*). Eelgrass provides numerous ecosystem services including nursery habitat for juvenile fish and invertebrates, but is declining in many locations worldwide, and is therefore now protected by no net loss provisions in US laws and regulations. We have studied the interaction between oyster aquaculture and eelgrass at both the local process scale and at the estuarine landscape scale in Willapa Bay, Washington. While there are important differences, most US West coast estuaries like Willapa Bay are small relative to the nearby coast, experience less riverine influence than estuaries where oysters are cultured on eastern edges of continents, and the majority of culture takes place in intertidal areas. The ecology of eelgrass and cultured Pacific oysters as well as their role as habitat is thus directly influenced by bathymetry and proximity to the coastal ocean. We summarize studies on the interaction between eelgrass and oyster culture at local scales, present data that suggest culture practices are important to consider, but the cumulative interaction is not necessarily negative for eelgrass at the estuarine landscape scale in Willapa Bay. We also summarize studies on the influence of sea level rise (SLR) and sea water chemistry (ocean acidification, OA), two projected changes in climate that are expected to occur over a broader spatial and longer temporal scale. SLR is projected to enhance the presence and interaction of eelgrass with oyster aquaculture in Willapa Bay, though this effect was mostly driven by bathymetry in our simplistic model and landward eelgrass expansion could be restricted elsewhere. OA has already influenced oyster culture especially in commercial hatcheries where it changes aragonite saturation state and the ability of larval oysters to deposit shell. Evidence for direct effects of carbonate chemistry in estuaries like Willapa Bay is more equivocal due to complex interactions, yet still related to the proximity of the ocean and cold upwelled water which also influences natural spawning on this coast. The presence of eelgrass may also buffer water chemistry at least over short time scales, but is less likely to affect juvenile oysters and may impact oyster growth by reducing water flow. These physical effects of structure also influence conspecific eelgrass plants and appear to be more important than water chemistry feedbacks. Recent initiatives to expand shellfish aquaculture in US west coast estuaries have received increased regulatory scrutiny due in large part to this interaction with eelgrass. Our data and review suggests that in addition to a permit process that

simply evaluates and prevents direct negative effects of oyster culture on eelgrass at small spatial and immediate temporal scales, managers should consider a broader adaptive approach that considers bathymetric and along estuary gradients that affect both of these resources and the services they provide, especially given the uncertainty of future climate.

Annotated Bibliography of Key Works

Barton, A., G.G. Waldbusser, R.A. Feely, S.B. Weisberg, J.A. Newton, B. Hales, S. Cudd, B. Eudeline, C.J. Langdon, I. Jefferds, T. King, A. Suhrbier, and K. McLaughlin. 2015. Impacts of coastal acidification on the Pacific northwest shellfish industry and adaptation strategies implemented in response. *Oceanography* 28: 146-159.

This is the most recent review of the history and science underpinning the effects of changing seawater chemistry on bivalve shellfish larvae and the impacts that have already taken place to the commercial shellfish aquaculture industry on the US West Coast. Multiple authors contributed to this review which addresses a broad audience but covers the leading research on direct effects to bivalve larvae as well as monitoring seawater conditions and adapting to these changes.

Dumbauld, B.R., and L.M. McCoy. 2015. The effect of oyster aquaculture on seagrass (*Zostera marina*) at the estuarine landscape scale in Willapa Bay, Washington (USA). *Aquaculture Environment Interactions*, 7: 29-47.

The authors groundtruthed and analyzed aerial photographs taken in three separate years to build spatial layers for seagrass cover in Willapa Bay, Washington, USA. They created spatial layers for shellfish aquaculture and several other factors such as distance to the estuary mouth and intertidal bathymetry that could influence eelgrass and then built a model to evaluate eelgrass cover in areas outside of shellfish aquaculture beds. This model was used to predict expected values within aquaculture beds and compare this with actual values to estimate the effect of aquaculture. The approach is unique in that it examined effects at the estuary scale and over several years and the authors have submitted a second manuscript that uses a similar approach to assess sea level rise.

Dumbauld, B.R., J.L. Ruesink, and S.S. Rumrill. 2009. The ecological role of bivalve shellfish aquaculture in the estuarine environment: A review with application to oyster and clam culture in West Coast (USA) estuaries. *Aquaculture,* 290: 196-223.

The authors review the role of shellfish aquaculture in US West Coast estuaries. While subsequent studies have clarified this role and the interaction between shellfish culture and other estuarine habitats like seagrass, general conclusions remain the same and suggest that most forms of shellfish culture as currently practiced have only short-term impacts in West coast US estuaries and habitats like eelgrass are generally resilient to these changes.

Hales, B., A. Suhrbier, G.G. Waldbusser, R.A. Feely, and J.A. Newton. 2017. The carbonate chemistry of the "fattening line," Willapa Bay, 2011-2014. *Estuaries and Coasts*, 40: 173-186.

The authors present detailed data on seawater chemistry (especially PCO_2 and aragonite saturation state) for Willapa Bay, Washington where Pacific oysters have been the mainstay of the oyster aquaculture industry for almost 100 years and there is a long term record of spawning and setting. They reconstruct this record for a longer historical period and their data suggest that recent conditions provide a smaller window of optimal conditions (low aragonite saturation state and warm enough temperatures for oyster spawning) than occurred historically. While they did not sample larvae (see Ruesink et al 2017 below) and therefore can't confirm effects, they substantiate the complexity of measuring these effects and attributing them to a single cause in a variable estuary.

Ruesink, J.L., A. Sarich, and A.C. Trimble. 2017 Similar oyster reproduction across estuarine regions differing in carbonate chemistry. *ICES Journal of Marine Science,* (DOI10.93/icesjms/fsx150).
These authors measured seawater chemistry in Willapa Bay, Washington, but unlike Hales et al (2017), they also present simultaneously collected data on four cohorts of Pacific oyster larvae that were collected over three summers. The southern end of Willapa Bay has two arms which create distinctly different characteristics because one is much more affected by riverine conditions that cause reduced aragonite saturation relative to the other. Oyster settlement differed greatly between cohorts, but they did not find differences they could attribute to this different water chemistry and instead found thermal conditions were perhaps more important.

Ruesink, J.L., S. Yang, and A.C. Trimble. 2015. Variability in carbon availability and eelgrass (*Zostera marina*) biometrics along an estuarine gradient in Willapa Bay, WA, USA. *Estuaries and Coasts*, 38: 1908-1917.
These authors collected data on eelgrass (*Z. marina*) and seawater chemistry along an estuarine gradient in Willapa Bay, Washington. They demonstrated that while eelgrass responded to carbonate chemistry (increased tissue carbon up estuary where PCO_2 increased due to freshwater input), eelgrass production was unchanged and instead responded more to a gradient with more organic rich sediments at this end.

13. *Offshore mussel aquaculture: strategies for farming in the changing environment of the U.S. EEZ in the Northeast U.S. Shelf*

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Abstract
The United States recently has become the largest importer of seafood in the world, overcoming the past leader Japan, because of the nation's limited domestic production. To satisfy the increasing national demand for fisheries products, domestic aquaculture is to be expanded. Challenges to U.S. aquaculture expansion, especially in the NE, include water warming and salinity change trends [1], as well as other possible climate associated changes, namely declining primary production, altered time of spawning, harmful algal blooms, and species physiological responses to these ecosystem changes [2]. As mariculture progresses offshore to the U.S. Exclusive Economic Zone (EEZ), new issues need to be overcome, such as the choice of appropriate practices for the high-energy environment and suitable species that favor production and minimize undesired environmental consequences. The blue mussel, *Mytilus edulis*, is a promising candidate for offshore aquaculture because it requires no feeds, assimilating in situ primary production and promoting nutrient bioextraction. Offshore mussel farming, however, has many constraints including the selection of ecologically favorable sites and seed availability and quality. To determine suitable sites and depth submersion of mussel ropes in the water column for submersed long-line mussel farming, NOAA's open source climatologies and remote sensing data of temperature and chlorophyll *a* from 2005 to 2012 were used to construct a "habitat suitability" analysis of southern New England EEZ areas. Special importance was given to temperature, which affects mussel feeding, triggers

reproduction, and indirectly affects byssus effectiveness to adhere to farming ropes [3]. Considering ecological factors at present and anticipating temperature increases, our results suggest mussel ropes be submerged during summer at a minimum of 15 m depth in northern and 20 m depth in southern areas of New England, where temperature is between 10-14°C and phytoplankton biomass abundant. Promising areas are where the thermocline is shallow such as offshore Long Island, Cape Ann, and offshore New Hampshire, although mussels can be placed deeper in water column in other locations during warmer months. Suitability of selected sites will be validated by assessing water quality and the performance of mussels in situ with a well-developed flow-through device [4]. The biodeposition measurements also will allow estimation of feeding patterns and feces and pseudofeces production that may have potential local effects. A future step is to estimate the availability (sufficient quantity), quality (mortality, free of diseases), and timing of spat offshore, as nearshore larvae are dispersed offshore by currents. These larvae have no chance to encounter a place to settle and currently can be considered "lost at sea", i.e., unable to contribute to natural recruitment of mussels. Mussel spat collectors will be deployed at trial farms at pre-defined seasons. Larval collection offshore will satisfy legal requirements of "locally collected" seeds using larvae that would otherwise be lost. The present project should ideally be conducted frequently to check for future ecological variations. Based upon comparisons of historical and modern data, this research will contribute to advancing American offshore shellfish aquaculture in the face of changing local oceanographic characteristics and aquaculture industry needs.

Annotated Bibliography of Key Works

[1] Fratantoni, P., T. Holzwarth-Davis, M.T. Taylor, 2017. Description of oceanographic conditions in the Northeast US continental shelf during 2015. Northeast Fisheries Science Center Reference Document 17-08.

The authors report on the hydrographic observations over different areas of the Atlantic Northeast Shelf: western Gulf of Maine, Georges Bank, and Middle Atlantic Bight. Not only averaged data but also anomalies were calculated, thus accounting for the variability that is not related to seasonality. Waters where found to be more saline and 0.4 – 1.7°C warmer in the samplings of the year 2015, with the highest anomalies in the Middle Atlantic Bight during spring and summer. This work summarizes the findings of the 2015 samplings and gives a general overview of oceanographic trends in the area.

[2] E.H. Allison, M.C. Badjeck, K. Meinhold. 2011. The implications of global climate change for molluscan aquaculture. In: Shumway, S.E. (Ed.) *Shellfish Aquaculture and the Environment*. Pp 461-490.

The authors of this paper instead of developing models predicting possible climate changes, discuss the impacts of the climate to shellfish aquaculture and market based on an extensive review of different relevant chemical and physical elements affecting the oceans. Authors also suggest mitigation and management plans that can be applied for the sustainability of the shellfish farming.

[3] Lachance, A.A., B. Myrand, R. Tremblay, V. Koutitonsky, E. Carrignton. 2008. Biotic and abiotic factors influencing attachment strength of blue mussels *Mytilus edulis* in suspended culture. *Aquatic Biology*, 2: 119-129.

In this paper, the authors describe a decrease in tenacity of mussel byssus during summer spawning season and a negative relationship between high water temperatures and byssus attachment strength, which affects the ability of mussels to support themselves on farming ropes. The results of this study have strong implications for the suspended mussel culture because with the warming water trends it is likely that mussels will begin to suffer more to support attachment compared to those in the past.

[4] Galimany, E., J.M. Rose, M.S. Dixon, G.W. Wikfors. 2013. Quantifying feeding behavior of ribbed mussels (*Geukensia demissa*) in two urban sites (Long Island Sound, USA) with different seston characteristics. *Estuaries and Coasts*, 36: 1265-1273.
The authors used for the first time in the USA an in situ flow-through equipment that allows for quantification of all the important filtration and feeding parameters of a bivalve and found out that ribbed and blue mussels have a strong plasticity, adapting their feeding strategies (filtration rate, gut transit rate, feces and pseudofeces production) according to the characteristics of the environment, such as organic and inorganic particulate concentrations. Those results can be used for calculation of contribution of bivalves as potential cleaners of autotrophic environments through bioextraction.

14. *Nutrient environment in Gokasho Bay, effects of fish aquaculture on inorganic nutrient levels*

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Abstract
With the global expansion of aquaculture production, eutrophication derived from aquaculture effluent and consequent environmental deterioration are becoming increasingly problematic in many parts of the world. On the other hand, eutrophication has been reduced in coastal waters of Japan as a result of mitigation efforts over the past thirty years. While such efforts have positive effects on maintaining environmental integrity, excessive reduction of nutrient load to the coastal environment is thought to have reduced the productivity of many fishery resources and unfed aquaculture in Japan. Our hypothesis is that putting aquaculture effluent into practical use enhances the production of coastal fishery and unfed aquaculture. This presentation is a partial report of the long-term periodical monitoring of water quality in Gokasho Bay, Mie, Japan. To acquire basic information on the influential extent of aquaculture effluent on carrying capacity of coastal waters, environmental surveys have been conducted to investigate the behaviour of nutrients and primary production covering the whole bay area and also more intensively around the red seabream, *Pagrus major*, aquaculture cages. Seawater samples have been collected monthly at 3 depths (surface, mid-layer and bottom) at 19 points in the bay, and seasonally at surface and depth of 5 m (i.e. midpoint of the cage depth) at 47 points approximately 20 m apart from one another around the red seabream aquaculture cages since November 2016. The concentration of the following nutrients has been analyzed: dissolved inorganic nitrogen (DIN: NH_4^+-N, NO_2^--N, NO_3^--N), PO_4^{3-} and SiO_2 with an auto-analyzer (TRAACS 800, Bran+Luebbe). A CTD (RINKO profiler, JFE Advantech) has been used to obtain the vertical profile of temperature, salinity, dissolved oxygen (DO), and chlorophyll *a* at depths of every 10 cm from the surface to the bottom. Although the DIN-N and DO levels in December 2016 were comparable to those from the same month in 1980s where aquaculture was more prosperous, the PO_4-P level was an order of magnitude lower probably due to diminished aquaculture production and improved feeding management including the switch from raw bait to formulated feed. During a diatom bloom observed in

November 2016, the depletion of SiO_2 implied that the availability of Si, but not N or P, seemed to be the limiting factor for the diatom growth in Gokasho Bay. There were spots with a higher NH_4-N level at the center and 20 m outside the red seabream cage area in January 2017. The chlorophyll *a* level was higher and NO_3-N was lower around the cages than in the surrounding water. The observed lower NO_3-N concentration may indicate that the enhanced primary production triggered by the NH_4-N supply from the aquaculture effluent rapidly consumed not only NH_4-N but the background NO_3-N in the area. If this is true, DIN-N excreted from red seabream may not travel far from the cages to fertilize seaweed aquaculture, and the seaweed should be cultured in the vicinity of the cages. The elevation of chlorophyll *a* indicates the possibility of productive co-culture of red seabream and bivalves.

Annotated Bibliography of Key Works

Yamamoto, T. 1992. Constant uptake of ammonium-N and nitrate-N by *Porphyra yezoensis* thalli. *J. Fac. Appl. Bio. Sci. Hiroshima Univ.* 31: 155–159.
The author experimentally determined the uptake rates of ammonium-N and nitrate-N by *Porphyra* (currently *Pyropia*) *yezoensis* using ^{15}N as a tracer. *Pyropia yezoensis* (laver or *nori*) is an important seaweed in Japan. Specific uptake rate of ammonium-N (0.0017/hr) was more than 8 times higher than that of nitrate-N (0.0002/hr). The uptake rates were constant over the 120-minute experiment, unlike in the case of phytoplankton that is known to rapidly absorb nutrients to satiation. Fertilizers with ammonium-N as the main component may be suitable for *nori* aquaculture. The nitrogenous fertilizer should be provided to *nori* at a low concentration over a long duration to avoid induction of phytoplankton bloom.

Kakehi, S., Fujiwara, T and Yamada, H. 2005. Seasonal variation in the nutrient standing mass and nutrient budget of Ise Bay. *Umino Kenkyu* (*Oceanography in Japan*) 14: 527-540.
The authors estimated the standing mass of dissolved inorganic nitrogen (DIN) and dissolved organic phosphorus (DIP) by the linear regression of apparent oxygen utilization (AOU) or the interpolation of the surface and bottom nutrient concentrations to elucidate the seasonal variations in Ise Bay, Japan. The DIN standing mass in the bottom layer ranged from 1500 to 2600 t, tending to be higher in summer than in winter. The DIN was smaller in the surface layer than in bottom layer in summer, and comparable between the two layers in winter. The DIP standing mass showed more distinct seasonal trend. It was 200 t in surface and bottom layer in winter; whereas it increased to 400 t in the surface and 800 t in the bottom later in summer. The temporal change of the standing mass of the nutrients was more dependent upon biological and chemical processes than physical processes such as seawater exchange. Chlorophyll level is inversely related with DIN and DIP in the surface layer in summer, but DIN and DIP are not completely synchronous. The DIP seemed to be released from the sea sediment in summer where hypoxic water is formed in the bottom layer. Denitrification seemed to take place year-roun

15. *Challenges and opportunities of IMTA in Hawaii and beyond*

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Abstract

Available consumable seafood for 7.3 billion population in 2014 was 20 kg per capita (FAO 2016). To maintain the same level of seafood supply for expected 9.7 billion population in 2050, the total world seafood supply requires additional 48 million metric tonnes. With the

stagnant yield from capture fisheries, the increase has to come from aquaculture. Although the annual growth of aquaculture production has slowed down, theoretically aquaculture production will reach the targeted production level. However, current intensive mono-aquaculture practices have faced the challenges of sustainability and must change its operation to meet the criteria of sustainable development defined and adopted by UN's 193 Member in 2015. UN members adopted the 2030 Agenda for Sustainable Development and call for an integrated approach that addresses all three dimensions of sustainable development (economic, social and environmental). Current aquaculture practices consume nature resources and compete with each other. Ecosystem based aquaculture management is essential to co-exist with other social activities and to efficiently utilize natural resources for food production and conservation of nature stocks. Integrated multi-trophic aquaculture (IMTA), an old concept with new knowledge, appears to be the answer to sustainable development in aquaculture. IMTA practice combines the cultivation of fed aquaculture species, and extractive aquaculture species (both organic and inorganic ones) to reduce wastes and to create balanced eco-systems. Additionally, IMTA can play important roles in disease control and management, climate change mitigation, and others. As a result, IMTA has received more and more attentions at the turn of the century. However, the feasibility of IMTA comparing to mono-culture has yet to be documented. This presentation discusses the sustainability of IMTA by reviewing the practice of IMTA concept in traditional Hawaii aquaculture back to 1000 A.D. to current practices in the U.S. and beyond; updates US-Korea bilateral IMTA project; and challenges of IMTA.

Annotated Bibliography of Key Works

Sato, V. T. and C.-S. Lee. 2007. *Keeper of Molii Pond*. Oceanic Institute. 148 pp.
An oral history of a man, George Uyemura who spent 70 years of his life at Molii Pond was documented at this book to share his knowledge and experience in managing the fish pond. This book offers a look at the history and methodology of sustainable management of Hawaiian fishponds. It is a start reference book to know more about Hawaiian fishpond.

Soto, Doris (ed.) 2009. Integrated mariculture- A global review. FAO Fisheries and Aquaculture Technical Paper 529. 184 pp.
This report contains three desk studies encompassing global views of practices and future prospects for integrated aquaculture in coastal and marine areas in three climatic zones: temperate, tropical and Mediterranean Sea as a special Mediterranean enclosed ecosystem. The commissioned review papers describing integrated aquaculture in coastal and marine environments were technically supervised by Mrs. Doris Soto, Senior Fisheries Officer (FIMA). The activity and the publication have been partly funded through a Japanese Trust Fund Project (Towards Sustainable Aquaculture: Selected Issues and Guidelines). It is a good reference report to get start to know about integrated mariculture.

Thomas, Susan A. (ed.) 2011. Integrated Multi-Trophic aquaculture: A Workshop" at Peninsula College Port Angeles, Washington. *Bull. Aquacul. Assoc. Canada* 109-2, 13 pp. https://www.researchgate.net/publication/257819653
This report summarized the first US-based workshop on integrated multi-trophic aquaculture (IMTA). The two days' workshop included presentation and breakout sessions to conduct "strengths-weaknesses-opportunities-threats" (SWOT) analysis for ecological, economic, and social impacts of IMTA. It concluded IMTA could help to move the US toward becoming a major aquaculture producer in the world, because it might resolve some of the issues that seem to be limiting such progress. This is a good reference base for any further SWOT analysis.

Bellona 2013. Traditional and Integrated Aquaculture. Bellona report 2013, 114 pp. www.bellona.org
Bellona has been involved in the hunt for new solutions, new resources and new products that will be important for the future. This report points out that salmonid industry has high ambitions for growth, but it must happen in harmony with the ecosystem. It explains why aquaculture should progress from salmonid monoculture to integrated and sustainable ecosystems and how. Also, this progress depends on the aquaculture industry, research institutions and politicians working together. It is a good lesson for other aquaculture industry to learn from a mature salmonid industry to think ahead.

Gunning, D., J. Maguire and G. Burnell. 2016. The development of sustainable saltwater-based food production systems: a review of established and novel concepts. Water, vol. 8, 598. 37pp.
This review article examines the potential negative impacts of saltwater mono-aquaculture operations and how the novel approach such as IMTA, constructed wetlands and saltwater aquaponics will mitigate the negative impacts.

Poster Presentations

Possible effects of terrestrial managements on seagrass ecosystem functionings

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Abstract
Seagrass species function as typical foundation species which support high productivity and diversity because of their high rates of primary production and their ability to provide associated organisms with trophic support, refuge from predation, and spawning substrates. Seagrass associated species, especially herbivorous invertebrates, can regulate the ecosystem functioning of seagrass beds, suggesting that this interaction is an important key to clarify the relationship between biodiversity and ecosystem functioning in coastal ecosystems. Seagrass communities are characterized by wide occurrence in shallow nearshore areas, where there is a boundary between terrestrial and marine ecosystems. Therefore, seagrass communities are often influenced by various factors derived from terrestrial habitats, such as agrichemicals and nutrients through fresh water input. Although terrestrial nutrients are essential for productivity for nearshore marine plants including seagrass species, increased nutrients cause eutrophication and phytoplankton blooming resulting in the degradation of seagrass growth and distribution. Agrichemicals from river, adjacent agriculture fields and forests also have serious effects on seagrass communities; in particular insecticide has caused mass mortality of the seagrass-associated invertebrates, resulting in vulnerable ecosystem functioning of seagrass beds. The inflow of both agrichemical and nutrients into nearshore areas has increased with the change of the adjacent terrestrial management. In this study, we demonstrated interactive effect of insecticide with eutrophication on ecosystem functioning of seagrass beds using manipulative experiments in Seto Inland Sea, Japan. In the manipulation, we used the insecticide carbaryl to exclude invertebrate herbivores and the fertilizer to add nutrients, which

is a technique developed by the Zostera Experimental Network (ZEN), a global collaborative network of scientists studying the structure and functioning of ecosystems supported by eelgrass. The technique enables us especially to demonstrate the indirect effect of epiphyte grazing by the associated invertebrates on eelgrass growth (e.g., Whalen et al. 2013). The carbaryl loading significantly decreased the density and diversity of herbivorous invertebrates and indirectly increased epiphyte biomass, resulting in a significant difference in seagrass growth, although carbaryl concentrations were within the safety standards even at the experiment site. However, the nutrient addition significantly changed the indirect effect of carbaryl loading on seagrass growth. These results suggest that seagrass-associated herbivores can regulate ecosystem functioning of seagrass beds, and indicate the possibility that both agrichemical and nutrient loading can easily change the seagrass ecosystem functionings even in lower concentration. Both agrichemical and nutrient loading from terrestrial habitat to nearshore areas would be easy to change and vary spatially with land use change, so that we should pay attention to the management for the adjacent terrestrial habitats.

Annotated Bibliography of Key Works

Duffy, J., P. Reynolds, C. Boström, J. Coyer, M. Cusson, S. Donadi, and S. Fredriksen. 2015. Biodiversity mediates top–down control in eelgrass ecosystems: a global comparative-experimental approach. *Ecology letters*, 18(7): 696-705.

This paper investigates top-down and bottom-up effects of adding nutrient and deterrents to eelgrass (*Zostera marina*) beds at 15 sites across the range of this species. They found that removing grazers had a stronger average effect on epiphytic biomass than local addition of nutrients, revealing stronger top-down control by grazers. Also, they found that the influences of biodiversity in their global analysis are very similar to results from other small-scale experiments. These include sites with more genotypically diverse eelgrass with higher crustacean biomass and lower algal biomass at sites with increased grazer species.

Reynolds, P., J. Stachowicz, K. Hovel, C. Boström, K. Boyer, M. Cusson, and J. Duffy. 2017. Biogeography of predation pressure in eelgrass across the Northern Hemisphere. Unpublished manuscript. Virginia Institute of Marine Science, Virginia USA.

Studies across broad geographic ranges exploring drivers of change in predator interactions are relatively rare. The authors surveyed predation on a common amphipod prey in eelgrass (*Zostera marina*) beds at 42 sites across the Northern Hemisphere. At all coasts, predation declined with latitude, but declined more in areas where temperature gradients are steeper.

Whalen, M., J. Duffy, and J. Grace. 2013. Temporal shifts in top-down vs. bottom-up control of epiphytic algae in a seagrass ecosystem. *Ecology* 94: 510-520.

The authors used a cage-free approach of manipulating mesograzer abundance and epiphytic loading over a temporal period, by using deterrent and nutrient treatments. They found that reduction of mesograzer abundance and increase in nutrients can allow increased epiphytic algae growth on eelgrass (*Zostera marina*). By performing the experiment in the fall and summer, they found that the dominant factors that controlled epiphytic algae abundance changed. In fall, there was a natural decrease in mesograzer abundance, and by adding nutrients, which caused bottom-up factors to dominate, increased epiphyte biomass. In summer, added deterrents, stimulating strong top-down factors, decreased mesograzer abundance and caused an increase in epiphyte biomass. Also, unexpectedly, they found that drift macroalgae indirectly reduced epiphytes by proving structure for mesograzers.

Genetic effects of the tiger puffer stock enhancement program on wild population in the sea around Japan

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Abstract
Since 1977, millions of hatchery-reared tiger puffer, *Takifugu rubripes*, juveniles have been released for stock enhancement in the sea around Japan. The stock enhancement program has contributed to catches, however, no information about genetic effects of the program on wild population is available. The genetic effects were evaluated with highly polymorphic DNA marker sets (1962 bp mitochondrial DNA sequences and 11 microsatellite DNA loci) using 316 mature wild adults from nine identified or possible spawning sites in the sea around Japan, 276 wild juveniles in the Ariake Sea which is a possible spawning site and an identified nursery, 85 hatchery-reared juveniles, 150 mature hatchery-released adults in the Ariake Sea. Both types of markers indicated that hatchery-reared and hatchery-released populations had lower genetic variability than wild populations, however, hatchery-released population had closer genetic variability to wild populations. Microsatellite F_{ST} estimates indicated hatchery-reared and hatchery-released populations were significantly different from wild populations. On the other hand, significant differences were observed only between hatchery-reared population and wild populations with mitochondrial Φ_{ST} estimates. Microsatellite F_{ST} estimates and Bayesian clustering analysis revealed population structure of the tiger puffer, however, the population structure was not associated with the history and scale of stock enhancement program. The genetic variability was almost equivalent among wild populations, no significant deviation from Hardy-Weinberg equilibrium and significant linkage disequilibrium were detected from wild populations. Moreover, putative wild juveniles having a high possibility of being related to mature hatchery-released adults were detected based on relatedness among individuals in the Ariake Sea. These results suggested that there is a high possibility that hatchery-released fish breed in the wild, however, negative genetic effects of the stock enhancement program on wild populations were not likely in the tiger puffer. As one of the factors, it is considered that mature hatchery-released population is composed of multiple groups and year classes and have close genetic characteristics to wild populations.

Annotated Bibliography of Key Works

Araki H., B. Cooper, MS. Blouin. 2007. Genetic effects of captive breeding cause a rapid, cumulative fitness decline in the wild. *Science*, 318: 100-103.
Captive breeding is used to supplement populations of many species that are declining in the wild. The suitability of and long-term species survival from such programs remain largely untested, however. We measured lifetime reproductive success of the first two generations of steelhead trout that were reared in captivity and bred in the wild after they were released. By reconstructing a three-generation pedigree with microsatellite markers, we show that genetic effects of domestication reduce subsequent reproductive capabilities by ~40% per captive-reared generation when fish are moved to natural environments. These results suggest that even a few generations of domestication may have negative effects on natural reproduction in the wild and that the repeated use of captive-reared parents to supplement wild populations should be carefully reconsidered.

Hamasaki K., S. Toriya, H. Shishidou, T. Sugaya, S. Kitada. 2010. Genetic effects of hatchery fish on wild populations in red sea bream *Pagrus major* (Perciformes, Sparidae) inferred from a partial sequence of mitochondrial DNA. *Journal of fish biology*, 99: 2123-2136.

Variation in the mitochondrial DNA transcriptional control region sequence was investigated in wild and hatchery-released red sea bream Pagrus major from Kagoshima Bay, where an extensive hatchery-release programme has been conducted for >30 years. The programme has successfully augmented commercial catches in the bay (released juveniles have been produced from the captive broodstock, repeatedly used over multiple generations). Samples were also obtained from outside the bay, where limited stocking has occurred. Genetic diversity indices measured as number of haplotypes, haplotype richness, haplotype diversity and nucleotide diversity were lower in hatchery-released fish than in wild fish. Genetic differences in wild fish from the bay, especially in the inner bay, compared with fish from outside the bay were detected in terms of decreased genetic diversity indices and changed haplotype frequencies. Unbiased population pair-wise F_{ST} estimates based on an empirical Bayesian method, however, revealed low genetic differentiation between samples from the bay and its vicinity. Mixed stock identification analyses estimated the proportion of hatchery-released fish in wild populations in the inner and central bays at 39·0 and 8·7%, respectively, although the precision of the estimates was very low because of the small genetic differentiation between populations and relatively small sample sizes. Hence, the long-term extensive hatchery release programme has affected the genetic diversity of wild populations in the bay; however, the genetic effects were low and appeared to remain within the bay.

Blanco Gonzalez E., M. Aritaki, S. Sakurai, N. Taniguchi. 2013. Inference of potential genetic risks associated with large-scale releases of red sea bream in Kanagawa prefecture, Japan based on nuclear and mitochondrial DNA analysis. *Marine biotechnology*, 15: 206-220.

Since 1978, millions of hatchery-reared red sea bream (*Pagrus major*) juveniles have been released in Sagami Bay and Tokyo Bay in Kanagawa Prefecture, Japan. The stock enhancement program has contributed to total catch; however, no information regarding the genetic interactions with wild counterparts is available. Here, we combined 15 microsatellite loci and mitochondrial D-loop sequencing to characterize the genetic resources of red sea bream in Sagami Bay and Tokyo Bay and to elucidate the potential harmful genetic effects associated with fish releases. Both types of markers evidenced higher levels of genetic diversity in wild samples (SB and TB) compared with offspring before stocking (H07 and H08) as well as a hatchery-released sample recaptured in Sagami Bay (HR). Microsatellite F_{ST} estimates and Bayesian clustering analysis found significant genetic differences among samples (F_{ST} = 0.013-0.054), except for the two wild samples (F_{ST} = 0.002) and HR vs. H07 (F_{ST} = 0.007). On the other hand, mitochondrial-based Φ_{ST} suggested haplotypic similarity between SB, H07, and HR. The low effective number of females contributing to the offspring over multiple generations may be responsible for the lack of haplotypic differentiation. Moreover, the putative hatchery origin to three fish (8 %) without deformity in the inter-nostril epidermis was inferred for the first time. Our results showed the usefulness of combining nuclear and mitochondrial markers to elucidate genetic interactions between hatchery-released and wild red sea bream and warned about potential harmful genetic effects should interbreeding takes place.

Nakajima K., S. Kitada, Y. Habara, S. Sano, E. Yokoyama, T. Sugaya, A. Iwamoto, H. Kishino, K. Hamasaki. 2014. Genetic effects of marine stock enhancement: a case study based on the highly piscivorous Japanese Spanish mackerel. *Canadian Journal of Fisheries and Aquatic Science*, 71: 301-314.

We used a before–after control–impact design to quantify the genetic effects of the large piscivorous Japanese Spanish mackerel (*Scomberomorus niphonius*) stock enhancement program on wild populations in the Seto Inland Sea. Samples of 1424 wild and 230 hatchery fish collected from 13 sites around Japan were genotyped using five microsatellite markers.

A total of 758 wild and 103 hatchery fish were sequenced for the mitochondrial DNA D-loop region. The population structure of Japanese Spanish mackerel was panmictic around Japan. Hatchery fish had significantly lower genetic diversity indices than did wild fish. However, there was no significant change in any of the diversity indices in the Seto Inland Sea, despite the substantial genetic mixing proportion of hatchery-origin genes (7.8%–14.5% from releases in 2001 and 2002), a conclusion supported by simulations. The estimated effective population size was surprisingly small (~430–970) but stable in the Seto Inland Sea compared with the large census size. A Ryman–Laikre effect was not likely in the Japanese Spanish mackerel.

Assessment of the ichthyotoxicity of harmful marine microalgae Karenia *spp. using cultured gill cells from red sea bream* (Pagrus major)

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Abstract
The present study reports the development of a method to investigate ichthyotoxicity of harmful marine microalgae using cultured red sea bream (*Pagrus major*) gill cells. The cultured gill cells formed adherent 1–2 layers on the bottom of the culture plate, and could tolerate seawater exposure for 4 h without significant alteration in cell survival. The microalgae *Karenia mikimotoi*, *Karenia*. *papilionacea*, *K*. *papilionacea* phylotype-I, *Karenia* digitate and *Heterosigma akashiwo* were cultured, then directly exposed to gill cells. Live gill cell coverage after *K. mikimotoi, K. papilionacea* phylotype-I, and *K. digitate* exposure were significantly lower than in the cells exposed to a seawater-based medium SWM-3 and IMK (control cells; $P < 0.05$). Toxicity of *K. mikimotoi* cells was weakened when the cells were ruptured, and was almost inexistent when the algal cells were removed from the culture by filtration. Significant cytotoxicity was detected in the concentrated ruptured cells, although cytotoxicity was weakened in the concentrated of ruptured cells after freezing and thawing; whereas, cytotoxicity almost disappeared after heat treatment. In addition, examination of the distribution of toxic substances from the ruptured cells showed that cytotoxicity mainly occurred in the fraction with the resuspended pellet after centrifugation at 3000 × g.

Asari clam predation by intertidal fishes: feeding habits of immature black porgy, Acanthopagrus schlegelii in Yamaguchi Bay, western Seto Inland Sea, Japan

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Abstract
Black porgy, *Acanthopagrus schlegelii* (Family: Sparidae), is a commercially important fish in Japan. In 2015, commercial catches of the porgy in Japan and the Seto Inland Sea of western Japan were 3,181 metric tons and 1,508 metric tons, respectively. This species is known as a major predator of Asari clam, *Ruditapes philippinarum* in tidal flats. On the other hand, Asari clam is a commercially important species, too. Recently, the clam catches have decreased in Japan. Especially in the Seto Inland Sea, the catches have remarkably dropped to 137 metric tons in 2015 from 45,023 metric tons in 1985 (peak level). Several reports concerning protecting clam beds with netting suggest that predation is one of the most important factors for the survival of the clam. In order to restore Asari clam resource, it is necessary to clarify the habits of the porgy. In this study, we investigated the seasonal occurrence and feeding habits of immature-sized porgy (less than about 25 cm total length) in tidal flats from 2005 to 2017 in Yamaguchi Bay, western Seto Inland Sea. 102 individuals of the porgy (10.4-27.7 cm TL) were collected by rod-and-line fishing there. The monthly catch per unit effort (CPUE: number of fish caught/3 hours/person) of the porgy ranged 0-2.9. The CPUE rapidly increased in June. In July, it reached 2.9, the highest annual value, after which the CPUE maintained high values from August to November. From December values were low (0-0.4) again. These results indicate that immature *A. schlegelii* occurs seasonally in the tidal flats from June to November. Bases on the stomach contents of the porgy, bivalves such as Asian mussel, *Arcuatula senhousia*, Japanese razor clam, *Solen strictus* were the most important prey items in wet weight. Next, Japanese mud shrimp, *Upogebia major* was the second important one. These benthic animals were in common and are filter feeders on phytoplankton, benthic microalgae, and detritus. Immature-sized porgy preyed on juvenile Asari clams ranging from 2.8 to 18.0 mm shell length. The values of stable isotopes of $\delta^{13}C$ and $\delta^{15}N$ on black porgy showed -17.6--16.0‰ and 16.2-17.7‰, respectively. In the Seto Inland Sea of Japan, resources of benthotrophic fish species, such as flatfishes and pufferfishes, which use the estuary in their early life history, have decreased remarkably. For recovery and regeneration of these critical resources, it is necessary to clarify the relationships between organisms and the estuarine ecosystem.

Annotated Bibliography of Key Works

Shigeta T. and H. Usuki. 2012. Predation on the short-neck clam *Ruditapes philippinarum* by intertidal fishes: a list of fish predators. *Journal of Fisheries Technology*, 5(1): 1–19. (in Japanese with English abstract)

Recently, commercial catches of the short-neck clam *Ruditapes philippinarum* have decreased in Japan. Especially in the Seto Inland Sea, western Japan, the clam catches have remarkably dropped. Several reports suggest that predation by fishes is one of the most important factors for the survival of the clam. In this review, we made a list of fish species that forage on the short-neck clam in the field. Twenty-three fishes ranging from Myliobatidae to Tetraodontidae (12 families) are listed in the world. Among them, 21 intertidal fishes (12 families) occur in Japan. It was clarified that five fishes, the Longheaded eagle ray *Aetobatus flagellum*, the Black porgy *Acanthopagrus schlegelii*, the Yellowfin seabream *A. latu*s, the Kyuusen wrasse *Parajulis poecilepterus* and the Grass puffer *Takifugu niphobles*, foraged on whole adult-sized clam (>20 mm shell length). At least, the siphon was cropped by eight fishes including the Stone flounder *Kareius bicoloratus*, the Marbled sole *Pseudopleuronectes yokohamae*, and the Japanese sillago *Sillago japonica*. Meanwhile, the Black porgy and the Kyuusen wrasse preyed on all parts except the foot of the clam. We are continuing to analyze details of the interaction between these intertidal fishes and the short-neck clam.

Evaluation of inexpensive Raspberry Pi-based time-lapse camera system for tidal flat ecosystem observation

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Abstract
In recent years, changes in the structure of coastal ecosystems, leading to a collapse of conventional fisheries, have been widely reported. Maintaining clam fisheries or aquaculture production in general has becoming increasingly difficult without adequate predator prevention measure, especially in the tidal flats of western Japan, indicating certain changes in the structure of the ecosystem. It is suggested that migratory fish species influence the benthic community structure through predation in the tidal flat ecosystem. However, inadequate information exists on the abundance or frequency of the appearance of migratory fish species in tidal flats; hence, its impacts on the benthic community are unclear. Observation using an underwater time-lapse camera system can be an effective approach to understanding the temporal change in the abundance of migratory fish species in tidal flats and their influence on the ecosystem. We have, therefore, developed and tested an inexpensive Raspberry Pi-based underwater time-lapse camera system to observe the tidal flat ecosystem processes. The Raspberry Pi is an inexpensive single-board computer that can be connected to a dedicated camera module. Our system consists of Raspberry Pi with a camera module, USB battery, time-lapse power control unit, and optional light emitting diode (LED) module and temperature sensor. The camera system uses the command line interface for operation setting, i.e., setting the initial wakeup time, repeat times, and the interval. It takes still and/or video images after wakeup, and then shuts down until the next scheduled wake-up time. We placed the entire system, excluding the LED module and temperature sensor, in an inexpensive underwater housing structure made with polyvinyl chloride (PVC) water pipe sockets and an acrylic window. The camera system successfully captured underwater time-lapse images during observations, except under low visibility conditions, or when biofouling occurs. However, certain improvements are required, which include improving the image quality under low-light conditions by increasing the brightness of the light module, widening the field of view of the image, and adding an anti-biofouling mechanism.

Development of Free-Ocean Real-Time Experimental System (FORTES) for in-situ CO_2 manipulation in eelgrass beds

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Abstract

Ocean acidification (OA) causes various effect on coastal resources. For eelgrass beds, positive and negative effects are expected on different functional groups of biological communities. In addition, the acidification level in coastal ecosystems vary greatly due to the CO_2 consumption and production by marine plants and input of freshwater. To understand the actual influences of OA under such complicated conditions, in-situ field experiments for manipulating CO_2 are promising. FOCEs (Free ocean carbon experiments, Gattuso *et al.*, 2014) have already been established in several marine habitats such as coral reefs and Posidonia seagrass beds. However, these systems have several problems such as changing in-site hydrodynamic conditions, the needs to electrical power to operate the system, and high installation cost. To overcome such difficulties, we have developed a newly CO_2 manipulating system on the site, named FORTES (Free-Ocean Real-Time Experimental System). The system allows control of the acidification level in the area of square meters of eelgrass beds by supplying a high concentration of CO_2-dissolved water under mostly opened condition. No electrical power is required because this system could be operated by the pressure and buoyancy of injected CO_2. The CO_2-dissolved water is always emitted to the experimental area from the upstream direction even when the current direction changes with tide and other factors. In the test trials of FORTES in eelgrass beds in Oki Island and Akkeshi lagoon in Japan, the acidification level expected in 2100 was reproduced successfully. Furthermore, this system enables the supply of water-soluble nutrients and the deterrent of invertebrate grazers along with the CO_2 for simultaneous control of nutrient levels and grazer densities. This orthogonal design allows the experiments to examine interacting effects of ocean acidification and other factors in the eelgrass bed community.

Annotated Bibliography of Key Works

Gattuso, J-P., W. Kirkwood, J.P. Barry, E. Cox, F. Gazeau, L. Hansson, I. Hendriks, D.I. Kline, P. Mahacek, S. Martin, P. McElhany, E. T. Peltzer, J. Reeve, D. Roberts, V. Saderne, K. Tait, S. Widdicombe, and P. G. Brewer. 2014. Free-ocean CO_2 enrichment (FOCE) systems: present status and future developments, *Biogeosciences*, 11: 4057–4075.

Free-ocean CO_2 enrichment (FOCE) systems are designed to assess the impact of ocean acidification on biological communities in situ for extended periods of time (weeks to months). They overcome some of the drawbacks of laboratory experiments and field observations by enabling (1) precise control of CO_2 enrichment by monitoring pH as an offset of ambient pH, (2) consideration of indirect effects such as those mediated through interspecific relationships and food webs, and (3) relatively long experiments with intact communities. Bringing perturbation experiments from the laboratory to the field is, however, extremely challenging. The main goal of this paper is to provide guidelines on the general design, engineering, and sensor options required to conduct FOCE experiments. Another goal is to introduce xFOCE, a community-led initiative to promote awareness, provide resources for in situ perturbation experiments, and build a user community. Present and existing FOCE systems are briefly described and examples of data collected presented. Future developments are also addressed as it is anticipated that the next generation of FOCE systems will include, in addition to pH, options for oxygen and/or temperature control. FOCE systems should become an important experimental approach for projecting the future response of marine ecosystems to environmental change.

A comparison of environmental and biological parameters at asari, Ruditapes philippinarum, fishing grounds in Japan for understanding the cause of recent catastrophic decrease of asari clam

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Abstract
The catastrophic decrease of catch of the asari clam, *Ruditapes philippinarum*, has been observed for the last three decades in Japan's coastal waters. Many factors including overfishing, disease, habitat loss, competition with invasive species, global warming, and altered trophic cascade are suggested to be involved. However, major factor is still not well characterized to explain the widespread and long-term decrease of the catch. We conducted comprehensive comparison of environmental and biological characteristics among asari fishing grounds in Japan. Significant relationship was observed between water nutrient level (i.e., total nitrogen and chlorophyll *a*) and the asari catch. Stable carbon isotope ratio of asari was found to be a useful indicator representing not only the nutrient level but also the asari catch per unit area. Significant relationship was also observed between the benthos biomass (macrobenthos, meiobentos, and nematodes) and the asari catch. All these observations suggest that recent catastrophic biomass decrease is occurring not only for asari but also for wide range of benthic organisms in Japan's coastal waters.

This study was conducted by a research fund entitled a feasibility study on biodiversity assessment methods in fishing ground environment from Fisheries Agency.