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International Symposium on "Sustainability Science on Seafood and Ocean Ecosystem Conservation"

国際シンポジウム「明日の海と食を守る水産海洋サステナビリティ学」



Program & Abstracts

Date: November 7, 2009
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Venue: Faculty of Fisheries Sciences, Hokkaido University
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Organizers:
Faculty of Fisheries Sciences, Hokkaido University
Science Council of Japan (SCJ)

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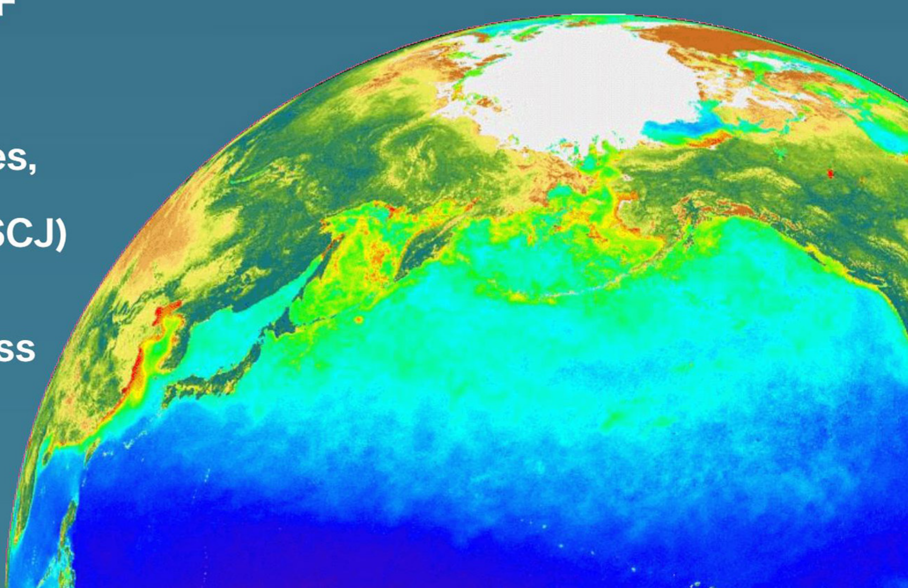

International Symposium on

“Sustainability Science on Seafood and Ocean Ecosystem Conservation”

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プログラム＆要旨集

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Symposium Outline

Seafood should be reproducible resources for human being. However, world fish catches have peaked since the 1990s despite increase in aquaculture production. Traditional fisheries science consider only fisheries, some consequences of which include "fishing down" marine food webs, the over fishing by the tuna laundering, the tragedy of common, the food mileage, ecosystem crash, and food pollution. A paradigm shift, therefore, should be needed from the traditional fisheries science to a new ecological fisheries science for the protection of marine ecosystems and human food resources in order to be human well-being in future generation. This symposium aims to discuss the sustainability of ocean ecosystem and seafood for human species in the future.

Co-Chairs:

Masahide Kaeriyama: Professor, Faculty of Fisheries Sciences, Hokkaido University

Sei-Ichi Saitoh: Professor, Faculty of Fisheries Sciences, Hokkaido University

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Program

10:00 **Opening Remarks**

Akihiko Hara
Dean, Faculty of Fisheries Sciences,
Hokkaido University, Japan

10:10 **Invited Lectures**

"Spatial Bioeconomics for Seafood and Marine Ecosystem conservation"

Ussif Rashid Sumaila
Director, Fisheries Centre, The University of British Columbia, Canada

"An Ecosystem-based Fisheries Assessment and Forecasting Approach"

Chang Ik Zhang
Professor, Institute of Fisheries Science,
Pukyong National University, Korea

"Sustainability of the Alaska Salmon Fishery"

William W. Smoker
Professor of Fisheries Emeritus, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, USA

"Current Status and Recent Advance of Aquaculture in China"

Hongxin Tan
Vice Dean, College of Fisheries and Life Science,
Shanghai Ocean University, China

12:30 **Lunch**

13:30 **Lectures**

"Ocean Ecosystem Conservation and Seafood Security for Future Generation - A Case Study of Ecosystem Approach to Fisheries and the Adaptive Management of the Shiretoko World Natural Heritage Site"

Yasunori Sakurai
Professor, Faculty of Fisheries Sciences,
Hokkaido University, Japan

"Health Management of Hatched Fry for Sustainable Salmon Propagation and Provides 'Safe and Worry-free' Salmon Products"

Mamoru Yoshimizu
Professor, Faculty of Fisheries Sciences,
Hokkaido University, Japan

"Sustainability Sciences for Ocean Ecosystem Conservation and Seafood Security"

Masahide Kaeriyama
Professor, Faculty of Fisheries Sciences,
Hokkaido University, Japan

15:00 **Coffee Break**

15:30 ◆ **Panel Discussion**

Coordinator

Sei-Ichi Saitoh
Professor, Faculty of Fisheries Sciences,
Hokkaido University, Japan

Panelists

Chunhong Yuan
Assistant Professor, Faculty of Fisheries Science, Hokkaido University, Japan
"Culture and Processing of Silver Carp, a Plankton Feeder Fish -- for Sustainable Development of Freshwater Fisheries in China"

Rizalita Rosalejos-Edpalina
JSPS-UNU Postdoctoral Fellow,
United Nations University Institute of Advanced Studies (UNU-IAS), Operating Unit Kanazawa/Ishikawa, Japan
"Management Options to Mitigate Environmental Impact of Aquaculture in the Philippines"

I Nyoman Radiarta
Post Doctoral Research Scientist, Faculty of Fisheries Sciences, Hokkaido University, Japan
"Spatial Information Systems Approach toward Sustainable Aquaculture"

Gakushi Ishimura
Assistant Professor
Center for Sustainable Science, Hokkaido University, Japan
"Sustainable Management of a Transboundary Fishery Resource under Climate Variability: Desperate Fishing Games of Pacific Sardine Resource"

16:50 **General Discussion**

17:20 **Closing Remarks**

Kohei Yamauchi

Director, South Ehime Fisheries Research Center,
Ehime University, Japan

Abstracts

Invited Lectures

Spatial Bioeconomics for Seafood and Marine Ecosystem Conservation

Ussif Rashid SUMAILA

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I present in this talk new research that integrates ecology and economics to develop a bioeconomic spatial index that can help us use marine fisheries resources sustainably through time, for the benefits of both current and future generations of people. The index is calculated for each half degree by half degree cell of the global ocean, and represented spatially using GIS techniques to depict areas in the ocean that need special management approaches (e.g., marine protected areas) and areas where market based approaches (e.g., territorial use rights in fisheries or TURFs) can be used. The proposed index can help managers use scarce management resources in a targeted, efficient and effective way to ensure the conservation of seafood and marine ecosystems through time.

Invited Lectures

An Ecosystem-based Fisheries Assessment and Forecasting Approach

Chang Ik ZHANG

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A comprehensive ecosystem-based approach is required to holistically assess, forecast and manage fisheries resources and their associated habitats by considering ecological interactions of target species with predators, competitors, and prey species, interactions between fishes and their habitats, and the effects of fishing on these processes. A pragmatic ecosystem-based approach was developed for the assessment of fisheries resources involving three management objectives: sustainability, biodiversity, and habitat quality (Zhang et al., 2009). This approach has a two-tier analytical method. Tier 1 was designed for situations where sufficient information is available to allow for a quantitative evaluation of the status of the system, while Tier 2 was designed for situations where available information necessitated a semi-quantitative or qualitative assessment. In this approach a total of 20 Tier 1 indicators and 24 Tier 2 indicators were developed for assessment of ecosystem status, and both target and limit reference points were chosen for each indicator to assess the status of species, fisheries and ecosystems. Nested risk indices, such as objectives risk index (ORI), species risk index (SRI), fishery risk index (FRI), and ecosystem risk index (ERI), were developed to assess the ecosystem status at the management unit level. In this study an integrated fisheries risk assessment, forecasting and management for ecosystems (IFRAME) is developed by extending the approach developed by Zhang et al. (2009). IFRAME has an additional management objective, socio-economic benefits, and it also includes three sub-models, namely, assessment, forecasting, and management sub-models. The method was demonstrated by applying it to the Korean large purse seine fishery. It was found that this approach can be used to compare the status of species, fisheries and ecosystems spatially and temporally, to evaluate the performance of management options under various scenarios using an ecosystem perspective.

Keywords: Ecosystem-based approach, Assessment, Forecast, Two-tier analytical method, Ecosystem indicators, Reference points, Risk index

Invited Lectures

Sustainability of the Alaska Salmon Fishery

William W. SMOKER

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Status of the Alaska salmon fishery. In 2009 Alaska continued over three decades of sustained harvest above 100M salmon; the harvest this year was above 150M including over 40M sockeye, 90M pink, and 16M chum salmon (preliminary State of Alaska data). It was near the median of harvests for the past decade. For some species in some regions the harvest in 2009 was predominantly of hatchery-origin salmon (e.g. Prince William Sound pink salmon, Southeast chum salmon) but most of the harvest depended on locally-managed fisheries dependent on naturally-reproducing salmon in healthy ecosystems. Managers of some local area fisheries suspect that a trend over several recent years toward smaller body size may be occurring (e.g. chum salmon in northern part of Southeast; pink salmon in Southeast.)

Marine Stewardship Council Ecolabel. The Alaska salmon fishery was certified Sustainable in 2000 and recertified in 2007 for five years by the Council. Thus salmon harvested in Alaska have been able to carry the MSC sustainability ecolabel in the marketplace. A single certification, applying to all salmon harvested in all parts of Alaska, was sought by Alaska Department of Fish and Game because the market would have been confused by multiple certifications of multiple fisheries for multiple species. Certification applies to all five species harvested in any of the waters of Alaska. The five species are divided into 16 Units in the certification process which evaluates each Unit in certifying the entire fishery. Each Unit is a different regulatory Area or a combination of fishing gear type and Area. Continued Certification is dependent on successful annual surveillance audits by an agent of the Council. The auditors require detailed reports from the Client each year. The Client for the certification process, Alaska Department of Fish & Game, has withdrawn from the process as of May 2009. This means that Alaska salmon harvested before November 2009 can be marketed with the MSC certification ecolabel but if surveillance audits are not provided by a new Client the certification may lapse. It is possible that Alaska Seafood Marketing Institute will undertake the responsibilities of the MSC Client.

Alaska Seafood Marketing Institute. The Alaska seafood industry and the State of Alaska cooperate through the Institute in increasing the economic value of the harvest. They intensively promote the sustainability of fisheries, including salmon, to diverse markets. They call attention to Alaska's success in meeting the sustainability criteria defined by the United Nations Food and Agriculture Organization in their efforts to educate domestic retail, domestic food service, and international customers.

Invited Lectures

Current Status and Recent Advance of Aquaculture in China

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Food and Agriculture Organization of the United Nations predicts that worldwide harvest output of aquatic products will be stagnant or decreased whereas the consumption of aquatic products will be increased at the speed of 1.0% to 2.9%. The increase of aquatic product output will mainly be attributed to the development of aquaculture. For a developing country, especially for a country with a large population and fast developing pace as China, aquaculture in the 21st century will not only face favorable developing opportunities but severe challenges as well.

1. A brief introduction to the development of Chinese aquaculture

China has a very long history in aquaculture. Chinese aquaculture industry has witnessed the growth rates of more than 10 percent every year. Since 1989, China's aquatic product output has been in the first place of the world. At present, it accounts for 40% of the world's aquatic product output, among which the aquaculture output accounts for 70% of that of the world. China thus becomes the only fishery country that aquaculture output exceeds fishing yield, with 9 billion US dollars of export volume which accounts for 30% of the total export volume of agricultural products. Export of aquatic products has enhanced China's international competitiveness in the field of fishery, thus promoted the development of domestic aquaculture and aquatic processing. In 2006, the freshwater aquaculture area was 60,200 hectares and the aquaculture output was 19.5 million tons which accounted for 97% of the total output of cultured fishes. Aquaculture is a vibrant industry in China, Chinese aquaculture producers are rapidly upgrading their technology to produce species such as black carps, grass carps, silver carps, bighead carps, tilapia, catfish, eel, shrimp, abalone, sea bass, turbot, sea bream, red drum, crab, flounder, trout, mussels, salmon and more.

2. A major challenge for Chinese aquaculture

China suffers from environmental pollution and a shortage of freshwater resources. The problems of shortage of water resources and water quality-induced water shortage become more and more prominent in China. The current fishery pattern costs a great deal of resources and we need to shift the fishery pattern to the resource saving and environmentally friendly orientation. This is not only a scientific issue but also a social issue. However, the current scientific development of fishery in China does not meet the transformation of fishery growth modes.

3. Aquaculture should be resource saving and environmentally friendly

How to make aquaculture be shifted to the resource saving and environmentally friendly orientation? Simply speaking, in order to realize the goal of shifting to the resource saving and environmentally friendly orientation, sustainable aquaculture mode will become the direction of China's aquaculture. Sustainable aquaculture must consider the ecological, social, and economic aspects of development. Recently, governments and industry have realized that the focus of aquaculture must evolve into the development of an industry that is both environmentally and socially sustainable in the long term. Positive changes are being made with this growing interest and awareness of improving the sustainability of aquaculture. With the expected expansion of aquaculture in the coming years it will be vital that sustainable practices be implemented and further developed to avoid environmental and social problems.

There are a number of alternative ways forward in the development of aquaculture, which can offer more sustainable solutions. In some cases these methods have been around for centuries, but they have rarely been adopted in the modern aquaculture industry, and in other cases they are innovative practices that can be explored by aquaculture proponents. Alternatives include ecological aquaculture, organic aquaculture, polyculture, mollusc farming, and closed and low discharge systems. These alternative practices have been successfully implemented in different areas of the world; however, they must be examined for their application on a wider scale.

Concerns for water conservation and reduced waste discharges have prompted the increased use of closed recirculating aquaculture systems. The systems are made up of three basic components: culture tank, settling tank, and biological filter. Recirculating systems have less of an impact upon the environment because of their closed nature – wastes and uneaten feed are not simply released into the ambient environment in the manner that they are with netpens and exotic species and diseases are not introduced into the environment. In recirculating systems, wastes are filtered out of the culture system and disposed of in a responsible manner. Recirculating systems can be built just about anywhere, including in urban settings where they can use existing structures and be placed close to markets, thereby reducing transportation costs. Recirculating systems can be used to grow a wide variety of fish species year-round in controlled environments. Species commonly grown in recirculating systems include hybrid striped bass and tilapia. Additionally, much research has been dedicated to developing recirculating systems for marine species of fish and this technology holds much promise.

Ecological aquaculture has been defined as "an alternative model of aquaculture research and development that brings the technical aspects of ecological principles and ecosystems thinking to aquaculture". Ecological aquaculture focuses on the development of farming systems that preserve the environments in which they are situated and enhances the quality of these environments while at the same time maintaining a productive culture system. All aspects of the operation are interconnected in order to minimize negative impacts on the community, both natural and social. Ecological aquaculture can also be incorporated into sustainable fisheries management and coastal zone management. In 2007, Shanghai has launched the construction of standard ecological aquaculture bases, as a means to transform its traditional aquaculture model. The base will form an ecological system, with 20 ponds with distinct functions such as seedling raising, prawn-farming, a fish pond and artificial wetland. A 1200 hektares ecological aquaculture area will be completed during the 11th five-year-plan period. Shanghai will explore a low-cost and highly efficient way to popularize the application of aquaculture model.

Lectures

Ocean Ecosystem Conservation and Seafood Security for Future Generation -A Case Study of Ecosystem Approach to Fisheries and the Adaptive Management of the Shiretoko World Natural Heritage Site

Yasunori SAKURAI [1] and Mitsutaku MAKINO [2]

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1. Human dimensions of global change in marine ecosystem

Marine ecosystems are impacted by global-scale climate variability and change. It was recognized, however, that human activities such as intensive fishing also have strong impacts on marine ecosystems, which may occur on more immediate time scales than those of climate change. The recent international ocean research programs such as IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) focus on the human dimensions of global change in marine ecosystems, and expand on the concept of coupled marine social-ecological systems. Fisheries management is evolving towards ecosystem-based approaches from the study and management of single species. Efforts are now being made to measure and alleviate the ecosystem effects of fishing (Hall 1999) and focus is very much on how an Ecosystem Approach to Fisheries (EAF) may be implemented (Garcia and Cochrane 2005).

Further, a full social-ecological system approach to the management of marine resources must involve multiple-scale (from government to local fishing sectors) objective setting based on societal choices, including ecological, economic and social considerations. Operational objectives need to be established, requiring the identification of indicators and reference points for sector impacts. Decision support and performance evaluation rules need to be established, including their uncertainties. Future change in marine systems will not be due to climate alone, but to the interactions of climate variability, climate change, and direct-human effects, and future marine research and management must take account of this reality. How to evaluate the ecological status of the world's exploited marine ecosystems subject to multiple drivers is to bring together a broader group of experts to further explore, test and expand the development of a suite of robust ecosystem indicators for detecting ecosystem change in response to fishing and environmental impacts.

2. EAF and adaptive fisheries management of the Shiretoko World Natural Heritage Site, Hokkaido, Japan

Marginal seas contribute a substantial share to the world fisheries catch are hence significantly impacted by human exploitation. Additionally these areas are increasingly affected by climate variability and change. For log-term sustainable utilization of marine resources in marginal sea, local fisher’s awareness change regarding the EAF and adaptive fisheries management may be needed. Adaptive management predicts and monitors changes in the ecosystem and subsequently reviews and adjusts the management and use of natural resources (Matsuda et al., 2009). Such predictions and monitoring are best accompanied by feedback controls, such as the verification of hypotheses based on the results of monitoring in order to review and modify management activities.

Fisheries management in Japan is characterized by seeking balance between sustainable use and ecosystem conservation and involving the co-management of fishers' organizations (Makino et al., 2008). Fisheries in Japan face several important challenges, e.g., (i) exclusive use by fisherman with fishery rights/licenses (there are few exceptions for free-fisheries and recreational angling), (ii) lack of full transparency in management procedures, (iii) lack of objective benchmarks or numerical goals in management plans, and (iv) strong dependency on political pressure from abroad. Here, we elaborate upon these characteristics of and issues facing the management of marine ecosystems in Japan (Matsuda et. al., 2009).

We will present the Marine Management Plan for the Shiretoko World Natural Heritage Site, Japan, as a case study of adaptive marine ecosystem management and co-management of coastal fisheries.

The Oyashio shelf region and the seasonally ice-covered areas north of Hokkaido including Shiretoko are highly productive, supporting a wide range of species such as marine mammals, seabirds and commercially important species in the western subarctic Pacific (Sakurai, 2007). Shiretoko is the third World Natural Heritage Site registered in Japan and earned this title because of its (i) formation of seasonal sea ice at some of the lowest latitudes in the world, (ii) high biodiversity, and (iii) many globally threatened species. The natural resource management plan of the Shiretoko site is characterized by transparency and consensus building, because (i) UNESCO and IUCN require that the plan be sustainable; and (ii) the Government of Japan has guaranteed local fisheries that there will be no additional regulations included in the plan. The Marine Management Plan describes which species and factors are monitored, how these data are evaluated, and how the benchmarks specified by ecosystem management are determined. The Plan will provide a valuable example for the establishment of "environment-friendly fisheries" in Japan and other countries, because it includes voluntary activities by resource users that are suitable for use in a local context, flexible to ecological/social fluctuations, and efficiently implemented through increased legitimacy and compliance. This approach is appropriate for developing coastal countries where a large number of small-scale fishers catch a variety of species using various types of gear (Matsuda et al., 2009).

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Lectures

Health Management of Hatched Fry for Sustainable Salmon Propagation and Provides "Safe and Worry-free" Salmon Products

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Sustainable propagation of salmonid fish under the ocean ecosystem is essential for salmon industry. Salmonid fish including chum salmon (*Oncorhynchus keta*), pink salmon (*O. gorbuscha*) and masu salmon (*O. masou*) are important species for hatchery reared and released fish in Japan. Diseases, especially viral and bacterial diseases are serious problems and one of the limitations of successful propagation and/or aquaculture of salmonid fish. Methods currently used to control the diseases in hatcheries are 1) hygiene and facility sanitation, 2) disinfection of water supply and waste water, 3) health monitoring of matured fish and hatched fry. Under these circumstances, hatched fish are healthy and specific pathogen free, but there is still a possibility of infection with some pathogens in environmental waters after they are moved to river or pond. For prospective study, development of effective vaccines and immunological tools for judgment of vaccination effect is necessary.

To create safe and worry free salmon products, we have established a system using a risk analysis based on hazard analysis (HA) and set up the critical control point (CCP) from fishing through processing to distribution. Model program for improvement the quality control of fisheries products from fishing to market was created using chum salmon as a model fish species in 1999 with Hokkaido government, Japan. One town, located in east part of Hokkaido, was selected to become the model district in addition to its position as leading producer of chum salmon. This town received high marks for its efforts to promote the advanced measures to preserve freshness, as well as its approach to enhance the quality control of the marine products, such as the positive sanitation and hygiene measures adopted by local processors. This town implemented a local HACCP manual. Through this HACCP effort, the industry in the town district was integrated. Today, Japanese government considers that a safe and worry-free food product of the highest quality, by practicing the HACCP program and Good Practice program is necessary for fisheries industry and consumer. This Local Town District HACCP System has been accepted in many fishermen's cooperatives, and created this HACCP system in many towns and areas in Hokkaido and Tohoku. This risk analysis using HA and set up the CCP are combined with traceability system and accepted among consumers in Japan.

Keywords: Salmonid fish, Propagation, Disinfection, Vaccination, Risk analysis, HACCP, Hygiene, Sanitation

Lectures

Sustainability Sciences for Ocean Ecosystem Conservation and Seafood Security

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Marine food should be a renewable resource for humans. However, world fish catches have peaked since the 1990s, despite increase in aquaculture production. Fish provide more than 2.9 billion people with at least 15% of their animal protein intake (FAO, 2009). Tuna (*Thunnus* spp.) abundance decreased severely by overfishing since the 1980s (Myers and Worm, 2003). Bluefin tuna (*T. thynnus*) is already listed as a 'critical species' in the IUCN. Although production from aquaculture is increasing worldwide, many aquaculture programs cause destruction of aquatic ecosystems, such as destruction of mangrove forests due to the introduction of shrimp aquaculture over the last 20 years in Eastern Asia (Primavera et al., 2005), marine pollution and threats to marine food security (e.g. contaminants in farmed Atlantic salmon; Hites et al., 2004). Traditional fisheries science considers only fisheries, some consequences of which include fishing down marine food webs (Pauly et al., 1998), overfishing of tuna, tragedy of the commons, food mileage, ecosystem crashes and food pollution. A paradigm shift is needed from traditional fisheries science to a new ecological fisheries science and oceanography for protection of ocean ecosystems and human seafood resources for the well being of future generations. The objective of this presentation is to consider risk management, including adaptive management and precautionary principles based on the ecosystem approach for protecting marine ecosystem and seafood security.

Carrying capacity and long-term climate change Population dynamics of Pacific salmon (*Oncorhynchus* spp.) are directly affected by a number of stresses (climatic and human impacts) that need to be considered within an ecosystem context. A significant positive correlation was observed between the Aleutian Low Pressure Index (ALPI) and carrying capacity at the species level. Residual carrying capacity was significantly positively correlated with body size and negatively related to age at maturity in chum salmon (*O. keta*) as an example of a density-dependent effect (Kaeriyama, 2008). On the other hand, the biomass of wild chum salmon populations in the 1990s decreased to 50% of that in the 1930s, despite the significant increase in hatchery populations. This phenomenon suggests that the increased number of hatchery salmon impacted the reproductive value (e.g. fecundity) of wild populations.

Global warming is affecting marine organisms. How will Pacific salmon be affected by global warming in the near future? Using the SRES-A1B scenario of the IPCC, it is possible to infer the global warming effect on chum salmon based on their optimal temperature for growth (8–12ºC). This suggests that chum salmon would be brought into direct competition with other salmon populations, leading to decrease in the survival rate and population density-dependent effects because of reduction of distribution area, displacement to the north (e.g. the Arctic Ocean) and loss of migration routes (e.g. the Okhotsk Sea).

Sustainable conservation management based on the ecosystem approach The structure of ecosystems includes interaction between the abiotic environment and organism, while the function of ecosystems includes interaction between the abiotic environment and biodiversity. The aquatic ecosystem is subject to disturbance by natural factors and human impact. Recently, human impact has strongly affected the aquatic ecosystem (e.g. global warming, overfishing, habitat loss, creation of artificial river channels, dam construction and the negative effects of aquaculture and hatchery programs; Kaeriyama and Edpalina, 2004). We need to identify the limitations of fisheries management, focused at the population level, and establish sustainable conservation and management based on the integration of population level approaches within a wider ecosystem-based approach.

Definitions of an ecosystem-based approach to fisheries management have been proposed by several authors (NRC, 1999, Witherell et al., 2000, FAO, 2003, McLeod et al., 2005, Murawski and Matlock, 2006, Marasco et al., 2007). We have used the definition of McLeod et al. (2005) in this section: ‘Ecosystem-based management is an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern. It considers cumulative impacts of different sectors.’

In this century, ecosystem conservation and stable production of food from marine sources are the most important issues for humans in the global earth system, considering increases in the human population and impacts such as global warming. Sustainable conservation management based on the ecosystem approach (SCMEA) for Pacific salmon should be part of the sustainability science of fisheries and oceans. Three aspects of the structure and function of the ocean ecosystem should be monitored, particularly for Pacific salmon: (1) spatial and temporal changes including carrying capacity, food web and trophic level; (2) climatic oceanic conditions including global warming and regime shifts and (3) biological interactions between wild and hatchery populations, density-dependent effects and inter- and intra-specific competition. For the SCMEA of Pacific salmon, adaptive management and precautionary principles are important. In particular, adaptive management should be conducted based on the feedback of monitoring, modelling and adaptive learning, which includes learning by conducting risk analyses and consensus building.

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Panel Discussion

Culture and Processing of Silver Carp, a Plankton Feeder Fish ---- for Sustainable Development of Freshwater Fisheries in China

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With economical development and life style changes, billions of people want to diversify their diets by consuming less plant starch and more animal protein. Compared to other animals, fish are highly efficient at converting feed into protein. Health concerns have also prompted some people to shift consumption from beef and pork to poultry and fish.

These resulted in the quick development of fish culture.

According to FAO statistics, aquaculture output expanded from 13 million tons in 1990 to 48 million tons in 2005, growing by about 9 percent a year. China is the leading producer, contributing 83.6% of the increment. In 2005, China's aquaculture production is made up 70.5% of the world total.

China has a long history in aquaculture back to 2000 years ago. Since 1970s, under the reform policies and driven by the economic benefits, the rapid development of China's aquaculture both in fresh waters and sea waters has been the focus of the world attention. China's freshwater fisheries output has increased rapidly by more than ten times in the last 50 years, reaching more than 19 million tons (mt) in 2007, which is equivalent to about 14% of the total world catch. The most commonly farmed species are grass carp (3.55 mt), silver carp (3.07 mt), bighead carp (2.22 mt), common carp (2.13 mt), crucian carp (1.94 mt), which accounts for 65.5% of the total freshwater aquaculture.

Why these traditional species are farmed so abundantly? We should have an insight into the characterization of Chinese freshwater fish culture.

Freshwater fish culture in China mainly refers to pond fish culture, which accounts for about 70% of the total freshwater aquaculture production. Technological system for pond fish culture is basically the ancestors' traditional Chinese fish farming technology, which is refined and improved through knowledge and experience from research and development efforts of last five decades. One of the outstanding features in pond system is mixed and polyculture with high density: Several species are cultured in the same pond. This experience was explored and accumulated by the Chinese fish farmers in a long period of practical production activities. Different species of fishes are cultured in the same pond according to their biological characteristics, food and feeding habits, and the water column inhabited by different species, so as to fully utilize the water space and the available natural feed to maximize production per unit area.

Over time, China has evolved a remarkably efficient fish polyculture using four types of carp that feed at different levels of the food chain, in effect emulating natural aquatic ecosystems. Silver carp and bighead carp are filter feeders, eating phytoplankton and zooplankton respectively. The grass carp, as its name implies, feeds largely on vegetation, while the common carp is a bottom feeder, living on detritus on the bottom. China's aquaculture is often integrated with agriculture, enabling farmers to use agricultural wastes, such as pig or duck manure, to fertilize ponds, thus stimulating the growth of plankton. Now, Fish polyculture which typically boosts pond productivity over that of monocultures by at least half also dominates fish farming in India.

The above is the reason why cyprinid fish holds an overwhelming proportion in freshwater fish culture.

The silver carp (*Hypophthalmichthys molitrix*) is a species of freshwater cyprinid fish, which is a native species of China and has been raised in ponds since historic times. Silver carp, like all *Hypophthalmichthys* species, have no stomachs; they are thought to feed more or less constantly. Silver carp are thought to feed largely on phytoplankton; they also consume zooplankton and detritus. As silver carp is a plankton feeder fish, it occupies the upper region (surface waters) of culture ponds. As plankton feeders throughout life, silver carp is indispensable for polyculture, which is widely practiced in China. Silver carp is not very competitive with other adult fish, is less susceptible to disease, and grow rapidly. As it is a fast-grower fish able to feed on the lowest level of the food chain (phytoplankton). Silver carp is also used as a means of biological control of algal populations due to its high filtering rates. And it is usually raised in polyculture with other carp species. The overall aim of this practice is to make the best use of the production in the water body and to ensure equilibrium between the different species in their different ecological niches. Silver carp is chosen the principal species if ponds have been heavily fertilized. The above several desirable characteristics that are sought for by aquaculturists, also are the reason why Silver carp is imported to so many countries. Silver carp are usually farmed in polyculture with other Asian major carps, or sometimes Indian major carps or other species. Nowadays, this species is farmed in almost every major continent. In fact, silver carp is the most widely fish species cultured in the world. In China, the production cycle of silver carp lasts for two years: in the first year silver carp are grown to 50 g, and reach 500-1000 g after the second year. At this point, fish are sold.

Despite the fact that freshwater fish resources in China have expanded rapidly, their distribution sphere and storage period are very limited since most freshwater fish are transported as live fish without treatment, such as freezing and processing. Compared with marine resources, freshwater fisheries resources lack the diversity of consumption because of the backward transportation and processing technologies. A big gap existed between China and some developed countries in the world in the fish processing industry, particularly in fishery products finely processed. Only 30% of landed fish are processed compared to 70% in developed countries such as Japan. Freshwater fish are almost always sold alive. Although the sector of freshwater fish processing has gained a great development, the volume of the processed aquatic product from freshwater fish only occupies 10% of the total according to the statistics in 2004, even less with fine processing. Due to backward post-harvesting technologies compared with fast increment of the production of freshwater fish, overproduction is the problem in harvesting season in some fish farming regions. The market value of freshwater fish drops because of the excess of supply over demand, which definitely would hinder a further development of fish farming. To develop freshwater fisheries environmental friendly and sustainabaly, the development of processing industry is essential to reduce losses through poor handling of fish, to utilize over catch fish, and to raise the value of fish products. In addition, improving fish quality, flavor, healthy and safe fish products are another goals for Chinese government. In some means, processing becomes the neck of the development of freshwater fisheries.

To address the post-harvest problems and fully utilization of the abundant animal protein resource, Japan and China initiated a collaborative research project titled "Development of freshwater fish surimi". Because surimi is generally manufactured by applying a simple technology of washing minced meat by water, dehydration, and mixing with cryoprotectants and has a long frozen shelf-life, it is an intermediate foodstuff with high potential for free productivity of texturized products, such as imitation crab. Because of the low cost for aquaculture and low market value, silver carp maybe a good materiel for making surimi. Our research group has investigated on the utilization and processing of freshwater fisheries resources efficiently including silver carp since 1996. We proposed that silver carp has good gel forming ability, which is comparable to that of surimi made from Pollack, which is a typical commercial marine fish surimi that accounts for more than 60% of world surimi production. Silver carp showed a setting effect (suwari), texture-enhancing treatment by pre-incubating salted surimi at temperatures lower than 40 °C before cooking at high temperature (85 °C). As silver carp is a temperate fish, large temperature changes occur in a year, we found the thermal stability of myosin, which is a main component in fish myofibrils, differed seasonally. This also resulted in the different gel forming ability of silver carp surimi which was prepared in different seasons. Now the industrial use of silver carp surimi is conducted. It is promising that many kinds of seafood products, ready-to-fry fish portions, surimi-based products, and fish sausages and cakes maybe processed from freshwater fish species. It is believed that the improved processing technologies of freshwater fish should ensure the sustainable development of freshwater fisheries.

Panel Discussion

Management Options to Mitigate Environmental Impact of Aquaculture in the Philippines

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Asia-Pacific represents the most important region for fisheries and aquaculture production. It is world's largest contributor to the world's aquaculture, producing 46.9 million tons or 91% of the global aquaculture production (FAO, 2005). The growth of aquaculture production has been very strong for the last ten years due to the increased production from China. The aquaculture production in Southeast Asia is diversified comprising 41.6% freshwater fish, 23.5% of aquatic plants, 6.7% crustaceans, 7.3% marine/diadromous fish and 21.1% of mollusks (Fig.1).

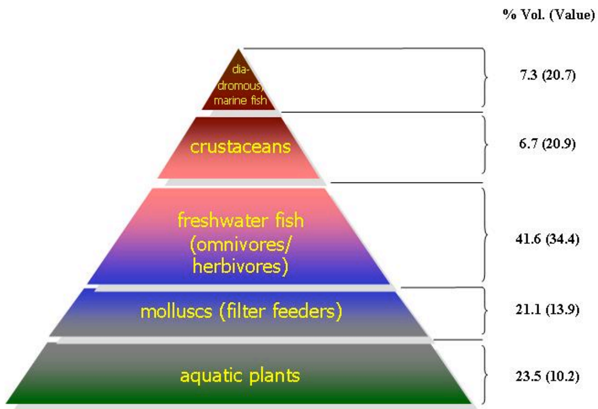

Fig. 1. Aquaculture production in Southeast Asia (Source FAO Yearbook 2006)

The Philippines consists of 7,107 islands and islets which has rich in marine and inland resources. In terms of coastline resources, Philippines ranked the fifth longest coastline worldwide having 36, 289 kms. in length. The Philippine coastal zone is typical of tropical coasts with five major resource units occurring along its shallow coastlines, i.e. coral reefs, mangrove ecosystems, beach systems, estuaries and lagoons. The linkage between the upland and coastal ecosystems is considered very important ecologically, therefore it is emphasized that Coastal Resources Management (CRM) should not be limited to only the coastal zone. The vast water resources allow Philippines to continue expanding its aquaculture production. However, this should be done in sustainable manner.

In the Philippines, fisheries and aquaculture are an important part of the Philippines' economy: growing rapidly, providing export income, providing rural employment and sustenance for poor people. Agriculture and fisheries account to about a fifth of the total economy and based on statistics, it employs a total of 10M people, nearly 40% of the labor force (BFAR, 2006). Agriculture-based communities are host to most of the poor in the country. Further, large increases of wild fisheries sector are unlikely due to limited resources. In contrast, aquaculture is still expanding rapidly and the long coastline with sheltered area provides opportunities for expansion. For aquaculture to be sustainable there must be planned development to ensure that production is within the carrying capacity of the waters and that the environmental impacts mitigated.

Aquaculture-related policy and legislations in the Philippines

The last decade of 19th century saw a major paradigm shifts towards conservation and management versus expansion and exploitation and sustainability over expanded production (Lopez, 2004). It was also in 1980s when decentralization of national policies and implementation of policies were devolved to local government units (LGUs) when Republic Act (RA) 7140 was enacted and came to force. This Law was followed with the issuance of RA 8435, otherwise known as Agriculture and Fisheries Modernization Act of 1997 (AFMA) which provides for the maximized and sustained utilization of production area towards local industrialization. The promulgation and approval of RA 8550 (Fisheries Code of 1998) likewise is a significant milestone of the decade. The legislation provides the policy, legal and institutional framework for sustainable use of the fisheries resources with the long term goal of ensuring that the fisheries sector objectives can be attained. Another equally important legislation is the National Integrated Protected Areas System (NIPAS) Act of 1992 otherwise known as RA 7586. The law provides for the establishment of protected areas with natural biological and physical diversities of the environment particularly, those with biological features to sustain human life and development as well as plant and animal life. These include all areas of lands declared as parks, sanctuaries and refuges, reserves, landmarks, protected landscapes and seascapes, virgin forests and watersheds existing as of 1993 and other areas as may be declared under the Law.

Environmental impact of aquaculture

Like many other human activities, aquaculture produces wastes which, if not properly managed, may negatively affect the environment. Over the past decades, aquaculture industry has experienced considerable expansion with attention being paid subsequently to the environmental effects. The potential impacts of aquaculture are wide-ranging from pollution problems, fish kills and eutrophication, most especially in enclosed waters with poor water exchange rates. The increase in nitrogen and phosphorus from aquaculture activities results to eutrophication, oxygen depletion and consequently fish kills. Marine aquaculture operations and their associated infrastructure can disturb scenic rural areas. Fish production generate effluent (e.g. waste feed and faeces, together with associated by product such as pesticides) which can have unacceptable impacts on the environment. There are also unwanted effects on wild populations, such as genetic disturbance and disease transfer by escapes or ingestion of contaminated waste.

Aquaculture impact in the Philippines

Brackishwater Aquaculture

Most brackishwater aquaculture activities in the Philippines were developed on mangrove swamps. Some 400,000 has. of mangrove forests, less than half remains untouched. Most mangroves swamps were developed into fishponds which were converted into shrimp ponds. Fishpond developers clear-cut the mangrove area even up to the water edge disregarding and violating the regulations requiring at least 50 meters of mangrove to remain uncut. The clearing of forested mangrove area has decreased greatly in the Philippines from an estimated coverage of 450,000 ha in 1918 to less than 248,813 ha in December 2003. The most rapid decrease in mangrove coverage was during the

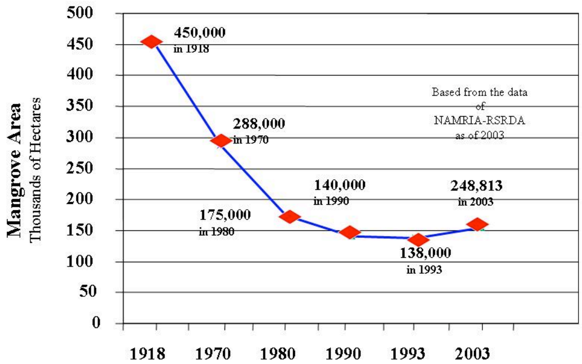

Fig. 2. Forested mangrove areas has decreased greatly in the Philippines

1960s-1970s when national policies encouraged the expansion of aquaculture. Today, fishponds cover about 289,000 ha, most of which were formerly mangroves (Fig.2). It is worthwhile to note that the mangrove forest which is the interface between the land and the sea recognized as a rich nursery ground for various marine species.

Freshwater Fishponds

Freshwater fishpond operation as practiced in the Philippines is not known to have had any adverse environmental impact. Production is very extensive and semi intensive systems. Wastewater should not pose any problem, if this is used to irrigate croplands instead of being discharged directly to a body of water.

Fishpens

Fish pens and cages structures to contain the fish in a body of water potentially pose more negative effects to the environment. The cage and pen cultures affect water body in the following manner:

- **Take up space, thuscompeting with other users**
- **Alter flow regimes which govern transport of oxygen, sediment, plankton and fish larvae**
- **Sediment and water column impacts**

A typical example is Laguna de Bay, Philippines during the early 1980s. The fishpens occupied 35,000 ha. of the lake's 90,000 ha. area. The total fishpen area slowly dropped over the years to reach only 4,425 ha. based on fishpen licensing records of LLDA (2002). This reduction has been due to increased eutrophication of the lake and rising number of fish kills.

Fish Cages

The uncontrolled proliferation of fish cages in small lakes has affected the dissolved oxygen regime, water nutrient levels and growth of fish in the cages in lakes such as Taal Lake, Philippines (Fig.3). Thus, during some seasons low oxygen levels and algal blooms can result in massive fish mortality which has happened many times. The sea cages are also showing signs of environmental impact.

Fig. 3. Indiscriminate installation and operation of fish cages in Taal Lake

Indiscriminate installation and operation has serious environmental consequences such as accumulation of organic matter on the seabed with later undergo anaerobic decomposition. The carrying capacity or the optimal area for fish cages in lake waters and coastal sea farming still remains to be studied. In 1993 to 1998, there was an increase production of Taal Lake from 13,778 MT to 40,263 MT specifically on aquaculture. The production increase has attracted more investors to engage in fish cage culture in the area resulting to the proliferation of fish cages at Pansipit River and Taal Lake. To attain maximum production rate, operators practiced high stocking density and intense feeding and as a result, fish kill occurrences were experienced in 1997 and in 2000. Because of the above incident, the lake-wide management plan for an integrated sustained aquaculture and fisheries based on scientific knowledge of the lake's carrying capacity was developed. To address the problem, the following management interventions (Fig.4) were implemented in the lake in coordination with the Local Government Units, local communities and other stakeholders;

1. **Conduct of research and development studies (fish kill investigation, feeds and feeding management of tilapia in the cages, isopod infestation of native freshwater fishes in the lake.**
2. **Strengthen the fisheries management councils in the area.**
3. **Advocacy and extension services to include water quality monitoring system, formulation of early warning systems and Information, Education and Communication**

Considering that Taal Lake is a designated protected are under the Republic act 7586 otherwise known as the National Integrated Protected Area System Act of 1992, a holistic Management Plan for Taal Volcano Protected Landscape (TVPL) was developed based on the guidelines provided for in the Act (Fig. 4), with the following components:

1. **Water quality and health of the lake**
2. **Aquatic living natural resources**
3. **Terrestrial watershed components**
4. **Disaster preparedness and management**
5. **Population and socio-economics**
6. **Research program and knowledge center**

Recommendations

It is very clear that environmental issues are emerging with the expansion of aquaculture and fisheries in the Philippines. The increased occurrence of fish kills and the degradation of municipal fishing grounds caused a serious ecological problem. To address this challenge, government, industry and civil society worked together in the formulation and implementation of the management plan for sustainable aquaculture based on the rules and regulations already in place. In general, the management of aquaculture and fisheries should be undertaken with an ecosystem approach based on their scientifically calculated carrying capacity based on appropriate regulations for management. Aquaculture development must be made within the carrying capacity of the environment so that it is sustainable. This requires good planning and management of development. It also requires coordinated management at the site level, using ecosystem-based management of the water resource. Monitoring impact of the environment is likewise required to ensure that it is not causing long-term change to the environment.

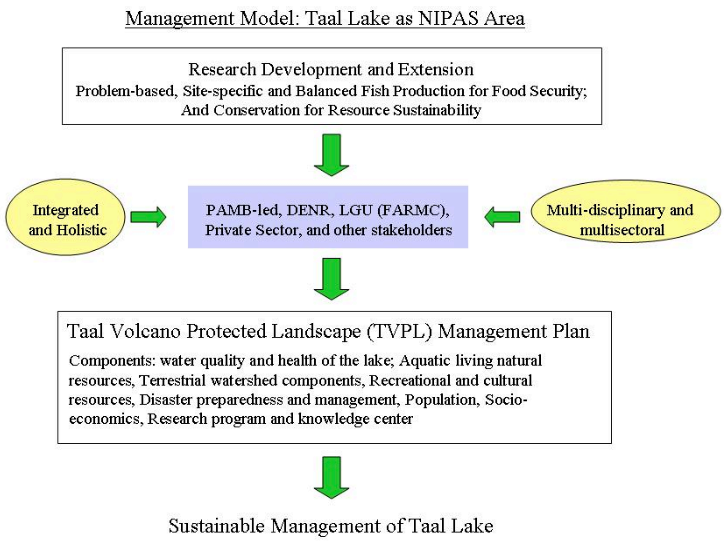

Fig. 4. Management model for Taal Lake

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Republic Act 8550, Fisheries Code of 1998

Republic Act 8435, Agriculture and Fisheries Modernization Act of 1997 (AFMA)

Republic Act 7586, National Integrated Protected Areas System Act of 1992 (NIPAS)

Panel Discussion

Spatial Information Systems Approach toward Sustainable Aquaculture

I Nyoman RADIARTA[1),2)] and Sei-Ichi SAITOH[1)]

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Aquaculture, probably the fastest growing food–producing sector, now accounts for almost 50% of the world's food fish and is perceived as having the greatest potential to meet the growing demand for aquatic food. In addition as sources of aquatic food production, aquaculture has great potential for alleviation of poverty and generation of wealth for the people living in coastal area. Many of the problems aquaculture has faced as a result of its own expansion and also because of increased activity by other sectors and stakeholders. This could effectively be resolved through a comprehensive aquaculture planning, zoning and management information system that would facilitate the formulation of strategies and planning for aquaculture development and sustain existing aquaculture systems. The FAO code of conduct gives the direction for planning and management of aquaculture (FAO, 1995). This code sets out principles and international standards of behavior for responsible practices with a view to ensure the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity.

Much of the information and data on aquaculture have been collected, such as environmental, water quality and socio economic; however, there are view studies which introduce a spatial element. To make the development sustainable, it is necessary to develop an analytical framework that can incorporate spatial (and temporal) dimensions of parameters that effect sustainability. Geographic information system (GIS) and remote sensing (RS) have an important role in all geographic and spatial aspects of the development and management of aquaculture. Both GIS and RS technology are also used to define geographic framework, specify environmental constraints and identify resources limitation. The extent of GIS and RS applications in aquaculture has rapidly increased. The applications in aquaculture include different targeting species (such as aquatic plants, fishes and shellfishes) with different main issues, include suitability of the site and zoning, environmental impact of aquaculture, planning for aquaculture among other uses of land and water, inventory and monitoring of aquaculture and the environment and fisheries and other competing uses. As an example, we have analyzed suitable sites for scallop aquaculture in Funka Bay. Our analyses were constructed from several sources of RS data and modeled using GIS based multi criteria analysis (Figure 1).

Regarding spatial information system, the Fisheries and Aquaculture Management Division at FAO is actively promoting the use of spatial analytical tools and geo-referenced information (GISFish, http://www.fao.org/ fishery/gisfish/index.jsp) for the analysis of fisheries and aquaculture data, and in the development of fisheries and aquaculture management. Moreover, an ocean color community is also promoting the use of RS for fisheries and aquaculture management through SAFARI (Societal Applications in Fisheries and Aquaculture using Remotely-Sensed Imagery, http://www.geosafari.org/index.html).

The main purpose of this topic is to promote the use of GIS and RS for improving the planning and management of aquaculture in order to support sustainable development. The capabilities of evolving GIS and RS provide a powerful tool for the efficient and cost effective management of sustainable aquaculture. These technologies are also useful for facilitating the decision making process in relation to aquaculture.

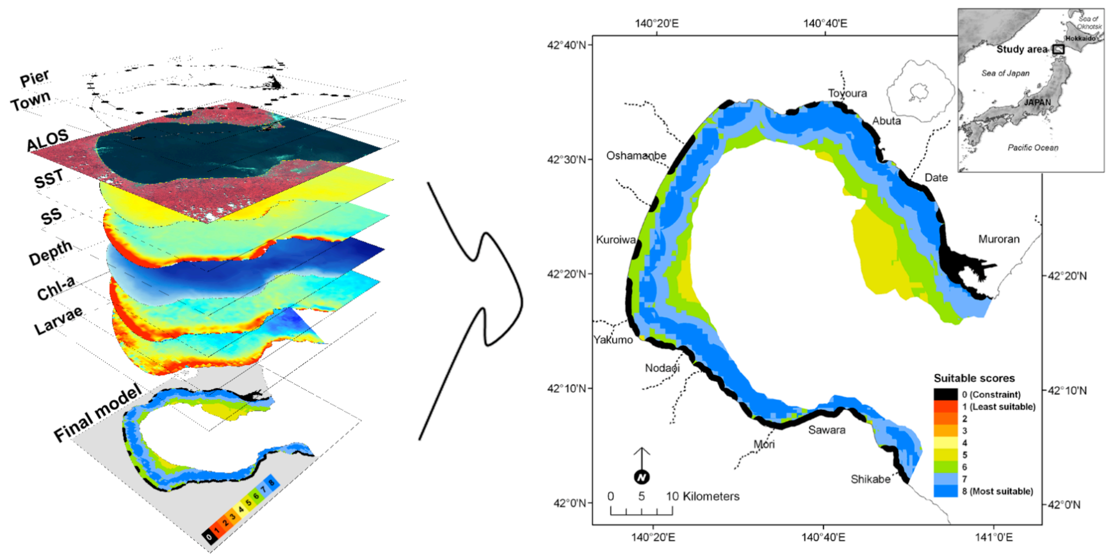

Figure 1. Data layers (left) used in GIS models for identifying suitable sites for Japanese scallop aquaculture potential in Funka Bay (right) (Radiarta et al., 2008).

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Panel Discussion

Sustainable Management of a Transboundary Fishery Resource under Climate Variability: Desperate Fishing Games of Pacific Sardine Resource

Gakushi ISHIMURA

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Compelling evidence signaling the effects of climate change are calling for urgent measures aimed to adapt extreme environmental variations. In this regard, fishery management and industries are far from exempt. Climate variability brings uncertainties in the complex interrelationships that characterize marine environments, which include sea temperature, salinity, water column stratifications, and nutrient availability for primary production. Subsequent changes in physiological environments and food accessibility in aquatic ecosystems often lead to dramatic changes in the abundance and spatial distributions of fishery. This is a pressing challenge for fisheries management and industries which targeting fishery resources exclusively distribute or migrate competitive multiple economic excusive zones (EEZs) – transboundary fish stocks.

This is particularly true for the Pacific sardine (*Sardinops sagax)* resource, which has exhibited extreme decadal variability in its abundance and geographic distribution corresponding to water temperature regime shifts within the California current ecosystem. Pacific sardine is a transboundary resource which is caught by Mexican, U.S. and Canadian fisheries. These two factors threaten the sustainability of the Pacific sardine resource, yet there is no formal transboundary conservation and management in place for the resource. Our study develops a three-agent bioeconomic game theoretic framework that incorporates environmental effects on sardine abundance and biomass distribution. Simulations are conducted to evaluate the conservation and economic benefits of full/partial cooperative and non-cooperative management strategies for the time variant/asymmetric shares of the Pacific sardine resource by three countries. Our results show that 1) under climate variability effective unilateral conservation and management by a country having a dominate share of the resource within its EEZ cannot be archived due to the actions of free-riders, and 2) full realization of the conservation and economic benefits from cooperative management of the resource is still greatly dependent on the domestic fishery policy of each country, and 3) climate variability prevents full cooperative exploitations by Canada, Mexico and the U.S. from stand-alone stable.

In this talk, with considering results from our study, I will discuss our anticipating challenges in the North Pacific fisheries,

シンポジウム概要

水産資源は，人類にとって再生可能なサステナブルな資源のはずですが，前世紀末から乱獲による漁業資源の減少や養殖による沿岸生態系の攪乱と食品安全性への不安という種々の課題を呈するようになってきました。本シンポジウムでは，海洋生態系と水産食料に関する世代間を越えてニーズを満足させる「世代間衡平性」を確実なものとする「明日の海と食を守る」ため，国際的な協調に向けた環太平洋の研究教育ネットワークの構築を模索することを目的としています。

共同議長

帰山 雅秀（北海道大学大学院水産科学研究院）

齊藤 誠一（北海道大学大学院水産科学研究院）

主催：北海道大学大学院水産科学研究院
日本学術会議

後援：函館市
北海道新聞社

プログラム

10:00 ◆ 開会挨拶

原　彰彦

北海道大学大学院水産科学研究院 研究院長

10:10 ◆ 招待講演

「水産食料と海洋生態系の保全のための空間生物経済学」

ウッシフ・ラシード・スメイラ (Ussif Rashid Sumaila)

ブリティッシュ・コロンビア大学 水産資源研究所 所長，カナダ

「生態系ベースの漁業評価予測法」

チャン・イク・ツァン (Chang Ik Zhang)

釜慶大学水産科学研究所 教授，韓国

「アラスカにおける持続可能なサケ漁業」

ウィリアム・スモーカー (William W. Smoker)

アラスカ・フェアバンクス大学水産海洋科学部 名誉教授，米国

「中国における水産養殖の現状と最近の進歩」

譚　洪新 (Hongxin Tan)

上海海洋大学水産生命科学部 副研究院長，中国

12:30 ◆ 昼 食

13:30 ◆ 講 演

「次世代への海洋生態系保全と水産食料安全保障－知床世界自然遺産地域の水産生態系アプローチと順応的管理」

桜井 泰憲

北海道大学大学院水産科学研究院 教授

「持続的増養殖生産を目ざしたサケの健康管理とHACCPシステムをベースとした安全・安心な秋サケ製品の提供」

吉水　守

北海道大学大学院水産科学研究院 教授

「海洋生態系保全と水産食料安全保障のための持続可能性」

帰山 雅秀

北海道大学大学院水産科学研究院 教授

15:00 ◆ 休 憩

15:30 ◆ パネルディスカッション

コーディネーター

齊藤 誠一

北海道大学大学院水産科学研究院 教授

パネリスト

袁 春紅

北海道大学大学院水産科学研究院 助教

「プランクトン食魚類ハクレンの養殖と加工利用 －中国における内水面漁業の持続可能な発展のために」

リザリタ・ロサレホス・エドパリナ

（Rizalita R.-Edpalina）

国連大学高等研究所いしかわ・かなざわオペレーティング・ユニット JSPS-UNU ポストドクトラルフェロー

「フィリピンにおける水産養殖インパクト軽減のための管理選択肢」

ラディアータ・I・イニヨマン (I Nyoman Radiarta)

北海道大学大学院水産科学研究院 学術研究員

「持続可能な増養殖業を目指した空間情報システムによるアプローチ」

石村 学志

北海道大学サステナビリティ学教育研究センター 助教

「気候変動に影響される多国間共有水産資源管理の直面する問題，そして，持続的管理に向けた挑戦 －自暴自棄な Pacific sardine 資源管理ゲーム分析と政策提言」

16:50 ◆ 総合討論

17:20 ◆ 閉会挨拶

山内 晧平

愛媛大学南予水産研究センター長

要　旨

＊ 和文要旨の一部は，実行委員により和訳・作成
　されたものが含まれますのでご了承ください。

招待講演

「水産食料と海洋生態系の保全のための空間生物経済学」

Spatial Bioeconomics for Seafood and Marine Ecosystem Conservation

ウッシフ・ラシード・スメイラ

Ussif Rashid Sumaila

ブリテッシュ・コロンビア大学 水産資源研究所 所長，カナダ

- 現在および未来の人類の利益と魚類資源の持続可能な利用のために，生態学と経済学を統合した生物経済学的空間指数を提唱する。

- この指数は，特別な管理区（例えば，海洋保護区）や経済学的視点に基づく区域（例えば，区画漁業権）などを GIS 技術を取り入れ評価する。

- この指数は，時代をこえて，対象魚のリスク資源管理，水産食資源と海洋生態系の保全の効果にきわめて有効であろう。

招待講演

「生態系ベースの漁業評価予測法」

An Ecosystem-based Fisheries Assessment and Forecasting Approach

チャン・イク・ツァン
Chang Ik Zhang

釜慶大学水産科学研究所 教授，韓国

漁業資源の管理と予測に，生態系ベースの包括的評価法が求められている。具体的には，対象種に対する捕食，競争，餌生物との生態学的相互作用，魚類と生息場，それらに対する漁業の影響などである。実際の生態系ベース評価は，持続可能性，生物多様性および生息環境特性からなる 3 つの管理目標を含む漁業資源評価のために発展してきた(Zhang et al. 2009)。この評価法は２段階法からなる。第１段階では，システムの状態を量的に評価できる十分な情報がある状態をデザインしている。第２段階では，定量あるいは半定量の評価を必要とする利用可能な情報がある状態をデザインしている。種，漁業および生態系の評価を発展させるために，第１段階で 20 の指標が，第２段階で 24 の指標が開発された。入れ子状の危険指標，例えば目的危険指数(ORI)，種危険指数(SRI)，漁業危険指数(FRI)および生態系危険指数(ERI)が，管理単位レベルで生態系の状態を評価するために開発された。本研究における生態系のための包括的な漁業危険評価，予測および管理(IFRAME)は，Zhang et al. (2009)をさらに発展させた手法で開発されている。IFRAME は付加的管理目標，社会経済学的利益と３つのサブモデル（評価，予測および管理）を有する。このモデルは韓国の大型巻網漁業で実証されている。この提案は，時空間的に種，漁業および生態系の状態を比較するために，生態系俯瞰による様々なシナリオのもとで管理選択枝のパフォーマンスを評価するために利用できることが分かった。

招待講演

「アラスカにおける持続可能なサケ漁業」

Sustainability of the Alaska Salmon Fishery

ウィリアム・スモーカー
William W. Smoker

アラスカ・フェアバンクス大学水産海洋科学部 名誉教授，米国

- アラスカではこれまで 30 年以上にわたりサケの年間漁獲数を 1 億尾以上維持している（2009 年：ベニザケ 4 千万尾以上，カラフトマス 9 千万尾，シロザケ 16 百万尾，合計 1.5 億尾)。今年の漁獲数は過去数十年間で中位に相当する。今年のサケ漁獲数のうち，プリンス・ウィリアム・サウンドのカラフトマスや南東アラスカのシロザケは孵化場魚が多くを占めるが，他はすべて野生魚であり，各地域の健全な生態系において資源管理された結果である。一部の地域個体群（南東アラスカのシロザケとカラフトマスの一部）では，最近，体サイズの小型化傾向が観察されている。

- アラスカのサケ漁業は，生態系を配慮した持続可能な資源管理を行っていることを理由に，アラスカ州政府を顧客として海洋管理協議会(MSC)より 2000 年にエコラベルの認証を得た（サケ属 5 種，16 ユニット)。それは 2007 年に更新されている。

- 認証を継続するためには，顧客は，毎年，詳細な報告書を提出し，査察を受けねばならない。次回の認証を受けるためには，2009 年までに顧客を決め，その準備をしなければならないが，その顧客としてアラスカ水産食料マーケティング協会(Alaska Seafood Marketing Institute)が有力である。

招待講演

「中国における水産養殖の現状と最近の進歩」
Current Status and Recent Advance of Aquaculture in China

譚 洪新
Hongxin Tan

上海海洋大学水産生命科学部 副研究院長，中国

国連 FAO によると，最近，水産物の消費量は増加する一方で，漁獲量は現状維持あるいは減少傾向を，養殖生産物は増加傾向を示している。発展途上国，とりわけ人口増加と産業発展の著しい中国では，21 世紀に水産養殖の著しい発展が望まれる。中国における水産養殖は，歴史が古く，最近では年 10%以上の成長率を示しており，その生産量は 1989 年以降世界最大である。今日，世界に占める中国の割合は漁獲量で 40%，養殖生産量で 70%に達する。中国は水産国であり，養殖生産量は漁獲量を超え，その 30%にあたる 9000 億円を輸出している。淡水養殖は，2006 年において面積 60,200 ヘクタール，生産量 1950 万トン（全体の 97%）に及び，その養殖技術は著しく向上している。また一方では，中国は環境汚染と水資源不足に悩んでいる。最近の漁業パターンは膨大な資源を消費するため，資源保護と環境保護にシフトすることが，科学的にもまた社会課題としても重要である。しかし，最近の水産科学の発展は，必ずしも水産業の育成に活かされていない。今後，資源節約型で環境に優しい持続可能な水産養殖が重要であり，生態学的，社会的，かつ経済学的視点から発展させる必要がある。代替養殖として，生態学的養殖，有機養殖，多種養殖，貝養殖，閉鎖低排水型システムなどがあげられる。これらは，広大な規模で実証されることにより世界へ広めることが可能である。生態学的養殖は，「生態学的原理と生態系を考えた養殖の研究と発展の代替モデル」と定義できる。生態学的養殖は，生産量の増加と同時に環境の改善をも図ることに焦点を当てており，持続可能な資源管理と沿岸区域管理も含んでいる。上海は，2007 年に，標準的な生態学的養殖基地を開始した。その基地は種苗生産，エビ養殖，養殖池や人工湿地帯などのように異なる機能からなる 20 の池をもつ生態学的システムからなる。第 11 期 5 カ年計画で 1200 ヘクタールの生態学的養殖域が完成した。上海は，水産養殖モデルの適用を広めるために，さらに低コストで高効率な手法を開発するだろう。

講演

「次世代への海洋生態系保全と水産食料安全保障
－知床世界自然遺産地域の水産生態系アプローチと順応的管理」

Ocean Ecosystem Conservation and Seafood Security for Future Generation　-A Case Study of Ecosystem Approach to Fisheries and the Adaptive Management of the Shiretoko World Natural Heritage Site

桜井　泰憲 [1)]，牧野　光琢 [2)3)]
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1．海洋生態系はどのように変化する

海洋生態系は，漁業を含む人間活動と地球温暖化を含む気候変化に応答して常に変化する非定常で境界のないシステムである。すでに，漁業生産は増える見込みはなく，未利用資源もほとんどなく，むしろ減少した資源の再生と現存する資源の持続的な利用が求められている。海洋生態系や回遊経路がわずか 30 年間で激変した例として，アラスカ湾の底性生物群集（エビからタラ類），オホーツク海で繁殖するトドの越冬回遊が，オホーツク海の流氷域面積の減少に伴って変化した例がある。はやり，地球温暖化が心配であり，日本の周りでも，過去 100 年間の海面水温は，特に黒潮，対馬暖流が流れる海域で 1℃以上も上昇している。IPCC（気候変動に関する政府間パネル）の第 4 次報告の 21 世紀中における温暖化シナリオの一つとして，2050 年に 2℃，2100 年に 4℃上がると予想している。温暖化に対する海の変化のシナリオを作り，それに対する対応策も不可欠で，すでに，ノルウェーでは温暖化してタラが北極海に移動することを想定して，タラの完全養殖を始めている。このようなシナリオにならないように，温暖化を何としても防ぐ努力が不可欠と言える。

今，心配されている海の変化では，より大きな魚の乱獲が進み，次第に小型魚の世界に変わって生物多様性は失われ，寿命が 1 年のイカ類やクラゲ類の世界になる可能性がある。事実，日本海は大型のエチゼンクラゲや中南米太平洋沖の大型イカ，アメリカオオアカイカが爆発的に増加が起きている。海洋生態系は，食物関係を通して気候変化が原因のボトムアップ制御と，捕食者側の大型魚の増減（漁獲が影響する）によるトップダウン制御が働いている。さらに，気候変化などによって大きな増減をするイワシなの浮魚類やイカ類がその上下の栄養階層の生物に影響する制御（Wasp-waist）があることが判ってきた。講演では，南東ベーリング海生態系におけるスケトウダラ資源の増減がもたらす生態系変化の事例を紹介する。

海の環境は数十年間続く寒冷期，そして温暖期への変化（海洋環境のレジームシフト）を繰り返してきた。東アジアでは，冬の季節風（北西風）の強さが海の水温やオホーツク海の流氷の多さに影響を受けている。1970 年代半ば-1980 年代後半の寒冷レジーム期には，マイワシの爆発的増加があり，1988/89 年の温暖へのレジームシフト以降は，温暖な時に増えるカタクチイワシ，アジ，スルメイカが増えている。この現象は，海洋環境のレジームシフトに伴う“魚種交替”と呼ばれている。海洋生態系は複雑で変化の予測が難しいシステムである。将来何が起きるか，観測，生物採集などのモニタリング，

さらにモデリング，過去の出来事の解析などをもとに，予防原則に基づいた順応的管理を進める「持続可能な漁業管理を目指した生態系アプローチが」必要である。

2. 知床世界自然遺産海域における生態系アプローチと順応的管理

2005 年 7 月に，知床はユネスコにて世界自然遺産に登録され，岸から 3km までの海部分が遺産登録地域に指定されている。登録の際には，海域部分の管理保全にむけた海域管理計画の策定，加えて，サケ類が川に昇れるようにダムなどの改善が求められた。知床は，その豊かな海の生産を背景に，サケ・マスの定置網漁業やスケトウダラの刺し網・延縄漁業が営まれている。2008 年春に，知床の生態系の豊かさと持続的漁業の共存に向けた海域管理計画（環境省・北海道）を策定した。基本的なコンセプトは，既存の法律などのルールに加えて，漁業やリクリエーションでは，自主的管理方法の両輪で実施すること，適切な管理方策のための，海洋環境と生物のモニタリングなどを通して，海域と海洋生物の保護を行うルールを決めることである。知床の海では，トド，海ワシ類，鯨類などの高次な栄養階層からスケトウダラ，ホッケ，スルメイカ，さらには多様な生物の食うー食われるの関係が営まれており，漁業もその構成要素である。羅臼側のスケトウダラ漁業では，過去の漁獲量の激減などを経験している。これまでに，減船に加えて，スケトウダラの産卵場の禁漁区設定，漁具の刺し網の網目を大きくするなど，漁業者自身による自主的漁業管理のルールを作って，資源の保護に努めている。知床では，すでに海洋生態系の順応的管理は行われ，モニタリング，モデリング，管理計画の設計と実施，さらにそれを見直しながら，順応的な持続的漁業と海洋生態系の保全の両立に向かっている。

知床では，世界自然遺産にかかわる多様な委員会があり，中でも科学委員会には，国，北海道，町などの行政機関，科学者，漁業者も参加して，管理方策を検討している。どの委員会にも漁業関係者が参加しており，このような例は，国内外でも例を見ない。このような各種委員会が相互に機能して，環境の再生や保全，科学的なモニタリング，その評価を行う科学委員会の開催など，知床世界自然遺産地域の保全に向かっている。これにかかる費用は，2006 年を例にすると，この海域の漁業生産の約２％（約４億７千万円）に満たない。「知床方式」と呼ぶこの管理方策は，漁業者自らの知識と自主的漁業管理，多様な生態系を構成する海洋生物との共存（生態系アプローチによる漁業管理），であり，その意思決定に漁業者も参加している。ユネスコの世界自然遺産センターの Rao 所長は，「知床は，世界の海域を含む世界自然遺産の環境保護に向けた新しいモデルである」と高く評価している。

3. 最後に

持続的漁業と生態系サービスに基づいた生物多様性の保全は，相対立するものではない。知床の漁業者は，この共同管理に生態系アプローチを用いて積極的にかかわっている。責任ある漁業として，多様な水産生物の節度ある利用は，健全な海洋生態系の鍵種や構成要素ともいえる。ただし，ロシアが実効支配している北方４島がすぐ目の前にあり，ロシアによるトロール漁業でスケトウダラが漁獲されている。近い将来，北方４島を含めた世界自然遺産として，この海域の生態系の保全と持続的な漁業の共存できること，そして，この取り組みが，地球を１周するほどの沿岸線を持つ日本の豊かな海を守り続ける大切な一歩となることを願っている。

講演

「持続的増養殖生産を目ざしたサケの健康管理と HACCP システムをベースとした安全・安心な秋サケ製品の提供」

Health Management of Hatched Fry for Sustainable Salmon Propagation and Provides “Safe and Worry-free” Salmon Products

吉水 守
Mamoru Yoshimizu

北海道大学大学院水産科学研究院 教授

水産増養殖の最終目標は食料資源の生産供給であり，安全で安心して食べることのできる魚介類の提供が求められている。サケ資源を食料源として持続的に有効活用するためには，健康種苗を育成・放流し，資源管理のもと，成長した個体を捕獲して安心して食べられるよう，漁獲から加工，流通・消費者に至る過程を管理する必要がある。

魚を家畜同様，ヒトが管理すると病気の発生は避けられず，適切な防疫対策の実施が必須である。サケ・マス類の病原体は，成熟時に卵巣腔液や精漿に出現し，卵子や精子が汚染される。古くはこの汚染発眼卵が病原体伝播に大きくかかわり，孵化稚魚の発病による産業被害を引き起こした。現在は採卵親魚の健康調査を実施し，病原体の疫学調査に資すると共に，受精直後および発眼期に卵表面の消毒を行い，病原体フリーの用水で孵化・飼育を行って健康種苗を確保して放流している。

漁獲後は，食品としての安全性を確保すると共に消費者に安心を提供することが重要である。安全性は科学的に確認でき，客観的に評価できるが，安心は安全性と異なり心的な問題である。食品として信頼して食べるためには，健康障害を起こす可能性のある要因を科学的に整理し，その成果を安全性確保に生かす必要がある。現在はリスク分析手法を用いて，生産現場から食卓までの危害分析（HA）を行い，重要な管理点（CCP）を設定して，リスクを制御する方法が広く採用されている。加工場の HA-CCP のみならず，リスク管理を導入したフードチェーン・アプローチによって安全性が確保され，トレーサビリティーの導入により消費者に生産者の顔が見えるようになり，食品産業に従事する人々も責任を自覚するようになってきた。

水産食品には，刺身や寿司に代表されるように，加工工程で熱を加えないものも多く，これらの安全性を確保するには，加工場での衛生管理はもちろん，原料段階での衛生管理・品質管理が重要である。加工原料としての漁獲物を衛生細菌による汚染から守ることは，より安全な食品を消費者へ提供するために必要な処置と考える。漁獲から消費者までの水産物の流れは，漁場→漁港→産地卸売市場→加工場→消費地卸売市場→小売店→消費者となっている。加工場から消費者への行程は衛生管理が普及しているが，漁獲から加工場に至るまでの漁港を含めた食品衛生に関する配慮がいま求められている。衛生管理型漁港の整備，漁港の衛生レベルの設定，水産物の衛生品質管理に優れた産地市場を認定し，認定市場を参考に産地市場の衛生品質管理の向上を目指す取り組み，さらに養殖魚の JAS の導入が進んでいる。資源管理に関しても MSC（Marine Stewardship Council）に対抗し日本版マリンエコラベル(MEL-Japan）が設立されている。今回，北海道の代表的な水産物であるサケを例に，漁獲から加工・流通・消費に至る各過程での衛生管理，特に，今まで見過ごされてきた漁獲から加工場に入るまでの衛生管理の必要性とトレーサビリティーについて考え，地域ぐるみの衛生管理を紹介したい。

講演

「海洋生態系保全と水産食料安全保障のための持続可能性」

Sustainability Sciences for Ocean Ecosystem Conservation and Seafood Security

帰山 雅秀
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FAO 統計によると, 2006 年の世界水産生産量は 110 百万トンに及ぶが, 漁獲量(53%)は 1990 年代以降減少傾向を示し，養殖量(47%)が近年著しく増加している。世界の 29 億人が水産生産物を食糧として利用し，一人当たりの年間消費量は 2006 年 16.7kg に増加し，動物タンパク質消費量の少なくとも 15%を占めている。漁獲量の減少は乱獲に負うところが大きく, 例えば北大西洋のクロマグロは絶滅危惧種に位置づけられている。一方，生産量が増加の一途をたどる養殖においても，例えばわが国で 20 万トン以上輸入している養殖エビの生産地では養殖地造成によるマングローブ林生態系の破壊や抗生物質汚染が拡大しており, 養殖生産量の増大が海洋を含む地球生態系の驚異となりつつある。一方，わが国のシロザケ資源は長期的な気候変動とリンクして最近増加傾向を示してきた。特に，最近の地球温暖化はシロザケ資源の増加にプラスの役割を果たしてきました。しかし，近い将来，その影響はマイナスに転じることが予想される。

ここでは，陸域の食資源が生産飽和状態であることを踏まえて，水産資源がサステナブルな食資源として今後ますます重要性を増しつつあること, 人類は不確実性の高いダイナミックな地球生態系と共存しなければ生きて行けないことを認識し, 海洋生態系を保全しつつ水産食資源の持続的利用をどのように図っていくかについて，ケース・スタディとしてサケ属魚類を例に紹介する。その上で，われわれが取り組まねばならないアクション・プランとして，伝統的な水産学から生態学的水産海洋学へのパラダイムシフトの必要性と持続的可能な社会をめざす順応的管理と予防原則によるリスク管理について述べる。

パネルディスカッション

「プランクトン食魚類ハクレンの養殖と加工利用
－中国における内水面漁業の持続可能な発展のために」
Culture and Processing of Silver Carp, a Plankton Feeder Fish
－for Sustainable Development of Freshwater Fisheries in China

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中国の淡水養殖生産量は 2007 年に 1971 万トンを記録した（中国漁業統計年鑑）。内陸の淡水養殖だけでも最近の日本の漁業生産量の三倍になる。その内，ソウギョは355.6 万トン，ハクレンは 307.56 万トン，コイは 222.86 万トン，コクレンは 213.54 万トン，フナは 193.71 万トン。ハクレンは第二位で，淡水養殖総生産量の約 16％を占めている。中国の淡水養殖の特徴の１つは混合養殖である。混合養殖は異なる食性を持つ魚を同じ池で養殖するシステムで，養殖池の中では，上層魚はプランクトン食性（ハクレン・コクレン），中層魚は草食性（ソウギョ・ダントウボウ），そして下層魚は雑食性（コイ）が適切な比率で同時に飼育されている。ソウギョは草類を，ハクレン・コクレンは排泄物で培養されたプランクトンを，下層では雑食性魚類が余剰物質を食べ，一つの池の中で食物連鎖を巧みに利用したシステムが作られている。このシステムでソウギョは立体的生物濾材（餌として摂った草類の cellulose particle）を提供し，ハクレンは濾材のクリーニングを行っている。アオウオやコイも底質の保全に役立っているとなる。つまり，混合養殖のシステムは，池の水質浄化を行う微生物や原生動物の集塊である活性生物フロック（活性汚泥）を培養し維持管理する機能を持っているのだと言われる。これらのことから，大量ハクレンの養殖生産が必要である。

しかし，これまで高い生産性を支えてきたハクレン等は消費者から次第に敬遠され，廉価のため加工による付加価値の向上が量的再生産を持続させるために必要とされている。淡水魚の食品利用を考えた場合，筋肉を構成するタンパク質，ミオシンがどのように変化するのかが，最も重要なことであると考えられる。なぜなら，筋肉タンパク質の主要成分で，肉製品の品質を決定付けているのは，ミオシンの性質であるからである。淡水魚は海水魚と異なり，季節または環境水温に対応してミオシンアイソフォームが発現する。この事実は同じ魚種でありながら，夏と冬では全く違う魚種と見なさなければならないことを示している。このような状況になれば，それぞれの淡水魚の筋肉タンパク質の特性を知らなければ利用が難しい。したがって，淡水魚肉タンパク質の加工機能に関する基礎ならびに応用の双方の研究に着手することが問題解決のために必要だと思われる。そこで，私たちは現在，日本で培われた魚肉タンパク質の研究成果を用いて問題解決を行いたいと考えている。淡水魚ハクレンを研究することにより，地域また季節のことを考慮して，魚肉加工品素材としての機能性を明らかにし，種々の製品への高度利用が可能となる。こうして淡水魚が多く生息する東南アジアへの技術協力に結びつける。また，発展途上国をはじめとする国際的な食料需給に対しても重要な意味を持つものである。

パネルディスカッション

「フィリピンにおける水産養殖インパクト軽減のための管理選択肢」
Management Options to Mitigate Environmental Impact of Aquaculture in the Philippines

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- アジアは世界の水産養殖の 91%に相当する 4,690 万トンを生産している(FAO 2005)。水産養殖生産量は最近 10 年間で著しく増加し,その傾向は特に中国で顕著である。

- 東南アジアにおける水産養殖は，淡水魚(41.6%)，藻類(23.5%)，甲殻類(6.7%)，海産魚と通し回遊魚(7.3%)および軟体動物(21.1%)に区分される。

- この水産養殖は，最近，様々な課題を抱えている。最も顕著な問題は，エビ養殖によるマングローブ林生態系の破壊と人間社会に及ぼすその影響である。

- このパネル・デスカッションでは，フィリピンにおける①水産養殖に関する政策と法律と②水産養殖による環境インパクト（汽水域，淡水養殖場，海網生け簀）について概括し，フィリピン水産養殖の将来展望について述べる。

パネルディスカッション

「持続可能な増養殖業を目指した空間情報システムによるアプローチ」

Spatial Information Systems Approach toward
Sustainable Aquaculture

ラディアータ・I・イニヨマン [1)2)]，齊藤 誠一 [3)]
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増養殖業は最も急速に発達した食料生産業である。現在では，増養殖業の生産量は，全世界で消費される魚介類のおよそ 50%に相当し，今後予測される水産食料品需要の拡大に対し非常に大きな可能性を持っている。増養殖業は水産食料生産を支えるだけでなく，沿岸住民の貧困や経済格差を緩和する上でも期待される。しかし，今日増養殖業が直面している問題は，増養殖業自身，あるいはその他の関連産業の発展から派生したものが主要因となっている。このような問題の解決には，包括的な増養殖計画，増養殖区域の規制および情報システムの管理が必要であり，これらが実践されることにより，養殖業のさらなる発展あるいは既存の増養殖業の持続が見込まれる。FAO 行動規範は増養殖計画および管理の方向性を定めており(FAO, 1995)，その中で生態系や生物多様性を尊重しつつも，水産資源の効果的な保全，管理および開発を視野に入れた責任ある行動をとるための理念と国際基準が明記されている。

増養殖業に関する情報として，これまで環境や水質，社会経済といったデータが主に集められてきた。しかしながら，空間要素を提供できるような研究はほとんど行われてきていない。持続可能な開発を行うためには，時空間的パラメータを考慮した理論的枠組みを確立させることが必要である。地理情報システム（GIS）やリモートセンシング(RS）は，増養殖業の開発・管理における地理的・空間的観点において重要な役割を果たす。GIS および RS は環境制限や資源量限界の把握といった地理的枠組みを定義する上でも利用されており，増養殖業においても GIS と RS の応用は急速に拡大している。

増養殖業における GIS や RS の実用では，多岐にわたる対象種が設定され，またその目的も，増養殖に適した海域の特定や，増養殖業による環境への影響の評価など様々である。その一例として，我々は噴火湾におけるホタテ養殖海域において，複数の RS データを基に GIS を用いて複数基準分析を行い，ホタテ養殖最適海域の空間モデリングを開発した。FAO の漁業・増養殖管理部門は，空間情報システムの利便性を評価し，漁業や増養殖管理の開発において漁業・増養殖データの解析のために空間解析ツールと地理関連情報（GISFish, P28 英文要旨参照）の利用を推進している。さらに，海色衛星リモートセンシング業界において，SAFARI（Societal Applications in Fisheries and Aquaculture using Remotely-Sensed Imagery, P28 参照）を通して漁業・増養殖管理のために RS の利用を進めている。

本講演における主な目的は，増養殖業の持続可能な開発をサポートし，増養殖業のよりよい計画と管理を実現するために GIS および RS が有用であることを理解してもらうことにある。GIS と RS の発展は，能率的で費用効果の高い持続的な増養殖管理を行う上で強力なツールとなるだろう。これらの技術はまた，増養殖業に関連する意思決定過程を促進するにも有用となる。

パネルディスカッション

「気候変動に影響される多国間共有水産資源管理の直面する問題，そして，持続的管理に向けた挑戦 －自暴自棄な Pacific sardine 資源管理ゲーム分析と政策提言」

Sustainable Management of a Transboundary Fishery Resource under Climate Variability: Desperate Fishing Games of Pacific Sardine Resource

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地球温暖化を含めた急激な気候変動へどのように適応してゆくべきか。それが人類の生存にとって解決しなければならない重要な課題であることは，日々明らかになりつつある。局地的な豪雨や強大化する台風による水災害，温暖化による海面上昇など，気候変動の不確実性のもとに起こる問題に対して，これから我々は一つひとつ対処し，変わりゆく環境に適応してゆかなくてはならない。

水産資源管理もその例外ではない。水産資源管理は，漁業という経済活動を通した人間と水産資源動態の相互関係を，広義の漁業規制を通じて管理し，1)水産資源の自立的再生産維持（個体成長や繁殖)のための資源量保護や，2）経済活動としての漁業および関連産業育成，3)食料としての市場への安定的水産物供給などを含む，持続的水産資源利用を目指すものである。海洋環境を変遷させ，不安定にする気候変動へどう適応していくかは，持続的水産資源利用を目指す水産資源管理にとって避けることのできない課題になりつつある。特に，複数国で排他的に共有される水産資源管理と，その水産資源漁業に従事する人々へは，気候変動によって引き起こされる現象が深刻な影響を与えることになる。気候変動が海洋環境を変えることにより，これまで水産資源の生育に適していた生理的環境，水産資源の餌となるプランクトン類の量などを変遷させ，結果として水産資源の 1)資源量変動（例えば魚の数）と 2)空間的資源分布変動（例えば複数国間の排他的経済水域にまたがる魚の移動など）を引き起こす。こうした気候変動の影響は，複数国で共有される水産資源の持続的利用の達成を阻み，さらには資源崩壊をもたらす恐れさえあるため，すみやかな解決が求められる差し迫った問題であると言える。

こうした気候変動の影響を大きく受ける複数国による排他的共有水産資源の一つに，カリフォルニア海流に生息し，カナダ，アメリカ，メキシコの三カ国で漁業がおこなわれている Pacific sardine（以下，マイワシ）がある。マイワシは，過去 70 年あまりの間でカリフォルニア海流の気候変動の影響を受け，資源量増減（温暖期に資源量増，寒冷期に資源量減）や，空間的資源分布（温暖期に広域に分布，寒冷期に狭域に分布）が大きく変化した。それにともない，三カ国における漁業も繁栄と衰退を繰り返してきた。しかしながら，現在まで，この三カ国による共同の資源保護や持続的資源利用に向けた協力的な取り決めが結ばれたことはない。そこで，我々はこれまでこの三カ国の漁業モ

デルと資源量及び空間的分布が気候変動の影響を受けるマイワシ資源変動モデルを統合した生物経済モデル（bioeconomic model）を作り，経済学やビジネス分野で使われるゲーム理論分析（非協力，協力，部分協力）を応用したモンテカルロ・シミュレーションをいくつかの気候変動シナリオに沿って走らせ，持続的資源利用のための経済・生物学的リスク分析をおこなってきた。我々のマイワシでの研究では，気候変動下，複数国で排他的に共有されている水産資源の持続的利用，また資源からの利益の最大化は，空間的資源分布が変化することにより 1)最も資源の占有率の大きい国が単独で目指してもフリーライダー（この場合，協力的資源管理の枠組みに入らず，自らの負担なしに資源からの利益を得る国）のために達成されない，2)国際協力の前提となる各国の内政水産政策に依存する，3)経済的合理性を仮定するとき，理論的には絶対安定な三カ国間での協力した水産資源管理政策は達成できない，といった結果が示された。この結果によって，気候変動下で持続的資源利用を達成するためには，マイワシのカナダ，アメリカ，メキシコでの，三カ国間での譲渡可能な漁獲割り当てなどの，柔軟な協力的共同資源管理体制の早急な確立が必要であることが明らかとなった。

持続的資源管理を目指した水産資源管理, 特に複数国が水産資源を共有する国際水産資源管理においての気候変動への適応は，早急な課題である。気候変動に対して，敏感に資源量が変化する水産資源を持続的に管理，利用するためには，リスク分析に基づいた積極的な資源保護のための予防的方策が 不可欠であり，空間的資源分布が変動する資源に対しては, 国境を越えた漁獲割り当ての譲渡の柔軟な枠組みが必要だと考えられる。こうした問題の対応，解決には，水産資源そのものを扱う水産学や，気候変動を扱う地球科学の研究の他に，漁業や水産物市場分析などの経済学研究，加えて漁業権等を取り扱う法研究など, 高度に学際的な研究や水産資源管理手法が必要になることが予想される。つまり，気候変動下の水産資源管理研究は，元来の水産学の枠組みのみでは，解決の難しい問題なのである。しかし，言い換えれば，実学であるべき水産学を，学際的な分野を有機的に統合した学問体系へと広げる機会に満ちた課題でもある。これから北太平洋の国際共有水産資源管理では, 気候変動によるこうした問題が発生することが予想される。しかし，こうした学際的な取り組みは日本のみならず，他国でもこれまでほとんど行われていない。我々が国際共有水産資源の持続的資源管理を行ってゆくためには，人材育成も含めた，新たな学際的水産学教育プログラムの創出が急務である。

本シンポジウムの開催に当たり下記団体のご協力を得ました。
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プログラム＆要旨集

主催：北海道大学大学院水産科学研究院
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