

**UJNR Aquaculture Panel      35<sup>th</sup> Scientific Symposium**



November 13<sup>th</sup>-14<sup>th</sup>, 2006

**Building Sustainable Food Supplies  
through Aquaculture, Wild Stock Enhancement,  
and Habitat Management**

**Program and Abstracts**



**National Research Institute of Aquaculture,  
Fisheries Research Agency, Mie 516-0193, Japan**

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### **Building Sustainable Food Supplies through Aquaculture, Wild Stock Enhancement, and Habitat Management**

#### Aim of the symposium:

The role of aquaculture in stabilizing food supplies has been globally important, while production based on capture fisheries has become depressed due to the decline of wild resources and over fishing. Since the sustainable use of resources in the exclusive economic zone (EEZ) was made an obligation by the United Nations Convention on the Law of the Sea, aquaculture technology R&D aimed to maintain sustainable production while preserving coastal environments and ecosystems have become the common issues to the US and Japan.

The UJNR Aquaculture Panel has discussed various science and technologies as follows: 1) algae and filter feeders aquaculture, 2) crustacean aquaculture and pathology, 3) ecosystems and carrying capacity of aquaculture grounds, and 4) finfish aquaculture in accordance with the 6th 5-years Plan (2002-2006). During the last year of the plan, how to achieve sustainable fisheries production and food supplies through aquaculture and stock enhancement will be explored among aquaculture scientists as well as socio-economists and member of governmental sectors, while summarizing discussions covering previously developed aquaculture technologies.

In the present symposium, the following issues will be discussed in order to promote the future sustainability of the fisheries community and fisheries industry by means of aquaculture and stock enhancement.

1. Aquaculture technologies harmonized with coastal ecosystems to realize sustainable production
2. Environmental conservation and mitigation technologies for sustainable use of aquaculture grounds
3. Conservation of genetic diversities and ecosystems for sustainable of aquatic resources
4. Sociological and economic measures for sustainable development and use of coastal resources

## **Program**

Monday, November 13<sup>th</sup>, 2006      Registration    13:00-14:00

**Opening remarks** (Yasuji Sakai, Japan Panel Chair)    14:00-14:10

**Aim of the symposium** (Kazumasa Ikuta)    14:10-14:15

**Keynote presentation** (Moderator: Kunihiko Fukusho & Conrad Mahnken)    14:15-15:00

An Overview of the US/Japan UJNR Aquaculture Panel, Past Present and Future

James P. McVey

**Coffee break**    15:00-15:15

**Session I. Aquaculture technologies harmonized with coastal ecosystems to realize sustainable production** (Moderators: Cheng-Sheng Lee & Takao Yoshimatsu)

1. Recent Progress in Closed Recirculation Seed Production System for Environmental Preservation in Japan    15:15-15:45  
Yoshihisa Yamamoto
2. Utilization of Waste *Porphyra* Products as Eco-friendly Feed Ingredients    15:45-16:15  
Tsuyoshi Sugita
3. The Relationship between Growth of Cultured Red Sea Bream (*Pagrus major*) and Method of Farming    16:15-16:45  
Takashi Uede
4. Manila Clam and Pacific Oyster Culture in Isahaya Bay – For the Sustainable Production in Stressful Environment -    16:45-17:15  
Junya Higano

Tuesday, November 14<sup>th</sup>, 2006      Registration    8:30-9:30

**Keynote presentation** (Moderator: Charles E. Helsley & Satoru Toda)    9:30-10:15

Recent Attempt towards Environmental Restoration of Enclosed Coastal Seas: Ago Bay Restoration Project Based on the New Concept of “*Sato Umi*”

Osamu Matsuda

**Coffee break** 10:15-10:30

**Session II. Environmental conservation and mitigation technologies for sustainable use of aquaculture grounds** (Moderators: Thomas A. Flagg & Hisashi Yokoyama)

1. The Role of Aquaculture in Integrated Coastal Management 10:30-11:00  
Charles E. Helsley
2. New Technology for Developing Biologically Productive Shallow Area in Ago Bay  
11:00-11:30  
Hideki Kokubu
3. Stable Isotope Analyses of the Trophic Structure of Macrobenthos on an Artificial Tidal Flat  
Developed using Sediments Dredged from Pearl-oyster Farms in Ago Bay 11:30-12:00  
Yuka Ishihi

**Lunch** 12:00-13:00

**Session III. Conservation of genetic diversities and ecosystems for sustainable use of aquatic resources** (Moderators: William Fairgrieve & Kazumasa Ikuta)

1. Introduced Species and Aquaculture 13:00-13:30  
Cheng-Sheng Lee
2. Countermeasures against Alien Fish (Largemouth Bass and Bluegill) in Lake Biwa  
13:30-14:00  
Atsuhiko Ide
3. Conservation Aquaculture Approaches for Hatchery Reform 14:00-14:30  
Thomas A. Flagg
4. Environmental Standards for Marine Aquaculture in the United States; Minimizing Negative  
Interactions of Escaped Farm Fish and Natural Populations 14:30-15:00  
Conrad Mahnken

**Coffee break** 15:00-15:15

**Session IV. Sociological and economic measures for sustainable development and use of coastal resources** (Moderators: Hiroyuki Sudo & James J. Sullivan)

1. Economic Evaluation of Various Roles and Functions of Propagation and Aquaculture  
15:15-15:45  
Yasuji Tamaki

2. Risk and Risk Management for Feed and Seed for Carnivorous Marine Fish Aquaculture  
15:45-16:15  
Michael B. Rust
3. Ecological Risk Assessment of Marine Fish Aquaculture in the Coastal Zone 16:15-16:45  
William Fairgrieve
4. The Measures for Sustainable Marine Aquaculture in Japan 16:45-17:15  
Ikuo Takeda

**General discussion** (Moderators: Michael B. Rust, Satoru Toda & Kazumasa Ikuta)  
17:15-17:30

**Closing remarks** (Robert Iwamoto, U.S.A. Panel Chair) 17:30-17:45

Keynote presentation 1

**An Overview of the US/Japan UJNR Aquaculture Panel, Past Present and Future**

**James P. McVey**

National Oceanic and Atmospheric Administration, Silver Spring, MD 20910-3282, U.S.A.

The UJNR was started by a proposal made during the Third Cabinet-Level Meeting of the Joint United States-Japan Committee on Trade and Economic Affairs in January 1964. The United States and Japanese counterpart panels on aquaculture were formed in 1969 under the United States-Japan Cooperative Program in Natural Resources (UJNR).

The panels currently include specialists drawn from the federal departments most concerned with aquaculture and, on the US side, Sea Grant Directors responsible for conducting research programs on aquaculture funded by the National Oceanic and Atmospheric Administration (NOAA). Charged with exploring and developing bilateral cooperation, the panel has focused efforts on exchanging information related to aquaculture which could be of benefit to both countries.

## **Recent Progress in Closed Recirculation Seed Production System for Environmental Preservation in Japan**

### **Yoshihisa Yamamoto**

Yashima Station, National Center for Stock Enhancement, Fisheries Research Agency,  
Kagawa 761-0111, Japan

Recently, there have been some problems with mariculture in Japan, and the most serious problem is self-pollution by mariculture using net cages. In some reports on nitrogen balance, it was shown about 70 % of total nitrogen by mariculture using net cages was discharged into the coastal waters. From the viewpoint of coastal environmental preservation, a closed recirculation system is spotlighted for rearing technology that is a type of “Zero Emission” by few discharges from fish rearing. Complete system control has led to a lot of benefits which are (1) reduction of pollution, (2) avoidance of external risks (e.g. disease and bad water quality etc.), (3) highly stable productivity, and (4) energy-saving effect. Therefore the development of efficient closed recirculation system and rearing technology using this system will be demanded quickly for formation of commercial scale rearing technology.

In the Yashima Station, NCSE, FRA, technical development of a closed recirculation system for seed production in red sea bream was started in 2000. The closed recirculation system in this center consists of a foam separation unit, an efficient bio-filtration system (filtrating materials volume is only 5% of the total water volume) and a UV system. Their functions are the removal of organic matter in rearing water, nitrification and sterilization of bacteria, respectively.

At present, we have been able to demonstrate most of above benefits in our experiments and the technical results of seed production using this system are higher than those of flow-through rearing. By using a closed recirculation system, (1) water exchange rate is minimal (below 0.5%/day). Therefore we can establish a near-perfect no discharge system for seed production. (2) In case of tiger puffer, avoidance of disease (*Vibrio anguillarum*) was achievable. (3) Survival rate and production densities of red sea bream from hatched larvae to juveniles of 30 mm in TL consistently reached 45~70 % and 5,000~7,000 individuals /kl respectively and highest density of 20,000 individuals /kl was achieved for 25 mm in TL. (4) As a result of estimation of seedling cost, advantages of running cost for keeping suitable rearing water temperature was found. Also for water quality, concentrations of ammonia nitrogen and nitrite-nitrogen in rearing water were kept below 1.0mg/l and 0.5mg/l, respectively. Therefore under the condition of minimal water exchanging rate, seed production by closed recirculation system is kept in suitable water conditions for survival and growth of juveniles.

For environmental preservation, we will try the newly developed waste treatment system by safety biological and physical methods and integrated aquaculture using biological eco-system which utilizes the nitrogen cycle, (e.g. phytoplankton, seaweed, shellfish, sea cucumber and polyceates). In the future, as the strategy for environmental preservation, it is necessary that the Japanese Government support new companies which use the closed recirculation aquaculture system and aquaculture companies which convert to the aquaculture system from net cage rearing to closed recirculation system for the reduction of self-pollution.

## **Utilization of Waste *Porphyra* Products as Eco-friendly Feed Ingredients**

**Tsuyoshi Sugita, Takeshi Yamamoto, and Takao Yoshimatsu**

Aquaculture Systems Division, National Research Institute of Aquaculture,  
Fisheries Research Agency, Mie 516-0193, Japan

Fish meal is an important feed ingredient for fish feeds because of its high nutritive value. However, the supply of feed-grade fish meal has recently been coming short due to the reduction of its production and increasing demand for formula feed production in the world. On the other hand, environmental pollution by nitrogen and phosphorus loading from fish farming has become a serious problem. Although the deterioration of water quality by phosphorus could be reduced using plant protein sources, the reduction of nitrogen emission could be achieved by reducing the dietary protein content with alternative dietary amino acids being balanced. Therefore, developing low or non-fish meal diets would become a promising mean to solve these problems. Nori, *Porphyra* spp. (red algae, purple laver) are commercially and culturally important species used widely as Japanese traditional foods. Nori products also contain high amounts of taurine, which is an important amino acid for marine fish, in addition to minerals and vitamins. In this paper we summarize our trials to develop an eco-friendly fish feed using waste nori of no commercial value.

Fingerling red sea bream *Pagrus major* (average body weight 10.1 g) were fed for 10 weeks on an optimal fat and protein (11 and 55 %) control diet and 2 experimental diets high fat and low protein (19 and 42 %, 25 and 36 %). All diets were supplemented with 5 % waste nori. Weight gain, specific growth rate and feed efficiency for the diet containing medium fat level were not different compared with those for the control diet, whereas those for the diet containing the highest fat level noted the lowest values among the diets. These findings suggest that dietary protein content can be effectively reduced from 55 % to 42 % by supplementing 5% waste nori in diets.



## **The Relationship between Growth of Cultured Red Sea Bream (*Pagrus major*) and Methods of Farming**

**Takashi Uede and Terufumi Takeuchi**

Fisheries Experimental Station of Wakayama Prefecture, Wakayama 649-3503, Japan

Wakayama Prefecture is located in the southwest of Honshu Island, Japan. The aquaculture industry is an important industry in Wakayama that occupies 1/4 of the total amount of all fishery products. The main aquaculture target fish is red sea bream (*Pagrus major*), and it reaches 80% of the total aquaculture production. In 1980's, the deterioration of the sedimental environment and the frequent occurrence of red tide were observed with an increase in the aquaculture production in Tanabe Bay where is one of the biggest aquaculture sites of our prefecture. After 1990's when the production had decreased by the depression of the fish value, both of these problems were improved. Hence, the environment of the Bay and the aquaculture production are regarded to be closely related by these findings. Therefore, to establish efficient use of the fish farming ground, we conducted a series of test research concerning rearing conditions of red sea bream. We introduce the following three cases here.

### *Loads of discharged of leftover feed and feces in red sea bream farming*

Some 3.6~15.6% of extrude pellets (EP) fed were discharged as leftovers and 7.7~21.8% of them were discharged as feces. In case of moist pellets (MP), discharged proportions of leftovers and feces were 10.1~19.2%, 12.8~30.0%, respectively. As a result, necessary amount (in dry weights) of EP to satiate the cultured red sea breams is 2.18 times greater than that of MP. Amount of feed particles discharged in the case of EP feeding is 2.92 times greater than the case of MP.

### *Relationship between feeding frequency and growth of red sea bream*

Red sea breams (130 ind., average weight 300 g) were distributed in three fish cages (22.5 m<sup>3</sup>), and feeding experiments were conducted for 225 days from March 14, 2003. The feeding frequencies were four (Ex.1), three (Ex.2) and two (Ex.2) times a week, respectively. As a result, the best growth was obtained in the fish cage of Ex.1 with high feeding frequency. Moreover, the growth of Ex.1 was better than the average fish growth obtained in three private farms in the prefecture. Therefore, the growth of red sea bream was enhanced with the increase of the feeding frequency.

### *Relationship between Edwardsiella disease outbreak and breeding densities*

Red sea breams (average weight 410g) were distributed in the four fish cages (22.5 m<sup>3</sup>) with the densities of 2.4 (Ex.1), 3.6 (Ex.2), 4.7 (Ex.3) and 5.7 kg/m<sup>3</sup> (Ex.4), respectively, and rearing experiment was carried out for 140 days from April 9, 2004. The mortality of red sea bream in Ex.2 due to the outbreak of *Edwardsiella* disease increased rapidly from the 100th day, although the best fish growth was maintained until the 130<sup>th</sup> day. Mortality gradually spread to Ex.3 and 2, and it occurred in Ex.1 after 130th days. As a result, when the rearing trial terminated, the stocking densities of Ex.2~4 became 4.8~5.7 kg/m<sup>3</sup> of the same level. Cumulative mortality rates of Ex.1~4 were 13.9, 11.8, 37.7, 48.7%, respectively, and affected its stocking density.

Presentation I-4

**Manila Clam and Pacific Oyster Culture in Isahaya Bay  
-For the sustainable production in stressful environment-**

**Junya Higano<sup>1</sup>, Keiji Hirano<sup>2</sup>, Shigeru Kitahara<sup>2</sup>, Masahiko Matsuda<sup>2</sup>,  
Kouji Mizuta<sup>2</sup>, Akihiko Fujii<sup>2</sup>, and Akira Shinagawa<sup>3</sup>**

<sup>1</sup>Aquaculture Systems Division, National Research Institute of Aquaculture,  
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Isahaya Bay is a branch of Ariake Sound, Kyushu, where tidal range is the largest in Japan. Panshell, *Atrina pectinata*, was dominant fisheries product in Konagai Fisheries Cooperative and caught by means of diving equipments. However, after the construction of Isahaya Reclamation Project it was diminished in 1990s. Culture of Manila clam, *Ruditapes philippinarum*, commenced 1970s and is currently the most important industry in the Cooperative. The marked characteristics of the clam culture in the Cooperative are introduction of demarcated fishery for Manila clam culture under common fishery right, individual management of culture ground such as sand placement on muddy substrate and several facilities for accumulating the juvenile clams and preventing predators, registered landing under the cooperative sales. The annual landing normally reaches 400-700t for ca. 100 individual fishermen. But Manila clam culture occasionally suffered from mass mortality in summer season since 1998 when the barrage in Isahaya Reclamation closed in the previous year. We studied about the mass mortality from the aspects of environment and physiology of the clam and elucidated that the main cause of mass mortality was anoxia by mean of continuous monitoring of water quality factors and analysis of organic acids in the pallial cavity fluid of Manila clams.

For sustainable and stable production of Manila clam, prediction and prevention of anoxic water intrusion to the culture ground are foremost important. Suspended culture of Pacific oyster, *Crassostrea gigas*, was introduced in late 1990s in Isahaya Bay which had naturally been produced delicious native oysters inhabited near the shoreline. The oyster culture industry has grown up to 175t of annual production by 42 fishermen in 2005. The oyster culture contributes to compensate for the reduction of Manila clam production. The seeds of cultured oyster were transported from Miyagi Prefecture, northern Japan. The growth of cultured oyster is very well and is able to harvest the excellent quality oysters in only half year growout culture. However, there are several problems for constricting the increase of the production, namely, summer mortality after spawning, heavy fouling by barnacles and lower consumer's demand in local market, etc. Exploit of the market demand and improvement of the culture technique are necessary.

Keynote presentation 2

**Recent Attempt towards Environmental Restoration of Enclosed Coastal Seas:  
Ago Bay Restoration Project Based on the New Concept of “*Sato Umi*”**

**Osamu Matsuda**

Professor Emeritus, Hiroshima University  
Core Research Laboratory, Ago Bay Restoration Project, MIESC, Mie 517-0501, Japan

Since the present status of the enclosed seas along the coast of Japan is more or less "damaged" or "deteriorated" mainly due to prolonged impact of human activities, environmental restoration followed by rehabilitation of natural ecosystem is one of the most important subject to be tackled from the view point of both environment and natural resources. Among 88 officially designated enclosed coastal seas in Japan, Ago Bay is one of the deteriorated bay especially from the view point of aquaculture ground. Although the bay is known to be a world-famous cradle of pearl culture, conditions of the bay in terms of sediment quality, dissolved oxygen and harmful algal blooms have been deteriorated during the long history of pearl culture spanning more than 100 years.

The ongoing “Environmental Restoration Project on Enclosed Coastal Seas in Ago Bay” conducted under the CREATE program of Japan Science and Technology Agency mainly deals with restoration of deteriorated tidal flats and sea grass beds and also development of environmental forecasting technology based on the environmental monitoring and modeling. Since the project includes not only scientific and technological studies but also includes components of environmental education, environmental management and wider cooperation with varieties of stakeholders, it can be a model of environmental restoration and management of enclosed coastal seas.

Outline of the project as well as the present status and future perspective will be introduced in the presentation with particular emphasis on the new concept of “*Sato Umi*”. “*Sato Umi*” in Japanese means coastal sea under the harmonization of sustainable wise use with conservation of appropriate natural environment and habitat conditions. Compared with deteriorated coastal environment, “*Sato Umi*” is able to provide higher biological diversity for habitat and higher biological productivity for living resources. These characteristics of “*Sato Umi*” are also suitable site for demonstrating multi-functional roles of fisheries. Restoration method for damaged shallow environment and habitat with use of environment friendly technology based on the concept of “*Sato Umi*” is being developed and applied in Ago Bay.

Presentation II-1

## **The Role of Aquaculture in Integrated Coastal Management**

**Charles E. Helsley**

School of Ocean and Earth Science and Technology  
University of Hawaii, Honolulu, Hawaii, HI 96822, U.S.A.

Coastal ecosystems have evolved to be in balance with the supply of nutrients from oceanic upwelling and runoff from land. Over or under supply of these essential nutrients can upset this balance and shift the ecosystem in undesirable way, at least undesirable from a human perspective.

Most coastal ecosystems are no longer in balance with the supply of nutrients for anthropogenic effects on shore and in the immediate offshore have greatly modified the natural system. Aquaculture can contribute to this problem or it can be practiced in an extractive mode and thus be used as a means of balancing this equation. Nutrient extractive aquaculture includes the culture of seaweeds (algae) and bivalves. It is also possible that certain filter feeding fish could also be used in this mode.

Models of ecosystem management can incorporate both extractive and additive aquaculture but most applied aquaculture does not follow these models for the economics of production and use of manpower and equipment heavily favors the nutrient additive forms of aquaculture. Nevertheless, it is instructive to examine the more balanced form of aquaculture to see if it can make economic sense.

## **New Technology for Developing Biologically Productive Shallow Area in Ago Bay.**

### **Hideki Kokubu and Hiroyuki Okumura**

Fisheries Research Division, Mie Prefectural Science and Technology Promotion Center,  
Mie, 517-0501, Japan

Ago Bay is located in Ise-Shima National Park and is famous for the cradle of pearl culture. However, harmful algal blooms and infectious diseases make sustainable pearl culture difficult. Furthermore, sediment eutrophication and frequent occurrence of oxygen-deficient water has caused the deterioration of benthic ecosystem and decrease of biological productivity in recent years. It is considered that one of the major causes of these phenomena is stagnation of the material circulation by reduction of shallow coastal area including a tidal flat, sea glass and sea weed beds. The natural shallow coastal areas were decreased everywhere in inner parts of the bay by land reclamation and the dike construction. Then we made clear by the multi-spectrum aerial picture analysis that approximately 70% of tidal flat and shallow areas have been already decreased in Ago Bay. Therefore, for environmental restoration of Ago Bay as the major site of pearl culture, it is necessary to enhance the biological productivity which tidal flat, sea glass and sea weed beds provide, and to recover a smooth material circulation around the shallow areas. We developed new technology for enhancing biological productivity by controlling sediment quality.

To determine the suitable sediment condition for the benthic species, we set up the six experimental tidal flats in which the organic content was changed. And sediment quality and benthic species of experimental tidal flat study areas have been monitored for 3 years. Then the suitable range of sediment quality condition of tidal flats for benthic species was found to be 3-10mg/gDW for COD and 15-35% for mud content ratio. By utilizing above result, we developed new technology to enhance the biological productivity in these following two types of shallow areas by controlling sediment condition.

#### *Tidal flat in front of dike*

In front of the dike, there are relatively oligotrophic tidal flats everywhere in Ago bay. These areas are about 84ha. These sediment of tidal flats are gravel and contain low organic matter, because the dike shut out the nutrient supply from the land. So, in these tidal flat, the abundance and diversity of benthos are very low. Then to enhance the biological productivity, we developed new artificial tidal flat using muddy dredged sediment which contains rich-organic matters and is usually treated as a useless material in Ago Bay. We constructed about 7200m<sup>2</sup> of artificial tidal flat with mixing muddy dredged sediment and oligotrophic sediment existing in front of dike. Then we investigated the sediment quality, benthic abundance and species diversity every season for 2 years. In this investigation, it is clear that for about 1 year the abundance and diversity of benthos were increased more than 4 times and the biologically productivity becomes high compare with the condition before construction.

#### *Unused wetland behind the dike*

Behind the dike, there are hypertrophic unused wetlands everywhere in Ago bay. These areas are about 153ha. These sediment of tidal flats are muddy and contain high organic matter, because the dikes store the nutrient supply from the land. So, in these wetlands, the abundance and diversity of benthos are very low. To enhance the biological productivity, we are developing the new technology to reduce the organic matter by promoting water exchange between wetland and outer sea. We set up the experimental field in which the water exchange is simulated natural tide by pumps. Now we are investigating the sediment quality, benthic abundance and species diversity every season in this project.

## **Stable Isotope Analyses of the Trophic Structure of Macrobenthos on an Artificial Tidal Flat Developed using Sediments Dredged from Pearl-oyster Farms in Ago Bay**

**Yuka Ishihi and Hisashi Yokoyama**

Aquaculture Systems Division, National Research Institute of Aquaculture,  
Fisheries Research Agency, Mie 516-0193, Japan

In Ago Bay, an artificial tidal flat was developed during the period from December, 2003 to May, 2005 by spreading organic enriched sediments that had been dredged from pearl oyster farms in this bay over a sandflat. We investigated the trophic structures of the macrobenthos on this intertidal flat before (November, 2003) and after (November, 2005) the development of the artificial tidal flat using the stable carbon and nitrogen isotope technique in order to evaluate the effect on the macrofaunal trophic structure of the macrobenthos.

Results show that (1) before the development of the artificial tidal flat, consumers were classified into 4 groups; suspension feeders that were composed mainly of bivalves (range of mean  $\delta^{13}\text{C}$  values = -19.5 to -18.0 ‰, range of mean  $\delta^{15}\text{N}$  values = 8.7 to 9.9 ‰), deposit feeders and grazers that were composed of gastropods and ocy podid crabs ( $\delta^{13}\text{C}$  = -14.8 to -10.7‰,  $\delta^{15}\text{N}$  = 6.7 to 9.8 ‰), omnivores that were composed of a variety of taxa including gastropods, polychaetes, hermit crabs and grapsid crabs ( $\delta^{13}\text{C}$  = -16.6 to -13.2 ‰,  $\delta^{15}\text{N}$  = 9.5 to 10.7 ‰) and carnivores that were composed of sea anemones and polychaetes ( $\delta^{13}\text{C}$  = -17.8 to -13.9 ‰,  $\delta^{15}\text{N}$  = 12.2 to 13.7 ‰) and (2) after the development of the artificial tidal flat, consumers were classified into 3 groups; suspension feeders ( $\delta^{13}\text{C}$  = -18.6 to -17.0 ‰,  $\delta^{15}\text{N}$  = 8.2 to 9.9 ‰), deposit feeders and grazers ( $\delta^{13}\text{C}$  = -14.5 to -11.0 ‰,  $\delta^{15}\text{N}$  = 7.0 to 9.0 ‰) and omnivores ( $\delta^{13}\text{C}$  = -16.7 to -12.9 ‰,  $\delta^{15}\text{N}$  = 9.1 to 10.1 ‰).

These results indicated that the development of the artificial tidal flat eliminated carnivores, led to an increase in the  $\delta^{13}\text{C}$  of the suspension feeders and a decrease in the  $\delta^{13}\text{C}$  of the deposit feeders and grazers. It seems that the observed increase of  $\delta^{13}\text{C}$  values for the suspension feeders resulted from the incorporation of benthic microalgae ( $\delta^{13}\text{C}$  = -15.9 ‰,  $\delta^{15}\text{N}$  = 5.7 ‰) that grew abundantly on the mudflat as well as coastal phytoplankton ( $\delta^{13}\text{C}$  = -21.5 ‰,  $\delta^{15}\text{N}$  = 7.5 ‰) and that the decrease of  $\delta^{13}\text{C}$  values for the deposit feeders resulted from the incorporation of organic matter that was contained in the dredged sediments ( $\delta^{13}\text{C}$  = -19.0,  $\delta^{15}\text{N}$  = 5.8).

## **Introduced Species and Aquaculture**

### **Cheng-Sheng Lee**

Oceanic Institute, Waimanalo, Hawaii, HI 96795, U.S.A.

Even though the current main sources of seafood come from capture fisheries, the total yield from this source reached a plateau in 1990 and no further significant growth is expected in capture fisheries. Aquaculture contributions have increased significantly since 1970 and now account for more than 37.5% of all fish consumed in 2003 (FAO, Fishstat). From 1950 to 2003, a total of 416 aquatic species have been cultured at least once. In 2003, of these species, 314 had production of one tonne or more.

Problems associated with the culture of local species led culturists to seek related non-indigenous species as alternatives (Stickney, 2001). Aquaculture as the main reason accounts for 38.7% of introduced species recorded in Food and Agriculture Organization (FAO) database (Garibaldi and Bartley 1998). The practice of culturing non-indigenous species has existed for many years to take advantage of existing markets, and available technology and resources. Almost 10% of world aquaculture production came from introduced species (Garibaldi and Bartley 1998). Following the expansion of aquaculture production and the increasing demand of diversified seafood from consumers, the pressure to culture non-indigenous species has increased.

Aquaculture farms in the U.S. currently produce more than 100 different species of aquatic plants and animals; most major aquatic species cultured in the U.S. are not native to their farm sites (Naylor et al., 2001). Non-indigenous species have been introduced for farming in particular regions because of the immediate social and economic benefits. Some non-indigenous species, however, have quickly adapted to the new environment, become established, and compete with indigenous species for limited habitats. Biological invasions are recognized as serious threats to marine biodiversity and ecosystem structure and function (Frisch and Murray, 2002). In addition, introduction of non-indigenous species for aquaculture has resulted in numerous unintentional introductions of pathogens, parasites, and pest species (Galil, 2000).

This presentation will review the significance of introduced species in total aquaculture production. The culture of marine shrimp will be used as an example to explain the impacts on surrounding environments in both physical and biological aspects. To keep the positive contribution of introduced species in aquaculture, certain measures must be developed to avoid any negative impacts. Developing mitigation strategies and monitoring capabilities for introduced species is very important to avoid negative impacts.

## **Countermeasures against Alien Fish (Largemouth Bass and Bluegill) in Lake Biwa**

**Atsuhiko Ide and Shinsuke Seki**

Shiga Prefectural Fisheries Experimental Station, Shiga 522-0057, Japan

Lake Biwa, located on the main island of Honshu, is the largest lake in Japan. It is also one of the world's most ancient lakes, with an origin going back four million years. Numerous aquatic organisms, including more than 30 endemic species of fish and mollusk, inhabit the lake, and fisheries of various kinds have targeted these animals from ancient days. The total annual commercial catch of fish and crustaceans was about 4000 metric tons during the 1970s and 1980s.

Bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*) were first found in Lake Biwa in 1965 and 1974, respectively. While bluegill spread gradually through the bays and small lagoons surrounding the lake, largemouth bass increased explosively in the 1980s. Simultaneously, native fishes such as crucian carp and bitterlings disappeared from the coastal shallows. After that, the population of bluegill began to increase and this species replaced most of the remaining native shore fishes. In recent years, bluegill have constituted over 90% of the fish fauna in Lake Biwa's south basin, and the annual catch of commercial species in the lake has decreased to half of that recorded in the 1970s and 1980s.

Since 1985, fishermen have been trying continuously, by several means, to reduce these alien species. Fishing gear such as "eri" (a labyrinth-like set-net), gill nets, and pot traps have been used. Recently, about 400 metric tons per year of these alien fishes have thus been eliminated.

At the same time, the Shiga Prefectural Fisheries Experimental Station has tried to develop more effective gear to catch them. We have devised a pot trap with its top covered by a sheet to provide shade, for efficient capture of bluegill, and a small beam trawl for use in beds of submerged aquatic plants. Other methods for the eradication of the alien fishes are currently under study.



## **Conservation Aquaculture Approaches for Hatchery Reform**

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Theoretically, one of the fastest ways to amplify population numbers for depleted stocks is through culture and release of hatchery-propagated fish. However, past attempts to use supplementation (i.e., the use of artificial propagation in an attempt to maintain or increase natural production) to rebuild naturally-spawning populations have often yielded poor results. The challenge is to develop hatchery reform protocols that increase fitness of hatchery-reared fish, thereby improving survival. Considerable conservation aquaculture and ecological interactions research has been conducted by the NOAA Fisheries, Northwest Fisheries Science Center, Manchester Research Station that has helped address consequences of hatchery reform actions.

In addition, NOAA is a partner in a formal process of hatchery reform that has been ongoing in the Pacific Northwest since 1999. The Hatchery Scientific Review Group (HSRG) is funded by the U.S. Congress and is a systematic, science-driven redesign of how hatcheries will be used to achieve the goals of: 1) helping to recover and conserve naturally spawning populations, and 2) supporting sustainable fisheries. Initial work by the HSRG included developing a Scientific Framework for Artificial Propagation of Salmon and Steelhead, a Benefit/Risk Assessment Tool, Hatchery Operational Guidelines, and Monitoring and Evaluation Criteria. These tools are being used by the HSRG in a comprehensive region-by-region review that evaluates hatchery programs for consistency with established scientific principles and the objectives of hatchery reform.

These combined efforts have resulted in operational guidelines for conservation hatcheries to help mitigate the unnatural conditioning provided by hatchery rearing. These are include: 1) Mating and rearing designs that produce minimal genetic divergence of hatchery fish from their wild counterparts to maintain long-term adaptive traits; 2) Simulation of natural rearing conditions through incubation and rearing techniques that approximate natural profiles and through increasing habitat complexity (e.g., cover, structure, and substrate in rearing vessels) to produce fish more wild-like in appearance, and with natural behaviors and higher survival; 3) Conditioning techniques such as anti-predator conditioning to increase behavioral fitness; 4) Release of fish at a size, stage, and condition which approximates the wild population to reduce potential negative ecological interactions and to promote migratory homing; and 5) Aggressive monitoring and evaluation to determine success of conservation hatchery approaches.

**Environmental Standards for Marine Aquaculture in the United States; Minimizing negative interactions of escaped farm fish and natural populations**

**Conrad Mahnken**

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The National Offshore Aquaculture Act of 2005 was introduced in the United States Senate in June 2005 and would establish a regulatory framework for offshore aquaculture in the United States. In addition to issuing permits and establishing research partnerships, NOAA would be required to develop environmental standards that would protect the marine ecosystems in which offshore farms are to be located. One element of environmental standards is the potential impact that escaped farm fish may have on local native stocks and species.

The rapid development of world cage farming of marine fishes has raised concerns over the possible genetic and ecological impact of escaped fish on natural populations. Potential effects include genetic alteration and reduced fitness, competition for food and space, and predation on native stocks. It is important to review the potential impacts of escaped indigenous and non-native marine fish on localized native stocks in order to develop risk assessment and management strategies. However, little data exists in the aquaculture, genetic, or ecological scientific literature on the interaction of farmed fishes escaped from aquaculture facilities and native marine fishes. Therefore it is presently difficult to predict the actual impact that escaped fish will have on their wild counterparts within the ecosystem.

There is some information available on the intentional release of marine fish species for purposes of stock enhancement, however there are almost no data available on accidental releases as applies to marine aquaculture. While intentional releases are intended to have a noticeable and positive effect on natural populations of con-specifics by increasing stock size and abundance, effects of accidental releases by species or number are considered to have negative effects (ICES, 2002, 2003, 2004, 2005). It should be pointed out that this is not necessarily true in all cases and depends on the genetic state of the escaped farm fish and the numbers and mean individual size of the escaped population.

Note: This introduction section should also contain a discussion on: magnitude of salmon escapes from marine farms (data rich), escapes of marine fish, mostly from the north Atlantic and Mediterranean farms and hatcheries (data poor), incidence of escapes from net pens insofar as data is available (data poor), knowledge on genetic and ecological interactions resulting from marine enhancement releases (data poor); and information on genetic stock structuring necessary to estimate the potential for negative interaction on natural fish populations.

Paucity of scientific information on the real genetic and ecological consequences of escaped farm fish makes it difficult to predict the negative interaction on natural fish populations. Therefore, environmental standards in Canada, the EU and Chile are aimed at preventing escapes in the first place through production monitoring, engineering of containment systems, best management practices, and methods to recover escaped fishes. Because hard scientific data is lacking, environmental standards are narrative rather than quantitative. Proposed environmental standards for the United States will include these elements plus the need for applying a numerical model as a planning tool for navigating the complexities potential genetic and ecological interactions.

Presentation IV-1

## **Economic Evaluation of Various Roles and Functions of Propagation and Aquaculture**

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I performed an economic evaluation of various roles of aquaculture, apart from its primary role in supplying marine products.

I defined these secondary roles as "provision of food security", "environmental improvement", "exchange between urban and fishing communities", "maintenance of traditional culture", and "formation and maintenance of local communities" .

In 2005, aquaculture without artificial feeding removed 6,090 t nitrogen and 595 t phosphorus from Japan's coastal seas. The economic value of this reduction in pollution was equivalent to 1298 hundred million yen in the cost of sewage treatment of this amount of waste.

From the results of a questionnaire-based investigation of the general population, I estimated by the CVM (Contingent Valuation Method) that non-use value of algae ground around Japan was 553 to 2109 hundred million yen.

Presentation IV-2

## **Risk and Risk Management for Feed and Seed for Carnivorous Marine Fish Aquaculture**

**Michael B. Rust**

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The provision of feed and seed for marine fish aquaculture often occurs external to the actual fish culture operation. How those external activities are conducted and applied impacts the potential ecological risk for the entire industry. Up stream ecological risks associated with feed and seed from culture of carnivorous marine fish aquaculture include the potential for over-fishing due to demand for wild juveniles for grow-out, and harvesting industrial fisheries for aquafeeds. Downstream ecological risk associated with feed includes organic loading and benthic impacts. Downstream risks associated with seed are associated with the potential ecological and genetic impacts of escapes on conspecific wild stocks if the cultured fish is native or ecological impacts on native species if the escapees are non-native. For each risk, the WHO risk assessment framework may be applied to focus research and development on strategies that could be used to manage or eliminate the risk. I suggest that situations where economic gain and ecological risk reduction are in-line are preferred and have a much higher chance of resulting in meaningful improvements. In both up stream cases, proper fishery management can reduce risk at a low level of demand, however at some higher levels of demand, substitution (i.e. hatchery development and alternative feedstuffs) provides a better option. In both later cases, economic gain is in line with ecological risk improvements, making adoption more likely. The development and adoption of formulated feeds over raw fish diets greatly reduces the organic pollution associated with fed fish aquaculture. Further refinements in diet formulation and processing can further reduce the organic loads associated with fed fish aquaculture. Gains in feed technology are also in line with economic gains once a critical level of production is reached. Risk associated with escapes can be managed at the hatchery by either raising fish with the same genetic make-up as wild stocks, or by domestication of the farmed species to reduce escapees' fitness in the wild. In this case, economic gains would favor domestication and not maintaining a wild stock genotype. Governments can create win-win situations by fostering research and development where ecological risk and economic gains are in line and both considered. In the case of feed and seed, this would include development of high quality compound feeds and hatcheries with associated selective breeding programs for new and existing marine fish industries.

Presentation IV-3

## **Ecological Risk Assessment of Marine Fish Aquaculture in the Coastal Zone**

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The presentation summarizes the proceedings of an international workshop organized to develop “Guidelines for the Risk Assessment of Marine Fish Aquaculture” (see: <http://www.nwfsc.noaa.gov> to download proceedings). The international participants adopted the structural approach to risk assessment developed by the World Health Organization (WHO), and which is now widely used. For each risk, the WHO framework begins with problem formulation, and proceeds through problem analysis to characterize the exposure and ecological effects of the risk before the final risk characterization. It ends with risk management. In addition to explaining the Risk Assessment Framework and its application in a global marine aquaculture setting, the Guidelines include ten example templates. Each template applies the process to a risk currently perceived by scientists or the public to have possible impact on the coastal and marine ecosystems depending on specific ecological conditions of various biogeographical zones and in a variety of other circumstances. The ten risks are: increased organic and inorganic loading, residual heavy metals in sediments, transmission of disease between wild and farmed populations, residual therapeutants in sediments, biological interactions of escapees with wild populations, physical interactions with marine wildlife, physical impacts on marine habitats, using wild juveniles for grow-out, and harvesting industrial fisheries for aquafeeds. Included in each risk template are sections on the current hypothesis for perception of the risk, the background experience or known information, the conceptual model of how the risk is manifest, its analysis and characterization, and finally a biological opinion regarding its possible incidence and management or prevention.

Presentation IV-4

## **The Measures for Sustainable Marine Aquaculture in Japan**

**Ikuo Takeda**

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Marine aquaculture in Japan has developed steadily since the 1960's, and it occupies an important position in the Japanese marine fisheries at this stage. In 2004, it accounted for 21.4 percent of the total production and 29.0 percent of the total value. Accordingly, the achievement of sustainable marine aquaculture is one of the important issues when considering Japanese fisheries policy. This paper outlines several measures and basic plan related to sustainable development of Japanese marine aquaculture.

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