Status of Resource Enhancement and Sustainable Aquaculture Practices in Japan

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Abstract

Contrary to the rapid increase in the world aquaculture production, fish production in Japan has been decreasing slightly due to the decreasing trend in seafood consumption of Japanese. Aquaculture production is approximately 20% in terms of yield, and 30% in terms of market value, of the country's total fisheries production. In Japan, about 80 species are targeted for release for sea ranching and resource enhancement purposes. The local governments (prefectures) are the main driving force in resource enhancement programs. Chum salmon, *Oncorhynchus keta*, and scallop *Mizuhopecten yessoensisis* are examples of successful resource enhancement in Japan. Japanese flounder, *Paralichthys olivaceus*, and red seabream, *Pagrus major*, represent intensely released fish species in Japan, and around 10% of the total catch of those species are estimated as released fish. The low price of products and increasing costs of production, such as costs of fuel and fish meal, are the major pressing issues in coastal fisheries and aquaculture in Japan. For aquaculture, the guarantee of food safety, minimization of environmental impact, and management of natural stock populations are highly necessary in order to achieve the sustainability of the industry. For resource enhancement, budget constraint is the major issue, and possible impact on natural stocks caused by released fish should also be considered. The Government of Japan (GOJ) is implementing some measures to rectify unstable business practices of aquaculture and to improve production techniques in aquaculture. For resource enhancement, the GOJ encourages cooperation among local governments (prefectures) for seed production and release of certain targeted species in order to reduce the cost and improve the efficiency of stock enhancement. In Japan, traditionally, the purpose for release was mainly sea ranching, namely harvesting all released animals. Nowadays, actual resource enhancement, i.e. the integrated release program including resource management and development of suitable nursery for released fish, is encouraged by the government. The evaluation and counter measures for the negative impact of stocked fish on genetic diversity of the wild population are also implemented. Recently, marked progress was achieved in seed production technologies of two important tropical fish species, namely coral trout, *Plectropomus leopardus*, and humphead wrasse, *Cheilinus undulatus*. These technologies are expected to contribute to the advancement of the aquaculture industry in the South East Asian region.

Keywords: resource enhancement, aquaculture practices, Japan, sea ranching, integrated release program

Introduction

Fisheries and aquaculture production in Japan have been decreasing in recent years (Figures 1 and 2). There are two major reasons for the decrease, namely the decreasing trend of the consumption of seafood by the Japanese and the reduction of fish price. Figure 3 shows changes in average daily consumption of seafood and meat by Japanese; consumption of seafood has been decreasing continuously, while meat consumption is increasing. Japanese who prefer meat to seafood is increasing because meat is easier to cook and eat, lasts longer than seafood and the price is comparable. The decreasing demand for seafood caused a reduction in price. Figure 4 indicates the changes in the price of Japanese flounder, *Paralichthys olivaceus*, and the red seabream, *Pagrus major* at the Tokyo Metropolitan Central Wholesale Market in Japan from 1993 to 2012. Prices are continuously decreasing. Therefore, the situation in fisheries and aquaculture in Japan is very tough these days; Japanese fishermen and aquaculturists have encountered difficulties in their business practices. The low price of products and increasing costs of production, such as costs of fuel and fish meal, have been the major pressing issues in coastal fisheries and aquaculture. In addition, for aquaculture, the guarantee of food safety, minimization of environmental impact, and management of natural stock populations are highly necessary in order to achieve the sustainability of the industry.

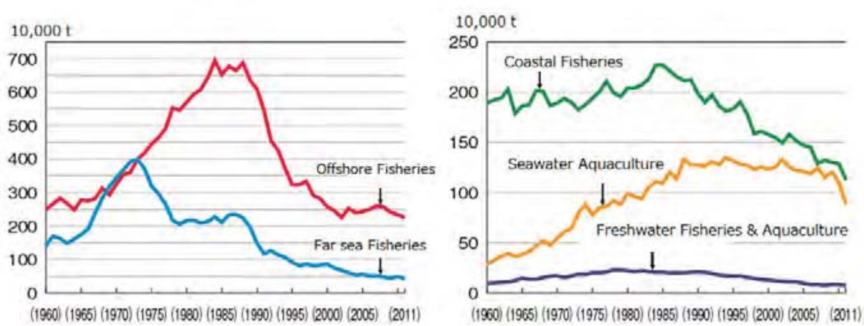

Figure 1. Changes in annual production of fisheries and aquaculture in Japan from 1960 to 2011. Aquaculture production in 2011 was influenced temporarily by the earthquake disaster. Figures are based on Fisheries and Aquaculture Production Statistics (2013), Ministry of Agriculture, Forestry and Fisheries.

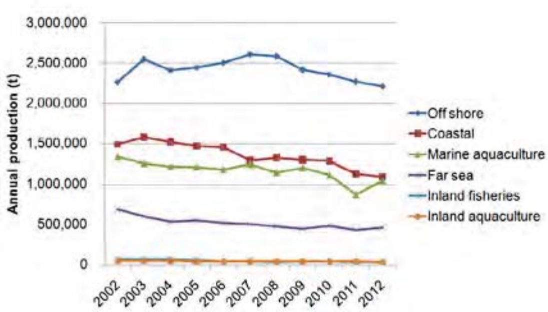

Figure 2. Changes in the annual production of fisheries and aquaculture from 2002 to 2012 in Japan. Marine aquaculture production in 2011 was influenced temporarily by the earthquake disaster. The figure was based on Fisheries and Aquaculture Production Statistics (2013), Ministry of Agriculture, Forestry and Fisheries.

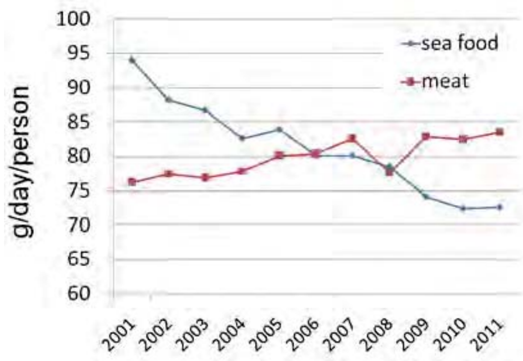

Figure 3. Changes in the consumption of seafood and meat per day per person in Japan from 2001 to 2011. Data was obtained from the Investigation for the Nutrition of Japanese Citizens, Ministry of Health, Labour and Welfare.

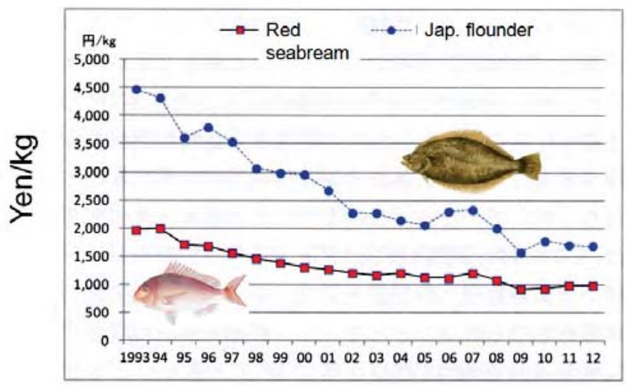

Figure 4. Changes in the annual average price of fresh red seabream (red squares) and Japanese flounder (blue dots) at Tokyo Metropolitan Central Wholesale Market in Japan.

Aquaculture in Japan

Present status

Contrary to the rapid increase in the world aquaculture production, Japan's aquaculture production has been slightly decreasing these days. Figures 1 and 2 indicate changes in the production of fisheries and aquaculture in recent decade; all productions are decreasing. In Japan marine aquaculture production is much bigger than inland aquaculture and marine aquaculture production is comparable to coastal fisheries. Aquaculture industry has contributed to compensate the decrease in fisheries production in Japan; the aquaculture production accounts for approximately 20% in terms of yield, and 30% in terms of market value, of the country's total fisheries production.

Figure 5 shows both marine and inland aquaculture production of each commodity in Japan in 2012. In marine fish culture, yellow tail is the most important commodity. Actually, two closely related species, namely, yellow tail, *Seriola quinqueradiata* and greater amberjack, *S. dumerili*, are included in this amount of production (160,215 t). The red seabream is the second, followed by coho salmon, *Oncorhynchus kisutsh* and bluefin tuna, *Thunnus orientalis*. In freshwater, eel, *Anguilla japonica*, accounts for half of the production and followed by ayu, *Plecoglossus altivelis*, rainbow trout, *Oncorhynchus mykiss*, and carp, *Cyprinus carpio*, followed.

In shellfish, the scallops, *Mizuhopecten yessoensisis* and the oyster, *Crassostrea gigas*, are the major commodities, and the laver, *Porphyra yezoensis*, dominates the seaweed aquaculture (Figure 6). The prawn culture industry is rather small in Japan and kuruma prawn, *Penaeus (Marsupenaeus) japonicus*, production is the highest (1,596 t in 2012).

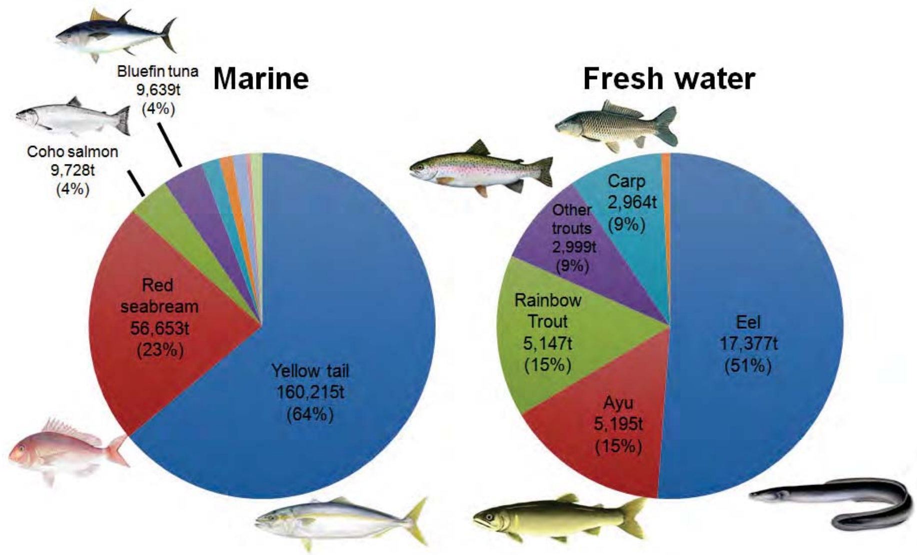

Figure 5. Marine (left) and freshwater (right) finfish aquaculture production in Japan in 2012. Figures were made from Fisheries and Aquaculture Production Statistics (2013), Ministry of Agriculture, Forestry and Fisheries.

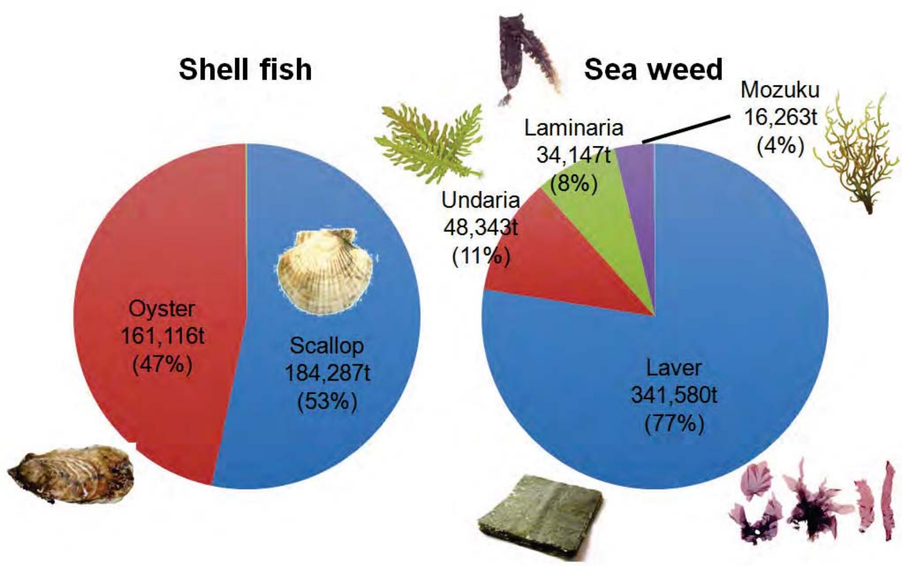

Figure 6. Marine shellfish (left) and seaweed (right) aquaculture production in Japan in 2012. Figures were from Fisheries and Aquaculture Production Statistics (2013), Ministry of Agriculture, Forestry and Fisheries.

Pressing issues in Japanese aquaculture

In Japan, most aquaculture farms are small in size, and their business practices are unstable. There are several reasons for the instability. The prices of aquaculture products are rather low, because of overproduction and/or oligopoly on price determined by the supply chain. High cost of production due to increases in the cost of fish meal, mandated environmental management, dependence of seed on wild populations and/or the risk of disease outbreak are also the issues. Increasing demands by consumers for guaranteed food safety of the products is another issue to be tackled.

Possible strategies for aquaculture

Measures to improve unstable business practices in aquaculture

There are three major policies implemented by the Government of Japan (GOJ) or Japan Fisheries Agency to improve unstable business practices of aquaculture in Japan. First, the expansion of mutual-aid systems to support business practices of fishermen and aquaculture farmers, including compensation systems for increases in feed and oil costs. Second, promotion of planned production in correlation with supply-demand balance. Japan Fisheries Agency set the guideline for aquaculture production every year, for example the ideal amount of production for yellow tail + greater amberjack and red seabream in 2014 were determined as 140,000 and 72,000 tons, respectively. Third, enhancement of added value to aquaculture products and promotion of exportation are recommended.

Measures to improve production techniques

Measures to improve production techniques include four aspects: 1) food safety, 2) conservation of the environment, 3) management of natural resources, and 4) new technologies for aquaculture.

Food safety

Food safety is an essential issue for the aquaculture industry. Management systems for food safety and information technologies for communication between producers and consumers are necessary. R&D for management systems of product quality assurance, e.g., global Good Aquaculture Practice (GAP) and traceability systems, should be further promoted. R&D for vaccines to prevent infectious diseases and the dissemination of such vaccines are strongly required. Risk management is also important for food safety.

Conservation of the environment

To achieve sustainable aquaculture, wastes such as uneaten feed and excretions should be minimized in order to maintain an appropriate environment and prevent red tide from occurring around the culture cages. For feeding-type aquaculture, the drawing up of plans for conserving the environment and using low-emission feeds are strongly recommended. For non-feeding aquaculture such as that of seaweeds and bivalves, monitoring of the coastal environment is necessary in order to prevent harmful environmental changes such as red tide, poor oxygen content, and high temperatures.

Management of natural resources

Aquaculture activities often impact natural resources. For example, wild juveniles of bluefin tuna, eel or yellow tail are used for aquaculture. Aquaculture feed also depends on the use of natural stocks of sardine and anchovy. Therefore, R&D to produce sufficient quantities of artificial seeds and the development of breeding technology is of high importance. Also, R&D to develop assorted feeds using alternative sources of protein having high quality is necessary.

New technologies for aquaculture

To reduce the cost and promote productivity, R&D for new aquaculture technologies are implemented. This includes 1) development of feeds with low fish meal content or inclusion level and determination of appropriate feeding amounts, 2) determination of appropriate fish density in order to avoid pathogen infections, 3) development of submersible net cages for offshore aquaculture to minimize environmental emissions, 4) development of breeding technologies to produce fish strains adaptable to various aquaculture conditions, and 5) development of enclosed recirculating aquaculture systems.

Resource enhancement

Present status of resource enhancement in Japan

In Japan, about 80 species are targeted for release for sea ranching and resource enhancement. Figure 7 shows the top 10 species released for resource enhancement in Japan. The local governments (prefectures) are the main driving force in resource enhancement programs. Chum salmon, *Oncorhynchus keta*, is an example of successful resource enhancement in Japan; around 1.7 billion fry are released and 50-70 million salmons return (recovery rate is 2-3%) every year. Sea ranching of the scallop is another success story, about 3 billion spats are released and 300,000 t scallops are harvested per year. The production of chum salmon (129,000 t) and scallop (302,000 t) accounts for about 40% of the total production from coastal fisheries (1,129,000 t) in Japan in 2011. Japanese flounder and red seabream are the representatives for intensely released commodities; around 15 and 12 million juveniles respectively were released in 2011 (Figure 8). Around 10% of total catch of these species are estimated as released fish.

Pressing issues in resource enhancement in Japan

There are several pressing issues in resource enhancement in Japan. Among them, budget constraint is the biggest one. Due to the long period of economic depression in Japan, most local governments, or prefectures, in Japan have suffered from severe budget constraint, and total budget for resources enhancement programs of all prefectures decreased from 7.5 billion yen in 2002 to 5.1 billion yen in 2012. In addition, budget from the GOJ drastically decreased since 2005.

Formerly, the GOJ had intensely encouraged stock enhancement programs and utilized sufficient amount of the budget for the stock enhancement when the economy was in good condition. However, the GOJ had changed the policy against resource enhancement and the roles of the GOJ in resource enhancement had decreased since 2005, and prefectures are

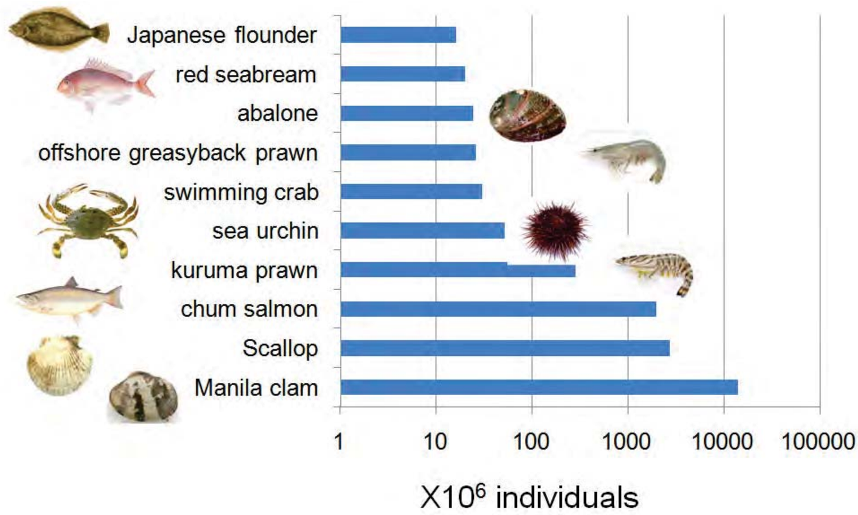

Figure 7. Annual release of top 10 species for resource enhancement in Japan. The numbers are the averages from 1983 to 2000. The figure was based on data in the Achievement of Seed Production and Release of Stock Enhancement in Japan.

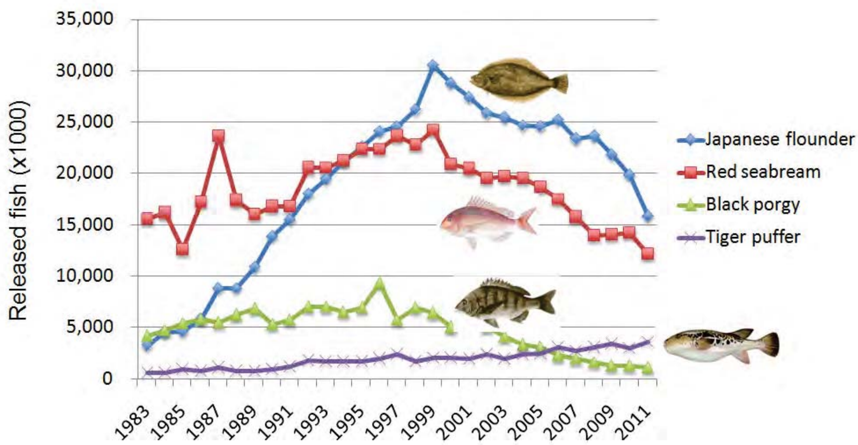

Figure 8. Changes in total numbers of released representative marine fish species aimed for resource enhancement from 1983 to 2011in Japan.

designated as the main driving force for resource enhancement programs. The GOJ allocated the budget for the resource enhancement that was formerly used by GOJ to the prefectures. However, because of the budget constraints in prefectures, they did not use all allocated budget for the resource enhancement activities but divert it to some other purpose. Taken together, the total budget for resources enhancement in Japan had shrunk, and this resulted in the decrease in the number of released fish, which is shown in Figure 8.

Another pressing issue is the impact on natural stocks caused by released fish, in other words reduction of genetic diversities. Several studies have been implemented to clarify the impact (Kitada *et al.,* 2009).

Possible strategies

To overcome the decreased budget problem, a strategy for the reduction of the cost for both seed production and release is being implemented in Japan. The GOJ encourages prefectural governments to cooperate with each other in seed production and release for migratory species, such as Japanese flounder and tiger puffer. For this purpose, the "Regional Council for the Promotion of Stock Enhancement" have been established in six coastal areas (Northern Pacific, Northern Japan Sea, Southern Pacific, Mid-west Japan Sea, Seto Inland Sea and Kyusyu) in Japan, which is composed of prefectural government, fisheries cooperatives, public-service corporation for seed production and other stake folders.

In Japan, traditionally, the purpose for release was mainly sea ranching, namely harvesting all released animals. Nowadays, actual resource enhancement, i.e. the integrated release program including resource management and development of suitable nursery for released fish, is encouraged by the GOJ. To mitigate possible negative impact on wild populations, the evaluation and counter measures for the impact of stocked fish on genetic diversity of the wild population is implemented by the Fisheries Research Agency of Japan (FRA) and universities and prefectural research centers. And the GOJ will set guidelines about this issue in the near future.

Recent progress in the seed production technologies of tropical fish species in Japan

The FRA recently achieved much progress in the seed production of two commercially important tropical fish species, namely coral trout, *Plectropomus leopardus* and humphead wrasse, *Cheilinus undulatus*.

Success in mass seed production of coral trout

Recently, the FRA achieved marked progress in seed production of coral trout (Takebe *et al.,* 2011). The seed production of this species was very difficult and unstable. The key for our success is to provide the ideal environment for rearing larva. Figure 9 and 10 show a horizontal and a lateral views of the rearing tank of coral trout that was developed by Takebe *et al.* (2011). We named this system as "new pump method". In this method, rearing water is circulating within a tank powered by an underwater pump. The pump placed in the center of the tank sucks water, then the water is discharged from the bottom of the tank (Figures 9 and 10). On the other hand, in the conventional method, water was supplied only in one side of the tank (Figure 9). With this new pump method, survival rate until Day 10 has drastically increased (Figure 11). Also, the survival rate until juvenile and total production drastically increased after employing the new pump method (Figure 12).

Success in seed production of humphead wrasse

Humphead wrasse, or Napoleon wrasse, is the largest labrid distributed around the coral reefs of the Indo-Pacific (Sadovy *et al.*, 2003). They are known as proterogynous species: all fish initially mature as females, and later change sex to be male. The age at maturity is relatively later than other labrids (Choat *et al.,* 2006), and this is a reason for the difficulty in the conservation of this species.

Humphead wrasse is an important fishery resource, especially in Hong Kong, Mainland China, and Southeast Asian countries. This fish is very popular as luxury species hence the wild resource decreased in the last two decades due to the heavy exploitation (Sadovy *et al.*, 2003). We also have local fishing in Ryukyu Islands, Okinawa, Japan with spear fishing, but this fish is not expensive in Okinawa, and mostly consumed locally or transferred to some luxurious Chinese restaurants in Chinatown in Yokohama.

Efforts to manage this resource has been made since this species was listed in CITES Appendix II in 2004. After that, international trade has been limited, or some countries in Southeast Asia or Oceania banned the fishing of this species.

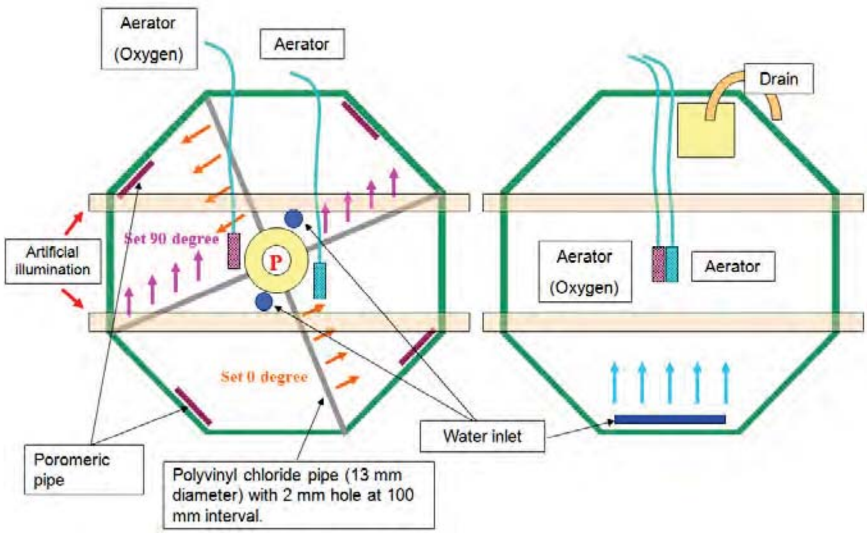

Figure 9. Horizontal view of the conventional (right) and new pump method (left) rearing 60 kL tanks for coral trout, *Plectropomus leopardus*, at Research Center for Subtropical Fisheries, Seikai National Fisheries Research Institute, Fisheries Research Agency of Japan (redrawn after Takebe *et al.*, 2011). The arrows indicate the directions of the discharged rearing water.

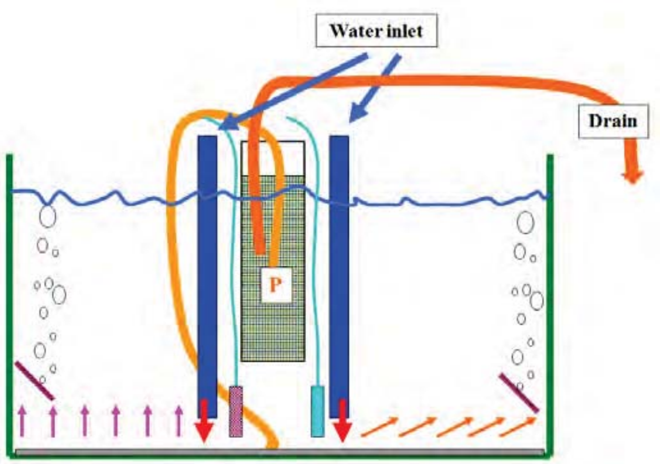

Figure 10. Lateral view of 60 kL rearing tanks with the new pump method for coral trout, *Plectropomus leopardus*, at Research Center for Subtropical Fisheries, Seikai National Fisheries Research Institute, Fisheries Research Agency of Japan (redrawn after Takebe *et al.*, 2011). The arrows indicate the directions of the discharged rearing water.

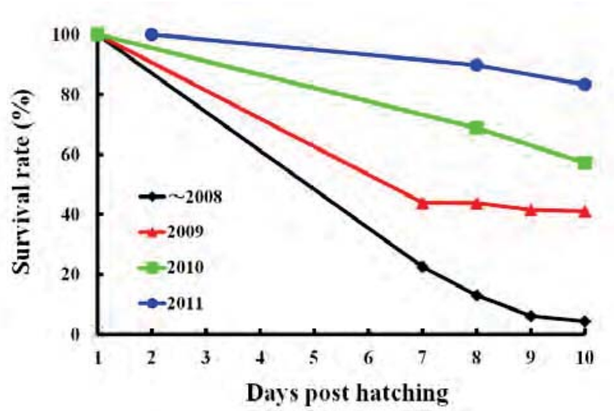

Figure 11. Changes in the survival rate with conventional (until 2008) or new pump method (from 2009 to 2011) until 10 day post hatching. Black line indicates survival rate with conventional method, and other colors indicate the result with new pump method.

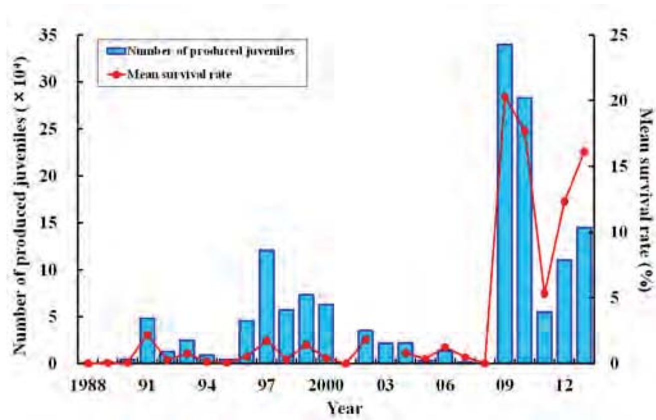

Figure 12. Change in mean survival rate (red dots and lines) and total number of coral trout juveniles (blue bars) produced annually in the Research Center for Subtropical Fisheries, Seikai National Fisheries Research Institute, Fisheries Research Agency of Japan.

On the other hand, the R&D on broodstock management and seed production for sustainable aquaculture of this species has been tried. However, the artificial seed production of this species is very difficult, and there was only one success in seed production recorded in Indonesia in 2003 (Slamet and Hutapea, 2005).

R&D for induced spawning

We collected wild humphead wrasse in Yaeyama islands in Okinawa and reared them in indoor octagonal 60kL tanks (maximum diagonal 5.8 m, depth 2.5 m) at the Yaeyama Laboratory, Research Center for Subtropical Fisheries, Seikai National Research Institute, FRA. We found that humphead wrasses spawn spontaneously in the tanks from June to September when water temperature exceeds 28°C in Ishigaki island (Hirai *et al.,* 2012). They spawn mainly at the onset of the new moon (one week before and one week after new moon). However, fertilization rate was less than 25%. Therefore, some intervention to induce spawning was required. By observing the behavior of the broodstock, we found that the male chased females when the water level was low, and that mating behavior could be induced when the water level is reduced. After each mating episode, we always obtained the fertilized eggs. There has been no failure for fertilization with this method in the three years of research. Thus, draining water in the rearing tank to a low level can induce mating behavior and fertilization of the humphead wrasse.

Study for larval rearing

Eggs of the humphead wrasse are rather small (egg diameter: 620-660 µm) and the larva hatch out in very short hours (16 hours at 28°C) and they are very small (total length is 2 mm). Accordingly, the mouth is also very small: the diameter is 154 µm and the width is 133 µm at first feeding. Thus, it was predicted that they could not eat the rotifers, *Brachionus rotundiformis* that are usually used as the first feed for most fish larva. Therefore, we tried to feed more minute rotifer *Proales similis* collected from Ishigaki island (Figure 13). This rotifer is smaller than SS type rotifer, the body mass is only 10% of SS-type rotifer. This proalid was tested in seven band grouper and larvae were found to feed on this monogonant (Wullur *et al.,* 2011). Moreover, in previous study (Hirai *et al.,* 2012), this proalid can be enriched by fatty acids, so it was considered to be a suitable candidate for initial feed for humphead wrasse larva.

The rearing conditions for humphead wrasse was studied (Hirai *et al.,* 2012), and the study revealed that the addition of oil prevents death on the surface (Figure 14) and that too much aeration caused the mortality of this species (Figure 15). After this study, using the improved rearing method and *P. similis* as initial live food, 22 and 537 juveniles of humphead wrasse were produced in August (survival rate 0.25%, mean TL: 9.0 mm), and September (survival rate 10.7%, mean TL: 9.1 mm) in 2011, respectively. The dietary sequence to raise juveniles was *P. similis* from 2-11 day post hatch (DPH), SS-type rotifers from 6-29 DPH, and S-type rotifers from 28-50 DPH. Humphead wrasse juveniles accepted *Artemia nauplii* after 50 DPH.

Figure 13. A photograph showing a *Proales similis* collected from Ishigaki island, Okinawa, Japan. Scale bar = 50 µm.

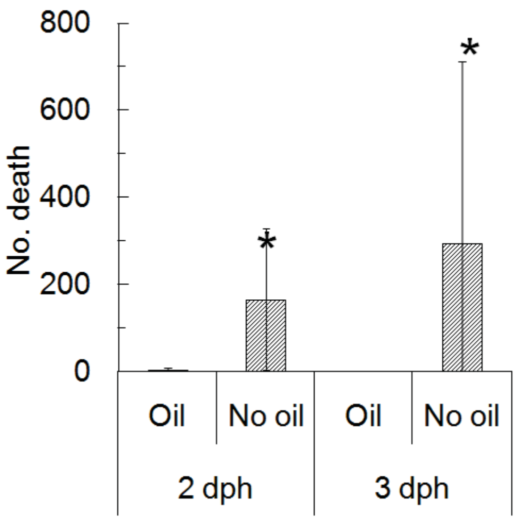

Figure 14. Effect of addition of oil to the rearing tank of humphead wrasse on the surface death observed at 2 and 3 days post hatch (redrawn after Hirai *et al.*, 2012). Values are means ± standard deviation. Asterisks indicate statistical differences ($p<0.05$) between oil and no oil groups.

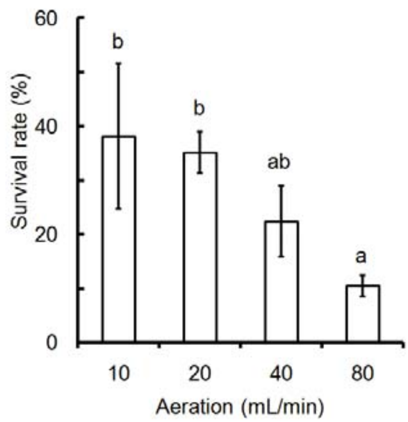

Figure 15. Effect of aeration on the survival rate at 4 days post hatch of humphead wrasse (redrawn after Hirai *et al.*, 2012). Values are means ± standard deviation. Values are statistically different ($p<0.05$) if there is no common.

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Suggested Readings

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