Mass Larval Rearing Technology of Marine Finfish in Japan

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With economic development and increased demand for high price fish, industrial scale marine finfish culture in Japan was started in 1960-1965 for yellowtail *Seriola quinqueradiata.* Sustainable supply of wild juvenile and development of floating cage with synthetic fiber net have spurred the culture of nearly 30 species and total production in 1991 is 265 x 10^3 metric tons (nearly 25% of total aquaculture production). Although salmon ranching had been started in 1888, a national project of ocean ranching was only initiated in 1963 with the present target of 26 species of marine finfish. Ocean ranching aims to increase fisheries resources in coastal sea by stocking hatchery-reared juveniles and preservation of environmental capacity and habitat. Therefore, mass production of marine finfish juveniles is being done for the intensive culture in net cage and for stocking coastal sea in Japan.

Nearly 200 million juveniles are produced by ocean ranching centers (14 national, 49 prefectural, 21 city and town, 53 fishermen's association). The number of target fish is about 60 species (excluding salmon and trout). The main species produced are red sea bream, *Pagrus major,* flounder, *Paralichthys olivaceus,* puffer, *Takifugu rubrapes,* rockfish, *Sebastes shlegeli,* and mud dab, *Limanda yokohamae.* More than one million juveniles of these species are produced at one hatchery or ocean ranching center per one fry production season. About 70% of total production of juveniles consist of red sea bream and flounder. Red sea bream could be used to introduce mass larval rearing technology in Japan since its mass production is well developed. The focus of the present paper is the present status and short history of the development in larval rearing technology for red sea bream.

The 10 phases of development of red sea bream larval rearing technology

In 1989, nearly 105 million fry was produced in Japan, 80 million for intensive culture in net cage and 25 million for stocking to coastal sea. Hatchery-reared fry comprised 60% of seeds for net cage culture while 40% still consist of wild juveniles caught in coastal sea. The most successful hatchery or ocean ranching center produce more than 3 million juveniles while the standard for fry production per one ocean ranching center is about one million.

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Thus, the technology for mass fry production of red sea bream is fairly reliable. The 10 phases of technology development are:

1) Introduction of rotifer *Brachionus plicatilis*

Mass larval rearing succeeded following introduction of the rotifer as an initial food organism in 1965. Introduction of the rotifer is considered to be a key factor in the development of mass production of marine finfish fry. Physiology, ecology, and the actual technique for mass culture of the rotifer are reviewed in several papers (Hirata 1979, Fukusho 1989a,b, Fulk and Main 1991, Fukusho and Hirayama 1992).

2) Broodstock and egg collection by natural spawning in tanks

During the initial stage, from 1965 to 1970, fertilized eggs were obtained by induced spawning (stripping) of wild spawner after hormonal injection. However, success was limited because of poor egg quality.

In 1968, natural spawning was observed in aquarium tanks. Thereafter, natural spawning method was introduced at many ocean ranching centers and hatcheries (Fushimi 1984). At present, the method is most commonly practiced and practical for mass spawn-taking, although induced spawning is still attempted for under developed.

Year-round spawn-taking is possible in flounder by controlling photoperiod while for red sea bream and other species spawning may be advanced 2-3 months before the spawning season by water temperature manipulation (Fukusho 1986).

Broodstock nutrition has been recently studied and it was clarified that reproduction and egg quality were greatly influenced by the nutritional value of the diets (Watanabe 1984). The eggs produced by females fed Antarctic krill and formulated feed containing cuttlefish meal consisted mainly of normal buoyant eggs with a high hatching rate resulting to high production of viable larvae as fish seed (Watanabe 1984).

3) Evaluation and improvement of nutritional value of food organisms

Mass mortality was observed in larvae (6 mm TL, or 16-20 days after hatching) fed on rotifers cultured with baker's yeast (BY-rotifers) alone (Kitajima 1978). Chemical analysis revealed that BY-rotifers contain low levels of ω^3 highly unsaturated fatty acids (HUFA) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Both fatty acids were found to be essential for larvae of marine finfish (Watanabe et al. 1983).

Based on this information, it has become a common practice to enrich or improve the dietary value of rotifers by co-culturing with a minute alga *Nannochloropsis oculata* for 12-24 hours before feeding to larvae. Further, baker's yeast fortified with HUFA (as w-Yeast) has been developed and is commonly used at mass fry production facilities (Imada et al. 1979).

The rotifer consumption per larva per day was investigated and reasonable food supply regime for larval rearing was established (Kitajima 1978).

4) Environmental management (use of large scale and indoor tank for larval rearing)

Small scale tank systems (0.5-1 m^3) were used for larval rearing with high larval density (2-5 x $10^4/m^3$) because of effective feeding of limited available rotifers. However, with this system, water temperature and other environmental factors fluctuated widely.

Large scale (50-100 m^3) and indoor tanks with lower larval density (1-2 x $10^4/m^3$) begun to be used for larval rearing with the consistent supply of rotifer following the development of mass rotifer culture technology. Thereafter, water quality has been stable and survival rate has increased (50% at 10 mm in TL or day 30). Use of large scale tank stabilized water quality in larval rearing tank.

Other chemical, biological, and physical environmental conditions were investigated and much information have been accumulated.

5) Occurrence and prevention of lordosis

Lordosis, frequently observed (30-50% at the maximum) in hatchery-reared red sea bream and other species, was the most serious among several of the larval deformities seen. Lordosis characterized by V-shaped vertebral column was found in fish with uninflated swim bladder (Kitajima 1978). To solve the problems of lordosis, studies were conducted in the areas of nutrition, environmental improvement, and genetics (Fukusho and Kitajima 1988, Fukusho 1985).

Various experiments showed that abnormally-developed swim bladder was caused by a failure of air gulping at the water surface during the early larval stages from physostomous with pneumatic duct to physoclistous condition (Kitajima 1978). With the of improved environmental conditions discovered in these studies, lordosis has scarcely been found in hatchery-reared red sea bream, although it is not clear how uninflated swim bladder induces lordosis.

6) Instrumentation and mechanization of rearing system

Mechanization of the rearing system is required to save manpower and reduce production cost. Examples of mechanized facilities are automatic bottom cleaners to remove sediment and deposited feeds (Fushimi 1984, Fujita et al. 1982) and automatic feeders for dispensing micro-formula feed.

Full-scale automatic rearing system is employed at several mass juvenile production facilities where green algae and rotifer are transferred from tank to tank using pump and line systems to save on labor cost (Fukusho 1989).

7) Development of micro formulated diet

Development and introduction of micro-formulated diet for larvae and juveniles could lead to a "revolution" of current larval rearing technique.

Micro-formulated diet used in Japan are classified into three types, 1) micro-encapsulated diets (MED); 2) micro-bound diet (MBD); and 3) micro-coated diets (MCD) (Kanazawa 1988). These diets are effective for larvae and juveniles, especially for larvae 6 mm TL or older than day 20 since they have the ability to digest artificial diet with the development of stomach and gastric gland. Daily consumption of feed begin to increase significantly from this larval size.

8) Acclimation to wild condition

For intensive culture in net cages, hatchery-reared juveniles have superior characteristics such as early initiation to feed on minced fish meat and commercial formulated feed, faster growth rate, and faster acclimation to artificial condition in net cages. But, they are inferior to wild ones (Fukuhara 1986) in swimming performance, activity, response to predator, and others.

Intermediate rearing, i.e., acclimation of hatchery-reared juveniles to wild environmental conditions is strongly required for effective stocking to coastal sea for ocean ranching. However, the actual technique to improve quality or acclimatize to wild conditions has not been completely developed although juveniles are raised to appropriate sizes so as not to be victims of predators. Establishment of technology for intermediate rearing, therefore, is one of the most important subject for future study.

The Japan Society of Fisheries Science held a symposium on technology of fry production for stocking on 5 October 1992. Improvement and acclimation of hatchery-reared juveniles were discussed, the differences between viable juveniles for stocking and intensive culture were considered, and a schematic illustration to show their differences was proposed (Tsukamoto 1993). The proceeding was published as a book (Kitajima, K. ed., "Healthy Fry for Release, and Their Production Technique", Koseisha-Koseikaku, Tokyo, 199 pp., in Japanese).

9) Introduction of foreign strain and species

Red coloration of red sea bream is a sign of celebration and increases its market price. Juveniles of red sea bream from Korea and Hong Kong have recently been introduced into Japan. These are being cultured by aquaculturists since they exhibit more desirable red coloration than the Japanese strain, although they are taxonomically the same species. Content of astaxanthin and carotinoid in the skin are different among strains, e.g. these pigments are rich in Korean and Hong Kong strain although they are reared on the same diet. Their genetic differences remain unknown.

Besides red sea bream, various kinds of fish like groupers, rock fish, and other species have recently been introduced and cultured in Japan. But, precise investigation of species and its quantity has not been conducted and the scale of intensive culture is not large. In the future, introduction or import of newly produced high quality strains will be common together with the development of genetic breeding technology.

10) Genetic breeding

Experiments have been conducted on the hybridization between different species to create races or strain that grow faster and are more resistant to disease and low salinity (Kumai 1984). Selection is one of the most successful and actual methods in breeding of red sea bream and flounder. Selected population (four to five generations) show nearly 40% higher growth rate compared to wild populations, and significantly the selected strain shows low resistance to disease.

Recently, chromosome manipulation was applied to develop triploid and all female individuals. These technologies are almost established, but the quality and characteristics of these fish are still being investigated and evaluated. Basic research might be important to clarify genetic mechanism of sex determination and environmental influences on sex control.

Some researchers suggest that genetic management is quite important to maintain the stock of the wild population, especially the ocean ranching project which liberate hatchery-reared juveniles in coastal sea (Taniguchi and Tashima 1978). Genetic degeneration resulting from inbreeding of the artificial population, derived from few broods, may happen in the sea (Taniguchi and Tashima 1978).

Several subjects to develop the technology for mass production of juveniles

1) Accumulation of biological information on larvae and juveniles

Studies on morphology and life history of various species have been intensively conducted, but physiological and ethological studies on larvae and juveniles are few at present. Accumulation of basic information like function and development of sensory organs relating to behavior of larvae and juveniles, feeding and digestion, differentiation of reproductive and endocrine organs, are very important to establish scientific and reliable techniques for rearing of larvae and juveniles.

A symposium was held to discuss early development in fishes by the Japan Society of Fisheries Science on 5 November 1990. The symposium has strongly emphasized the importance of biological studies on larvae and juveniles to develop mass fry production technology. The proceeding was published as a book (Tanaka, M. ed. "Early Development in Fishes", Koseisha-Koseikaku, Tokyo, 140 pp., in Japaness).

2) Development of complete microparticulated diet with high nutritional value and digestive quality

Most of the biological feed may be substituted by microparticulated diets in the near future. Alternative feed to the biological feed rotifer leads to savings in labor and tanks for natural food culture. However, microparticulate diets tend to contaminate rearing water and precautions must be taken to preserve rearing environments by changing water more frequently. Future challenges will be to improve the quality of microparticulate diets. It is important to study their properties, characteristic in suspension, and digestibility.

3) Design and structure of larval rearing tank for intensive feeding of microparticulate diet

Larval rearing tanks are circular, rectangular, or octagonal with 1-2 m depth and are designed for feeding rotifer and other food organisms. Design and structure of larval rearing tanks for intensive feeding of microparticulate diets should be studied.

Development of closed and recirculating systems for larval rearing is another subject for future study since national environment regulation will be more strict.

4) Protection against disease

Various kinds of diseases caused by parasite, bacteria, fungi, and virus have been observed and has caused tremendous damage to fry production. Damage caused by viral disease is particularly heavy, therefore, pathological and immunological study is important to prevent disease.

The establishment of quarantine technology and regulation is urgent to protect against exotic disease since introduction and import of marine finfish juveniles will be much more common in the future.

5) International collaborative study

On biotechnology, pathology, endocrinology, and fish nutrition, basic research and accumulation of fundamental information are required. Therefore, international collaborative studies are very important to solve quickly common problems and establish common technology for fry production.

References

Fujita S, Koose K, Shintani H, Setoguchi I. 1982. Introduction of an idea and actual design for mechanization and automation system in mass marine larval rearing. Saibai-Giken. 11(2):1-8. (In Japanese).

Fukuhara O. 1986. Qualitative evaluation of artificially reared fry. p. 26-36. In: Sea Farming Technology of Red Sea Bream. Tanaka M, Matsumiya Y (Ed.). Koseisha-Koseikaku, Tokyo. 170 pp. (In Japanese).

Fukusho K. 1985. Status of marine larval culture in Japan. p.126-139. In: Reproduction and Culture of Milkfish. Lee CS, Liao IC (Ed.). The Oceanic Institute and Tungkang Marine Laboratory, Honolulu and Tungkang. 226 pp.

Fukusho K, Fujimura T, Yamamoto T. 1986. Broodstock and advanced spawning of red sea bream in an indoor tank with manipulation of water temperature. The Aquiculture 34(2):69-75. (In Japanese with English summary).

Fukusho K, Kitajima C. 1988. Environmental management of larval rearing marine fishes - A short history of research to prevent lordosis in red sea bream, *Pagrus major*. p. 9-13. In: Environmental Quality and Aquaculture Systems. Sinderman, CJ (Ed.). NOAA Tech. Rep. NMFS 69, Natl. Mar. Fish. Serv., Seattle. 50 pp.

Fukusho K. 1989a. Fry production for marine ranching of red sea bream. Int. J. Aq. Fish. Technol. 1(2):109-117.

Fukusho K. 1989b. Biology and mass production of the rotifer, *Brachionus plicatilis* (1). Int. J. Aq. Fish. Technol. l(3):68-76.

Fukusho K. 1989c. Biology and mass production of the rotifer, *Brachionus plicatilis* (2). Int. J. Aq. Fish. Technol. l(4):40-47.

Fukusho K, Hirayama K (Eds.). 1991. The First Live Feed - *Brachionus plicatilis.* The Oceanic Institute, Honolulu, 144 pp.

Fulk W, Main KL (Eds.). 1991. Rotifer and Microalgae Culture Systems. The Oceanic Institute, Honolulu, 364 pp.

Fushimi T. 1984. The present status of seedlings technology for red sea bream and black sea bream, and mechanization for their mass production. p.68-79. In: The Present Status of Development and Research in Technology for Fisheries. Inoue H (Ed.). Gijutsu-Joho-Center, Osaka. 286 pp. (In Japanese).

Hirata H. 1979. Rotifer culture in Japan. p. 361-375. In: Cultivation of Fish fry and its Live Food. Styczynska E, Turewicz T, Backie T, Jaspars E, Parsoone G (Eds.). European Mariculture Society, Belgium.

Imada O, Kageyama Y, Watanabe T, Kitajima C, Fujita S, Yone Y. 1979. Development of a new yeast (w-Yeast) as a culture medium for living feeds used in the production of fish fry. Bull. Japan. Sci. Soc. Fish. 38(1):1207-1214. (In Japanese with English summary).

Kanazawa K. 1988. Formulated microdiets. p. 132-146. In: Fish Nutrition and Mariculture. Watanabe T (Ed.). Kanagawa International Fisheries Training Center (JICA), Yokosuka. 233 pp.

Kitajima C. 1978. Acquisition of fertilized eggs and mass culture of juveniles of red sea bream, *Pagrus major*. Special report of Nagasaki Pref. Inst. Fish. No. 5, 92 pp. (In Japanese with English summary).

Kumai H. 1984. Biological studies on culture of the Japanese parrot fish, *Oplegnathus fasciatus* (T. et S.). Bull. Fish. Lab. Kinki Univ., No. 2, 127 pp. (In Japanese with English summary).

Taniguchi N, Tashima K. 1978. Genetic variation of liver esterase in red sea bream. Bull. Japan. Soc. Sci. Fish. 44(6):619-622. (In Japanese with English summary).

Tsukamoto, K. Fry quality p. 102-113. In: Healthy Fry for Release and their Production Techniques. Kitajima C. (Ed.). Koseisha-Koseikaku, Tokyo. 119 pp. (In Japanese).

Watanabe T, Kitajima C, Fujita S. 1983. Nutritional value of live organism used in Japan for mass production of fish: A review. Aquaculture 34:115-143.

Watanabe T. 1988. Broodstock nutrition. p. 147-159. In: Fish nutrition and mariculture. Watanabe T (Ed.). Kanagawa International Fisheries Training Center (JICA), Yokosuka. 233 pp.