Breeding and Culture of Finfishes

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The contribution of the fisheries and aquaculture sector to food security and livelihoods is significant, providing millions of people with food, nutrition, income and employment, while supporting economic development through harvesting, processing and marketing (FAO, 2024). Globally, aquatic foods provide about 17% of animal protein, extending over 50 percent in several countries in Asia and Africa. The sector employs an estimated 58.5 million people in primary production alone, approximately 21 percent women. In 2021, total fisheries and aquaculture production worldwide reached 218 million tonnes (mt) (2% increase from last year), (mostly because of the growth of aquaculture in Asia and of capture fisheries in the Americas), comprising 182 mt of aquatic animals and 36 mt of algae. Out of the total production of aquatic animals, 91.2 mt accounted from capture fisheries and 90.9 mt was contributed by aquaculture sector (FAO, 2024). This shift signifies a significant change from a historically capture fishery dominant industry to a 50:50 share. This trend suggests that aquaculture is playing/will play an increasingly important role in meeting global fish/seafood demands.

Fish can be cultured in any of the four culture systems such as ponds, tanks, raceways, recirculatory systems or cages. With the growing population and demand of fish, it is projected that over 60% of seafood must be contributed from aquaculture (mariculture) sector by 2030. Mariculture refers to the cultivation of marine organisms in seawater, usually in sheltered coastal or offshore waters. Mariculture may consist of raising the organisms in or on artificial enclosures such in floating netted enclosures (cages) for fishes or on racks for mussels/oysters or raft for seaweeds. Mariculture offers opportunity and has great potential to meet the fast-growing demand for seafood in India. Pioneering efforts to develop aquaculture in the country were started in the 1970s by Indian Council of Agricultural Research (ICAR)-Central Marine Fisheries Research Institute (CMFRI) in Mandapam and Tuticorin with seaweed and bivalve cultivation. Since then, ICAR- CMFRI is in the forefront towards development and disseminating mariculture technologies in India through standardizing seed

production technology and farming of marine finfishes/shellfishes, Integrated Multitrophic Aquaculture (IMTA), Recirculating Aquaculture System (RAS).

Mariculture in coastal and offshore waters is an increasingly important aspect of India's aquaculture industry. With a vast coastline of 8118 kms, India possesses significant potential for mariculture development. This practice not only supports the country's seafood production but can also contribute significantly to the livelihoods of coastal communities, bolstering food security and enhancing the national economy. For the successful development of mariculture in India, standardized seed production techniques of candidate species with growth rate, market demand and price are required. ICAR-CMFRI has developed and standardized seed production techniques of several marine fishes with a view to expanding the mariculture sector in our country. With a view to develop and popularize open sea cage farming, ICAR-CMFRI has designed sea cages and demonstrated the prospects of culture of these marine finfishes in galvanized iron (GI) cages and high-density polyethylene (HDPE) cages in the sea. Disease-free-high-quality hatchery produced seeds in sufficient quantity and appropriate size are prerequisite for mariculture development in our country. Below are the details of breeding and seed production technology of high value marine finfishes developed and standardized by ICAR-CMFRI.

Breeding of marine finfishes

1. Cobia

Cobia (*Rachycentron canadum*), a popular marine species for aquaculture due to its fast growth and high market value, often involves hormone induction to ensure reliable spawning. The Mandapam Regional Centre of CMFRI initiated research on the seed production of cobia during the year 2008 and succeeded in induced breeding and seed production of cobia during 2013.

Broodstock development and induced breeding:

From the broodstock sea cages, healthy fishes weighing around 9 kg and above, are transferred and stocked in 60 t capacity FRP tanks/100 t capacity cement tanks with a recirculation system in an on-shore hatchery facility at the male: female ratio of 2:1. The fishes were fed with special maturation diets viz., squids, cuttlefish, crab, shrimps and chopped oil sardines once in a day. Once the ova reached a size of 700 µm diameter (determined by cannulation), the females were induced with hCG at the dose of 500IU/Kg body weight. The males are administered a dosage of 250IU/Kg body weight. The hormone is administered via intramuscular injection, usually in the dorsal muscle near the base of the pectoral fin. The spawning occurred within 36 hours after injection. The number of eggs spawned by cobia ranges from 0.4 to 2.5 million.

Spawning, hatching and larval rearing:

After hormone injection, the broodstock are monitored closely. Spawning usually occurs within 36-48 hours post-injection. The fertilized eggs floating at the surface were collected using a 500 µm mesh and then incubated. Unfertilized eggs, which settle at the bottom, were removed by siphoning. The fertilized eggs were incubated in 2tonne capacity rectangular or circular tanks, with a moderate stocking density of 200 to 500 eggs per liter. Embryo development was frequently observed under a stereo or compound binocular microscope. Hatching occurred between 18 to 22 hours. Before transferring the newly hatched larvae to larviculture tanks, 10 to 20 larvae are checked under a microscope for deformities, abnormalities, pigmentation, and internal organ development. The newly hatched cobia larvae, measuring around 3.4 mm, were stocked in 2-tonne capacity tanks containing filtered seawater at a density of 5-10 larvae per liter. The tanks were provided with mild aeration and microalgae at a density of $1x10^7$ cells/mL. The mouths of the cobia larvae open on the 3rd day, measuring around 230 µm. Newly hatched cobia larvae typically begin feeding at 3 days posthatch (dph) and can be fed enriched rotifers (*Brachionus rotundiformis*) at a rate of 1012 per mL, twice a day until 10 dph. From 8 dph, the larvae can be fed enriched Artemia nauplii at a rate of 5-6 per mL, twice a day. During the rotifer and Artemia feeding stages, the green water technique can be used in the larviculture system with the microalgae *Nannocloropsis oculata* at a cell density of $1x10^7$ cells/mL. *Artemia* nauplii were provided at a density of 5-6 per mL up to the 19th day.

Weaning to larval inert feed began on the 15th day, with co-feeding of Artemia continuing until the 19th day. During weaning, formulated feed was given 30 minutes before live feed. Frequent grading is necessary from this stage to reduce cannibalism,

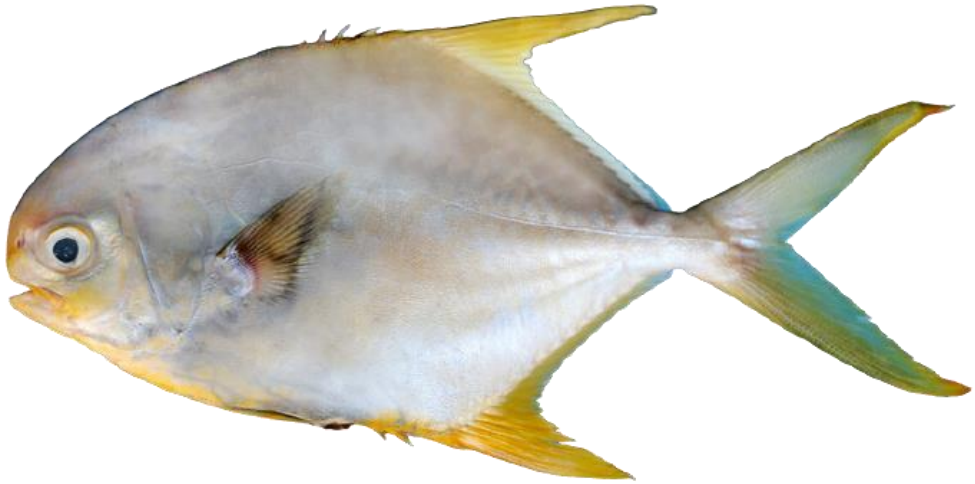
with daily grading advisable for better survival. From the 20th day, feeding was exclusively on inert larval feeds. The size of the artificial feed had to be smaller than the mouth size of the fish. Continuous water exchange was required during the weaning stage. Larval metamorphosis began on the 18th day, with all larvae transforming into juveniles by the 21st day. Water exchange was minimal until the 7th day and was gradually increased from 10% to 100% from the 8th to the 25th day after hatching. During the larviculture period, the following environmental conditions were maintained: Dissolved Oxygen (DO): > 5 mg/L, Ammonia (NH_3): < 0.1 mg/L, pH: 7.8 – 8.4, Salinity: 25-35 ppt and Water temperature: 27-33°C. Nursery rearing was conducted from the 25th to the 55th day. Initially, the fingerlings were provided with artificial feed of 800 µm size. Subsequently, they were fed with progressively larger sizes of floating extruded larval feeds. A daily water exchange of 100% was advisable. Water quality parameters such as salinity, temperature, pH, oxygen level, and ammonia were closely monitored throughout the larviculture period. After 55 days posthatching, fingerlings, now 3-4 inches in size, could be supplied to farmers for stocking in sea cages or ponds for further nursery rearing and grow-out farming.

2. Silver Pompano

Silver pompano, *Trachinotus blotchii* also known as the snubnose pompano is one of the suitable species for brackish water and marine water aquaculture due to its fast growth, adaptability to different salinity regimes, good quality meat, and high market demand. Silver pompano holds significant potential for boosting aquaculture production and supporting coastal economies. In India, the Central Marine Fisheries Research Institute (CMFRI) initiated aquaculture research on pompano at its Mandapam Regional Centre in 2007, and the first successful broodstock development, induced breeding, and seed production was achieved in 2011.

Broodstock development and induced breeding:

Silver pompano fish are induced to spawn when the oocyte reaches a diameter within the range of 520-580 µm, typically exceeding 520 µm. In induced breeding, a sex ratio of 1:3 (female to male) is typically maintained in the spawning tank, although ratios of 1:1 and 1:2 have also resulted in successful spawning. Selected brooders for induced spawning must be healthy and mature, with males typically larger in size and weight. Generally, individuals aged 2-3 years and weighing between 1.5-5 kg are preferred, with a minimum weight requirement of 2 kg for males and 1.5 kg for females to initiate spawning.



A standardized dosage of hCG, set at 350 IU per kg body weight, is administered as a single dose into the dorsal muscles of both males and females. Water circulation in the RAS is switched off in which hormone induced brooders are kept after administration of second dose.

Spawning, hatching and larval rearing:

Usually, the spawning could be noted within 36-48 hours after hormonal induction. The spawning in Pompano usually takes place between late night and early morning hours. The number of eggs spawned by pompano brooders ranged from 1.5 to 3.0 lakh eggs (female brooder, bodyweight 2-2.5 Kg). The fertilized eggs of pompano float and are scooped gently using a 500 µm net. The collected eggs are stocked in the incubation tank of 3 – 5 tonnes with a stocking density of 10 – 20 eggs/litre of water and the hatching rate takes places within 18 to 24hrs. The newly hatched larvae are stocked in larval rearing tanks of 3-5 t capacity tanks at 10/litre of water and *Nanochloropsis* sp. or *Isochrysis* sp. is added to maintain a density of $1x10^5$ cells/ml. The larvae's mouth opens at 3dph and measures around 230 mm.

Larviculture tanks should fed enriched rotifers at a density of 5-8 nos. per mL from 3 dph to 14 dph. Rotifers must be cofed with enriched Artemia nauplii during 8-12 dph, and thereafter maintain at a density of 3-5 nos./mL with enriched Artemia nauplii alone up to 18 dph. Co-feeding with Artemia should be continued until 18 days after weaning

to larval inert feeds. It is possible to feed exclusively on larval inert feeds from 19 dph onward. From 8 to 14 dph, it can be progressively raised from 10% to 100%.

Weaning feed (350µm) offered in 17th day. Around 25th day, the harvest is carried out; size grading should be done. However, anticipated survival is 20 – 25 percent. Nursery rearing commences at 25–30 days post-hatch (DPH), during which the juveniles are fed an artificial floating diet with particles sized at 800µm and progressively increasing size of pellets according to fish mouth size. The stocking density is set at 20 individuals per liter, and water exchange is maintained at approximately 200 percent. Regular siphoning is necessary to uphold optimal water quality parameters. Grading is conducted to mitigate mortality rates. On average, silver pompano experience a growth rate of 1mm per day. By 55 DPH, fingerlings attain a size of 2.5 – 3.8 cm.

3. Indian Pompano

The Indian pompano (*Trachinotus mookalee*) known for its high market value and good taste, is an emerging candidate for mariculture in India. This species is found in the Indian Ocean and is becoming increasingly popular for aquaculture due to its rapid growth rate, hardiness, and high economic value. The species has a wide salinity tolerance, so in addition to sea cages, this species is a suitable candidate for brackish water cages and ponds. Visakhapatnam Regional Center of ICAR-CMFRI succeeded in developing and standardizing induced breeding and seed production of Indian pompano.

Broodstock development and induced breeding

Adult fish of more than 3 Kg can be collected from the wild by hook and line and transported to the hatchery. The sexes are separate and the maturation size is around 3.0 Kg. These adult fishes were stocked in 125t capacity circular tank having recirculatory facility for broodstock development. The fishes were fed with squid along with clam meat and matured in four months. Broodstock tanks should have recirculating facilities with 300% water re-circulation. Sea water used for broodstock development should be filtered and clear with stable salinity of 30-35 ppt and water temperature of 27-32 ^{0}C. Once the female ova size attained a size of more than 500 µm, and the males are oozing, then both the sex need to be injected hCG at the rate of 350IU/ Kg body weight. The fishes respond after 36 h of injection at a temperature range of 28-32ºC.

Spawning, hatching and larval rearing:

The fertilized eggs of Indian pompano are non-adhesive and pelagic and range from 0.9 to 1.0 mm in diameter. The eggs hatched out after 18–20 h of incubation at a temperature of 29 ± 1 °C. The overall fertilization and hatching rate was found to be 69 ± 1.55% and 87.67 ± 0.81%, respectively. Larval rearing was carried out in 2 t capacity fibre reinforced plastic (FRP) tanks using green water system. The recommended initial stocking density for Indian pompano is 10 larvae/L. The newly hatched larvae was 2.12 ± 0.02 mm in total length, with an oval shaped yolk sac of 0.55 mm^2 and an oil droplet of 0.06 mm^2 in area. Immediately after hatching, the yolk sac serves as the sole source of nutrients for the developing Indian pompano embryos. This endogenous nutrient source sustains the larvae for 2 days. Following this period, exogenous feeding begins when their mouths open. The initial mouth gape is around 230 µm (40-46 h post hatch), necessitating the provision of appropriately sized feed such as copepod nauplii and screened rotifers. On the 2nd day post-hatching (DPH), *Nannochloropsis* sp. and *Isochrysis* sp. are introduced into the larval rearing tanks at a ratio of 1:3, with an algal cell density of 1 x 10^5 cells/mL. Rotifers filtered with a 100 µm mesh and copepod nauplii filtered with a 100 µm mesh are introduced into the larval rearing tanks on the 2nd day post-hatching (DPH), once the larval mouths have formed.

The density of rotifers and copepod nauplii is maintained at 10-15 and 2-3 individuals/mL, respectively, from the 2nd to the 5th DPH. After the 5th DPH, rotifers are introduced at densities of 20 individuals/mL, gradually increasing to 30 individuals/mL from the 8th to the 10th DPH. The density of rotifers decreases as larvae consume them, and by the 13th DPH, rotifers are no longer present. Freshly hatched Artemia nauplii

are introduced at a density of 0.5 individuals/mL starting from the 8th DPH, with their size increasing as the rearing period progresses. Weaning of pompano larvae onto artificial diets (formulated feed) begins on the 11th DPH, using an initial particle size of 200-300 µm. The formulated feed is sprinkled onto the water surface in small amounts frequently throughout the day, ensuring it is consumed within 5 to 10 minutes to prevent accumulation and decomposition, which can degrade water quality. The particle size of the feed is increased to 400–800 µm from the 22nd DPH. Water exchange should be increased to 20% per day when both rotifers and Artemia are being fed together (8th DPH). This exchange rate should gradually increase to 50% per day from the 11th DPH and to 100% per day from the 16th DPH. Larvae attain an advanced fry (2.0-2.5 cm; 0.2 g in size) stage after 35-40 days and at this stage it can be shifted to indoor based flow through nursery facilities.

4. Orange-spotted grouper

The orange-spotted grouper, *Epinephelus coioides* is distributed all along the Indian coast from Gujarat to West Bengal, including the Andaman and Nicobar Islands. Orange spotted grouper is highly prized in the world Live Reef Food Fish (LRFF) trade with several traits like fast growth, hardy in nature with tolerance to range of water salinities and high market value. Visakhapatnam Regional Center of ICAR-CMFRI succeeded in developing and standardizing induced breeding and seed production of orange-spotted grouper.

Broodstock development and induced breeding

E. coioides is a typical protogynous hermaphrodite fish that changes sex from female to male and remains male throughout its life span. Wild-caught adult females weighing 2-2.5 kg were transitioned into broodstock within an 8m diameter, 2.5m deep tank in a Recirculatory Aquaculture System (RAS). To mitigate barotrauma stress, the fish received prophylactic treatment upon arrival at the hatchery. After 15 days, half of the fish were randomly chosen for sex reversal, transitioning from female to male, through implantation with a combination of 17∝ methyl testosterone (MT) and letrozole at 5 mg and 0.2 mg per kg body weight, respectively, as outlined in Ranjan *et al.* (2015). The remaining fish underwent natural ovarian development without implantation. Subsequently, females underwent monthly cannulation using a 1 mm inner and 2 mm outer diameter catheter to assess the diameter of intra-ovarian eggs. After 3 months of stocking in the tank, females underwent final oocyte maturation with 65.53% of the ova having more than 400 µm size. The hormone implanted female fish got sex reversed to male and were found to be oozing after 2 months of implantation. The fishes were continually fed fresh squid twice in a day till satiation. Moreover, vitamin A, vitamin B-complex, vitamin C, vitamin E and vitamin–mineral mix were supplemented twice a week along with the feed to avoid any possible nutritional deficiencies in their diet.

Spawning, hatching and larval rearing:

Natural spawning of orange spotted grouper was observed in 4 months of hormone implantation and egg collection net of 500 µm was fixed in egg collecting chamber connected to broodstock tank. A total of 47.23 million of eggs were produced with an overall fertilization and hatching rate of 80.44 ± 0.56% and 85.79 ± 0.50%, respectively, without any hormonal intervention during the spawning. The eggs hatched after 1822 hours of incubation at a temperature range of 28-30 ^{0}C. The newly hatched larvae measured 1.2- 1.6 mm in total length. The larvae are stocked in FRP tanks of 2 t capacity for larviculture. The intensive larviculture tanks are provided with green water (*Nannochloropsis* sp. and *Isochrysis* sp. 3:1 ratio) at a density of about 1 x 10^5 cells/ml and screened rotifer with 80 µm enriched with ALGAMAC at a density of 5-10 numbers/ml from 3 to 5 DPH. The copepod nauplii are added @ 2 numbers/ml. The mouth opens between 2–3 days after hatching (around 60 hours) and the yolk is completely absorbed by 3-4 DPH (Days Post Hatching). The critical stage for the larvae is 3 to 5 DPH when they shift to exogenous feeding from yolk sac feeding. At the time of mouth opening, mouth gape was 120 µ which increased to 180 µ after 10-12 hours. The stomach and eyes becomes pigmented on 3rd DPH. The larvae are fed with rotifer

screened with 100 µm from 6th DPH onwards at a density of 10-15 numbers/ml, which is gradually increased to 20 numbers/ml from 11th to 18th DPH. Rotifer density gradually decreases with increase in the rate of rotifer consumption by the larvae and eventually by 30th DPH, the rotifers disappear.

Freshly hatched out Artemia nauplii are fed at density of 1 individual/ml from 15th DPH and their size increasing with advancing in rearing period. Adult copepods are fed during 16th-20th DPH in larval rearing. Weaning of grouper larvae with artificial diets starts from 15th DPH. Artificial diet with a particle size of 100-150 µm is used initially. The formulated feed is sprinkled onto the surface of the water in small amounts frequently throughout the day. The size of particulate feed is increased to 400–800 µm from 30th-45th DPH. 5-10% water exchange is started from 11 DPH gradually increasing to 100% from 35 DPH. Bottom siphoning of the tank is started on 8th DPH. From 4th to 6th DPH, there are no major morphological changes, but pigmentation around the stomach increases. After 25th DPH, body pigmentation increases, and the larvae appear darker in colour. The dorsal and pectoral spines begin to recede. Orange spotted grouper larvae show drastic changes in their shape as they grow from the newly hatched larva to the juvenile stage, just like in other serranids. The larvae before metamorphosis to the juvenile stage are highly sensitive to environmental conditions and substantial mortality occurs even due to minor stresses. Orange spotted grouper larvae metamorphose to juveniles at about 33rd- 37th DPH, but this can be delayed because of low water temperatures and poor nutrition and a survival of more than 12 % is achieved during the larval rearing.

The nursery rearing process for grouper involves two distinct phases. Initially, fry measuring 2.5-3.0 cm (0.4g) are cultivated in tanks for two weeks until they readily accept artificial feeds, reaching sizes of 5-6 cm within this timeframe. During this phase, the fry are reared in 1-ton capacity tanks at a density of one fish per liter. They are nourished with a combination of artificial diet and Artemia to facilitate complete weaning from larvae to artificial feed. The second phase entails the growth of fish from 5-6 cm to 10-15 cm, suitable for stocking in cages or ponds. Fingerlings undergo rearing in various environments such as pond-based hapa (with a 2 mm mesh size), flow-through cement tanks, or recirculatory systems. Feeding during this phase includes pellet feed with varying protein levels and minced fish meat. Among these options, pellet feed containing 45% protein yields the highest growth rates.

4. John's snapper

Lutjanus johnii, commonly known as John's snapper has immense potential for mariculture owing to its fast growth rate, easy adaptability to culture conditions, quick acceptance of artificial feed, pleasant appearance, good meat quality and high consumer preference. Success in captive spawning and seed production of the fish, which was carried out at the Visakhapatnam Regional Centre of ICAR-CMFRI, has set a stage for farming John's snapper using hatchery-produced seeds.

Broodstock development and induced breeding

Adult fishes of 3-3.5 kg maintained in the offshore cages installed off Visakhapatnam were selected and transported to the hatchery complex. They were subjected to prophylactic treatment for a period of two weeks and then stocked in an indigenously developed Re-circulating Aquaculture System (RAS) with a capacity of 125 t. The fishes were acclimatized and were fed upon squid, twice a day till satiation. The gonadal profile of the fish was assessed routinely using live ovarian biopsy. Once the ova size of females was found to be optimum, females and oozing males were injected with inducing hormones for spawning. The fish spawned after 36-42 hrs of injection with GnRH and hCG @ 50 µg and 500 IU/kg body weight to female and its half dose to male, with a fertilization rate of 79±6.01% and 83.25 ±4.21% respectively with a sexratio of 1:2.

Spawning, hatching and larval rearing

Induced fishes responded 42 hours post-induction, and the fertilized eggs obtained were collected using flow-through cum recirculation of tank water. The collected fertilized eggs were treated and stocked in FRP tanks with a capacity of 2 t for incubation and larval rearing. Larvae hatched out after 14 hrs. at 28-30 ^{0}C. Mouth opened 54 hrs. post-hatching. The larval rearing was carried out using a green water system with different live feeds such as *Nannochloropsis* sp., *Isochrysis* sp., copepod nauplii, rotifers and Artemia nauplii. Larval rearing was carried out in 2 tons capacity

FRP tanks using green water system. The mouth opening was formed after 45-46 hrs with 90-95 µm mouth gape at 28-29 0 C. Larval rearing was carried out with copepod nauplii (2 DPH), screened rotifers < 100 µm (5 DPH), Artemia nauplii (11 DPH). The larvae were weaned on artificial feed from 20 days post-hatch (DPH). Larvae started metamorphosis from 22 DPH, which was completed by 30th DPH, by this time; the larvae were fully weaned on artificial feed. After 42 days of rearing post-hatch, a survival rate of 3.67% was achieved and the fry reached an average size of 3.8 cm and 0.62 g.

5. Vermiculated spinefoot

Rabbit fishes are an excellent candidate species for culture in marine and brackish water because of their herbivorous/ omnivorous feeding habits, low protein requirements, tolerance to a wide range of environmental conditions, rapid growth, consumer preference and economic value. Vermiculated spinefoot, *S. vermiculatus* has been reported to be one of the fastest growing species among the genus *Siganus*. The standardized protocol for induced breeding and seed production of *S. vermiculatus* was carried out at Karwar Regional Station of ICAR-CMFRI.

Broodstock development and induced breeding

Fishes (250-500 g) can be collected from the wild and broodstock development could be carried out in either 6m diameter cages or 5 t RAS The fishes were fed with a maturation diet ie., 1 kg of formulated floating pellets (Growel, India; 40% protein, 10% fat, 3.5% fibre) enriched by adding 2 g of vitamin E, 1 g of vitamin C, 8 mL of cod liver oil and 20 mL of soy lecithin, at the rate of their 2% body weight twice per day for 4 months. The maturation diet was supplemented with squid meat @ 2% of their body weight during the entire rearing period. From the broodstock development facility,

female brooders were identified by cannulation using a flexible catheter (2 mm inner diameter; Ramsons Scientific and Surgical Industries Pvt. Ltd., New Delhi, India) and male brooders were identified by slight pressure on the abdomen. Among the mature fishes brought to the hatchery, a female having an average ova diameter of 400 µ and a running male were selected and stocked in separate FRP tanks. These could be induced with human chorionic gonadotropin (hCG) (two intramuscular injections @ 500 IU/ fish and 200 IU/ fish for female and male at 24 h interval respectively) or LHRHa (two intramuscular injections @ 20 µg/kg for female at 24 h interval and single dose of 20 µg/ kg to male during last injection to female) during all phases of lunar cycle.

Spawning, hatching and larval rearing:

Natural spawning without inducement can also be achieved by providing good nutrition and water quality parameters. Since the eggs are demersal and adhesive, tiles should be provided in the spawning tank for attachment and if required shifting to incubation tanks. Spawning occurs between 20 and 21 hrs after the second injection. Green water systems with microalgae, *Nannochloropsis salina* and *Isochrysis galbana* at a concentration of 2–3 × 10^6 cells/mL and 2–3 × 10^5 cells/mL were used in tanks (1000L) for egg incubation and larval rearing respectively. The fertilised eggs (0.57 ± 0.02 mm) hatched out between 24 and 25 hrs and the newly hatched larvae measured 1.92 ± 0.08 mm in total length with a transparent yolk sac (0.63 ± 0.04 mm) and an oil globule (0.23 ± 0.02 mm). A mouth gape of 89.03 ± 9.4 µm was observed after 42 hrs post-hatch. Since the mouth gape of rabbit fish is very small, the use of copepod, *Parvocalanus crassirostris* nauplii (40-60 µm) as the first feed of larvae ensures better growth and survival. Enriched rotifers (5–37 dph), copepodites (10–20 dph), umbrella stage of Artemia (18–24 dph), artificial pellet feeds (21–37 dph) and enriched Artemia nauplii (29–37 dph) were also used during various stages of larviculture. Metamorphosis was completed within 35–37 dph, during which post larvae with vermiculated body patterns measured 25.2–28.4 mm in length and 0.28– 0.30 g in weight.

6. Picnic seabream or black seabream

Picnic seabream or black seabream, *Acanthopagrus berda* is an important fish in fisheries and aquaculture because of its high recreational value, excellent meat quality, high economic value, ability to tolerate wide variations in environmental parameters such as salinity, temperature, strong resistance to diseases and faster growth rate. The

standardized protocol for induced breeding and seed production of *S. vermiculatus* was carried out at Karwar Regional Station of ICAR-CMFRI.

Broodstock development and induced breeding

Subadults and adults of *A. berda* (17–35 cm) collected from wild were maintained in a 6 m diameter galvanized iron framed circular floating net cage at the marine cage farm of the Station. The fish were fed with pellet feed (40% crude), Vitamin-mineral mixture (1 g kg−1 feed) and cod liver oil (10 ml kg−1 feed) were provided additionally along with the feed twice in a week. Males with oozing milt were available consistently throughout the period while asynchronized maturation of female was observed. A pair of mature male and a female (oocyte diameter of 440 ± 12 µm) were induced using a dose of (0.25 ml kg−1) gonadotropin releasing hormone analogue and female was given a similar second dose after 6 h.

Spawning, hatching and larval rearing:

The fishes spawned after 36 hours of inducement and the pelagic eggs hatched after 22 to 24 hours at a temperature of 28 to 30 ^{0}C. Fecundity was 0.25 million per female (450 g). Eggs were incubated in fibre glass tanks (100 L) in seawater (34 ppt) with gentle aeration and 86% of the eggs hatched after 24 hr. Planktonic larvae measured total length (TL) 1.7 ± 0.14 mm at 0-day post-hatch (dph), started exogenous feeding from 3 dph (TL 2.7 ± 0.48 mm) when the mouth size was 180 ± 2.8 µm. Yolk sac was completely exhausted by 3 dph. Marine microalgae, *I. galbana*, was added in all the tanks at the rate of 3 × 105 cells ml−1 and the same density was maintained till 20 dph. Co-feeding of rotifer *B. rotundiformis* at 5 nos. ml−1 and nauplii of copepod (*P. crassirostris*) at 3 nos. ml−1 yielded better initial larval survival. Metamorphosis of the larvae started at 25 dph (TL 12 ± 0.68 mm) and juveniles emerged from 35 dph (TL 22 ± 0.76 mm) with a survival of 9%. Partial water exchange was initiated on 4 dph; 10%

water was exchanged from 4 to 8 dph; 30% from 9 to 14 dph; 50% from 15 to 34 dph and 100% from 35 dph onwards.

7. Pink ear emperor

Lethrinids (emperors, emperor snappers or large eye breams) are important tropical coastal food fish that belong to the order Perciformes and family Lethrinidae. The Pink ear emperor, *Lethrinus lentjan* (Lacepede, 1802) is considered a delicacy in many states in India, Arabian Gulf and other Southeast Asian countries. *L. lentjan* was reported to attain sexual maturity at the end of the third year, when the fish measured 300 mm standard length. Vizhinjam Regional Centre of ICAR-CMFRI successfully achieved captive broodstock maturation in RAS, natural spawning, larval rearing and seed production of *L. lentjan*.

Broodstock development and induced breeding

Wild collected fishes (19–28 cm; weight: 760–1200 g) after quarantine treatment were stocked in 10 t RAS. Stocked fishes were fed twice daily at the rate of 3–4% of their body weight with fresh cleaned sardines, mackerel and anchovies. Fresh squid was given thrice in a week and along with vitamin C and vitamin E tablets once in a week. Fish were also fed ad libitum intermittently with compounded semi-moist feed. No specific external features of sexual dimorphism was observed in the brood fishes during rearing and after 5 months of rearing, brood fish swam one above the other and always moved as a group. The fish were observed to be at the bottom of the tank for most of the time with no specific courtship behaviour. Egg collecting mesh bag (200 µ) was tied to the side drain conduit to check the spawning.

Spawning, hatching and larval rearing:

Spawning was observed after 5 months of rearing in RAS. Water quality parameters in the broodstock tank during the rearing period were as follows: temperature: 28–29.5 °C, salinity: 32– 35.5 ppt, pH: 7.6–8.1, total ammonia: 0.354–0.422 ppm, DO: 4.04– 5.12 mg/L, alkalinity: 102–122 mg/L $CaCO_3$; CO_2: 4.12–4.67 mg/L; turbidity: 0.16–0.39 NTU, nitrate(NO3): 0.01–0.045 mg/L, nitrite:0.008– 0.027 mg/L and photoperiod: 12 h/ L: 12 h D. The fertilized eggs (714.21 ± 11.91 µm) had a single oil globule (146.63 ± 3.51 µm) and were clear, pelagic, and non-adhesive. Fertilized eggs (714.21 ± 11.91 µ) were transparent, and non-adhesive. Eggs were directly stocked at the rate of 10 egg l^{-1} into larval rearing tanks of 2-ton capacity having a blue /yellow colour interior and filled with filtered (2 µ cartridge filter) seawater (35 ppt).

Hatching of eggs was observed after 17 h 30 min of post spawning at 28 °C. Size of hatchling (yolksac-larvae) ranged from 1355.147 µ to 1534.631 µ with an average body length of 1469.04 ± 54.66 µ and the yolk sac length measured 846.37 ± 54.8 µ. A mixture of *N. salina, I. galbana* and *C. calcitrans* in ratio of 3:1:1 was added into the larval rearing medium (average total cell density: 2.1 × 10^6 cell/ml) with mild aeration. Copepod adults of *P. crassirostris and Acartia* sp. (0.1–0.2 nos./ml) were added to ensure that long with Acartia sp. (45–55 µ) was added at the rate of 2–3 nos./ml to make sure that sufficient number of copepods nauplii was available for the fish larvae to feed on without searching for the prey. From 6 dph onwards larvae were fed with enriched rotifers (4–10 nos./ml) till 14 dph. Newly hatched artemia (0.5–1.0 no./ml) were fed from 14 to 18 dph and enriched artemia (1–2 nos./ml) were fed from 18 dph onwards and it continued till 25 dph. Artificial feed of 150 µ size was fed from 16 dph onwards and continued till 20 dph. From 20 dph pellet size of 200–400 µ was fed along with 150 µ and it feeding continued till 30 dph. Between 25 and 40 dph the larvae were fed 300 µm feed along with 500 µ, and by this time the larvae started moving to bottom and were found to be very sensitive to physical disturbances and handling stress resulting in sudden mortality of larvae in large numbers. Larvae became juvenile (length – 19.2 mm; weight – 0.096 g) after 35 dph resembling the adult fish colourations. In-situ biological filter (Sponge filter or bucket filter with airlift) was kept in the tank when the larva were fed with artificial diet and continued till 35dph.

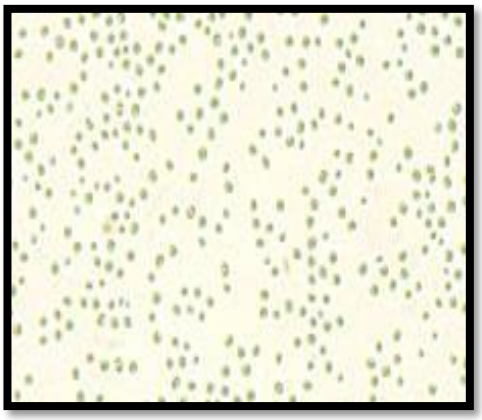
Live feeds for larval rearing

Live feed refers to small, microscopic living organisms which are used to feed fish larvae especially during the early larval stages. Live food organisms include all plants (phytoplankton) and animal (zooplankton) lives grazed upon by economically

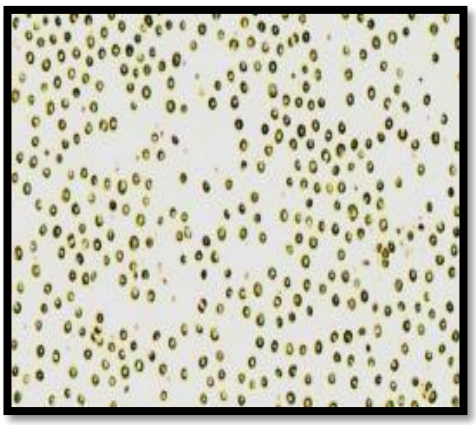
important fishes. Phytoplankton are generally eaten by zooplankton and forms the basis of the food chain. Live foods can swim in water column and are constantly available to fish and shellfish larvae and are likely to stimulate larval feeding response. Most of the fish and shellfish larvae in nature feed on small phytoplanktonic and zooplanktonic organisms. The success in the hatchery production of fish fingerlings for stocking in the grow-out production system is largely dependent on the availability of suitable live food for feeding fish larvae, fry and fingerlings. Live food organisms contain all the nutrients such as essential proteins, lipids, carbohydrates, vitamins, minerals, amino acids and fatty acids and hence are commonly known as "living capsules of nutrition".

1. Microalgae

Microalgae are the primary food source of all marine food chains and provide energy for all successive trophic levels in the marine ecosystem. They are generally free living, pelagic and in the nano- plankton range (2-20µm). According to the nature of photosynthetic pigment, algae are further classified into three divisions such as Chlorophyta (green algae), Phaeophyta (brown algae) and Rhodophyta (red algae). The prime requirements of aquaculture practice are the production of appropriate nutritionally balanced, non- polluting, economically viable and readily acceptable micro algae which will ensure maximum survival and optimum growth of cultivable organisms. Nearly 16 genera of microalgae are commonly employed for aquaculture purposes. Species mainly used ones belong to the genus *Isochrysis, Nanochloropsis, Pavlova, Chatoceros, Dunaliela, Tetraselmis* and *Chlorella*.



Nanochloropsis



Isochrysis

Algae culture media

Algae media refers to the solution or culture in which algae grow. All the media have several components in common: sources of phosphorus, vitamins and trace metals. However, the specific types of these nutrients, their concentrations and ratios vary between the media. For the successful production of microalgae various culture media have been used depending on the organisms to be cultured. The two commonly used media are F/2 media and Conway or Walne's media. Walne's or Conway media contains all the ingredients and widely used in the laboratory maintenance. It is economic to use commercial fertilizers for the mass production of microalgae in outdoor mass production systems.

Sterilization of seawater

For the sustained production of any algae production sterilized seawater is required. The sterilization can be done by many ways like filtration, autoclaving, pasteurization, UV irradiation, chlorination or ozonization. Care must be taken to eliminate chances of contamination from microorganisms like ciliates.

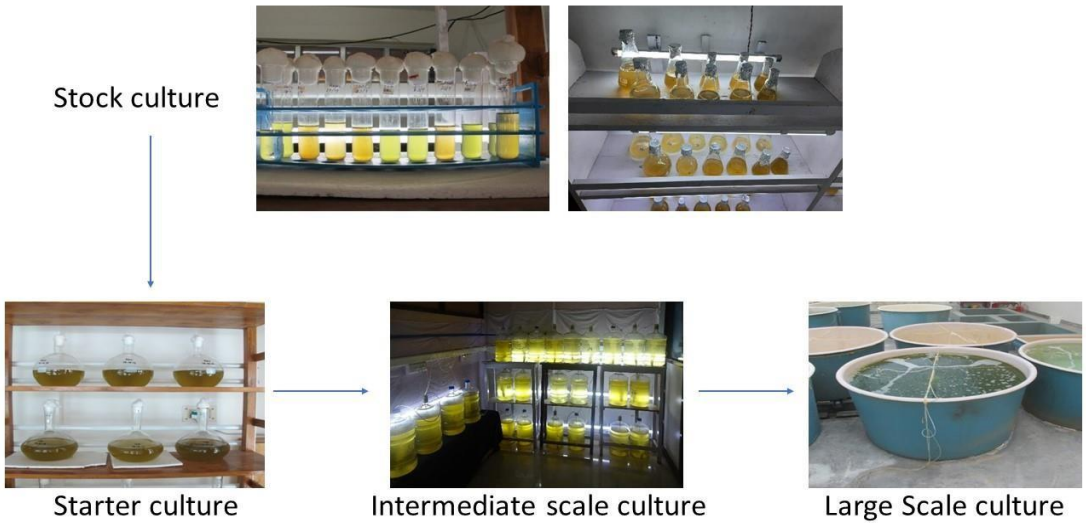
Optimal conditions for culture of microalgae

The factors which affect the growth of micro algae are light intensity, temperature control, aeration, nutrients inoculums and desired salinity. These factors are critical for maintaining a stock room in a successful way.

Parameters	Range	Optimum
Temperature (°C)	16-27	18-24
Salinity (ppm)	12-40	20-24
Light intensity (Lux)	1000-10000	2500-5000
Photoperiod Hrs (L:D)	16:8	24:0
pH	7-9	8.0-8.5

Stock culture development and maintenance

Stock cultures or master cultures are considered as the basic foundation of culture. To reduce risks of contamination, two series of stocks are often maintained, one which is usually used for the starter cultures for the production system and the other which is only subjected to the handling necessary for stock maintenance. Stock cultures are maintained in test tubes (50 ml) or conical flaks (100-250 ml) at a light intensity of about 1000 lux and a temperature of 19 to 22 °C. Stock cultures usually make in a small quantity and some of these cultures keeps to meet unforeseen conditions like contamination and the remaining cultures can be used to produce culture in large volume by inoculating in bigger glass wares to produce starter cultures (upto 3-4 L), intermediate culture (up to 20 L) and large scale cultures (above 50 L).



Starter cultures (250 ml to 4 l in volume) are grown quickly for 7 to 14 days for flagellates and 3-5 days for diatoms. When ready, a small portion of the volume is used to start a new starter culture and the main portion to begin an intermediate-scale culture. Intermediate scale cultures (usually of between 4 l and 20 l in volume) may be used as food for larvae or to start a large-scale cultures after 7-14 days. Most laboratories and hatcheries requiring small volumes of algae for food use plastic buckets or clear plastic carboys of up to 25 l volume. These are generally operated as batch culture systems. In this method the entire culture is harvested when the cell density reaches the desired level. Then the culture tank is filled with enriched water and the required inoculum is added. When the cell density reaches the desired level the

entire culture is harvested. Batch culture method is the most reliable method, but it is labour intensive.

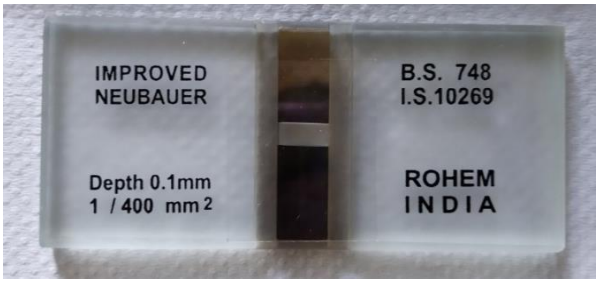
Outdoor culture of microalgae

Large scale outdoor culture of microalgae required for hatcheries can be carried out economically by enriching with agricultural fertilizers like ammonium sulphate (100g), urea (10 g) and super phosphate (10 g) in a ratio of 10:1:1. For 1 t of seawater.

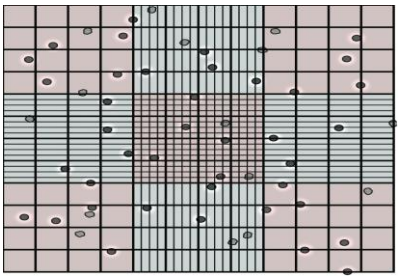
Agricultural fertilizer/1 tonne	Weight
Ammonium phosphate	100 g
Urea	10 g
Triple super phosphate	10 g

Harvesting the culture

The culture should be harvested during the exponential stage of growth after determining the cell density. The culture in the declining or death phase, should not be used for any feeding because the metabolites will be more and cells may not be in good condition. After harvesting the culture, cell densities are determined using haemocytometers.



Haemocytometer



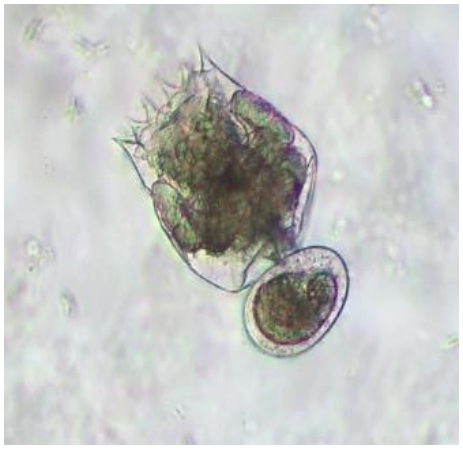
Haemocytometer under microscope

2. Rotifers

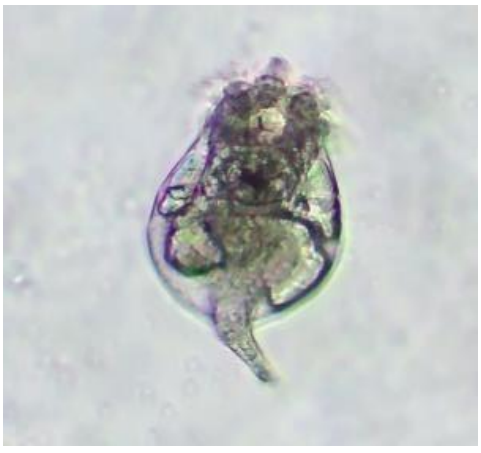
Rotifers are very small organisms mostly ranging from 0.1 to 0.5 mm belongs to the Phylum Rotifera. Rotifers were found to be suitable as first feed for marine fish larvae in Japan in the late sixties and early seventies. Rotifers became ubiquitous in all mass rearing trials after their successful use in the mass rearing of the red seabream *(Pagrus major)* in Japan. The introduction of rotifers marked the first regular successes in the

mass larval rearing of several marine species of economic value marine fishes during seventies and eighties. The success of rotifers as a culture organism are manifold, including their planktonic nature, tolerance to a wide range of environmental conditions, high reproduction rate. Moreover, their small size and slow swimming velocity make them a suitable prey for fish larvae that have just resorbed their yolk sac. However, the greatest potential for rotifer culture resides, however, is the possibility of rearing these animals at very high densities and even in a short period of time. Last, but not least, the filter-feeding nature of the rotifers facilitates the inclusion into their body tissues of specific nutrients essential for the larval predators.

Euryhaline rotifer species, *Brachionus* are used extensively used for marine fish larval rearing in many hatcheries throughout the world. *B. plicatilis* (L type) and *B. rotundiformis* (S-type) are the two common species used for larviculture of marine fishes. The differences among the two types can be clearly distinguished by their morphological characteristics: the lorica length of the L-type ranging from 130 to 340 mm (av. 239 mm), and of the S-type ranging from 100 to 210 mm (av. 160 mm). Moreover, the lorica of the S-type shows pointed spines, while of the L-type has obtuse angled spines. Another strain. SS-type rotifers (Super small rotifers) are preferred for the first feeding of fish larvae with small mouth openings (rabbitfish, groupers, and other fish with mouth openings at start feeding of less than 100 mm). Those rotifers, however, are genetically not isolated from S-strains, but are smaller than common Sstrains.



B. rotundiformis



B. plicatilis

Stock culture

Relying only on mass cultures of rotifers for reinoculation of new tanks is too risky an approach because the threat of mass mortality. In order to minimize this risk, small stock cultures are generally kept in closed vials in an isolated room to prevent contamination with bacteria and/or ciliates. These stock cultures which need to generate large populations of rotifers as fast as possible are generally maintained on algae.

Stock culture of *Brachionus*

Upscaling of stock cultures to starter cultures

The upscaling of rotifers is carried out in static systems consisting of conical flask of 500 ml placed 2 cm from fluorescent light tubes (5000 lux). The rotifers are stocked at a density of 50 individuals.ml^{-1} and fed 400 ml freshly harvested algae (10^6 cells.ml^{-1}). Next two days rotifers are fed approximately 50 ml of algae. Within 3 days the rotifer concentration can increase to 200 rotifers/ml.

Mass culture

Batch culture system is probably the most common method of rotifer production in marine fish hatcheries. The culture strategy consists of either the maintenance of a constant culture volume with an increasing rotifer density or the maintenance of a constant rotifer density by increasing the culture volume. Batch culture system normally follows a 4–5-day culture period. Initially a tank (0.5-1 ton) is inoculated with rotifers (≥ 200 nos./ml). The rotifers are then fed each day with microalgae (10^6 cells/ml) and the volume of the culture is also increased to keep up with rotifer growth. Many species of microalgae such as *Nannochloropsis*, *Chlorella*, *Pavlova*¸ *Isochrysis* etc, are used for feeding rotifers. Rotifer densities reach up to 500 nos. /ml after 4-5 days. Rotifers are harvested after the culture period using 300 µ and 50 µ mesh sieves, so that dust free rotifer will be collected on the 50 µ mesh sieves. Both filters are placed inside a container full of water to avoid damage to the rotifers due to pressure of outgoing water. A gentle air bubbling along the inner side of the filter helps to keep the filter free from clogging. A part of the harvested rotifers are used as the innoculum for the next culture.

Rotifers are also cultured using a combination of microalgae and baker's yeast and promotes better growth of rotifer cultures. The tanks are half filled with algae (10^6 cells/ml) and inoculated with rotifers at a density of 100 nos./ml. The first day active baker's yeast is administered two times a day at a quantity of 0.25 g/10^6 rotifers. The next day the tanks are completely filled with algae at the same algal density and 0.375 g baker's yeast per million rotifers is added twice a day. The next day the rotifers are harvested and new tanks are inoculated (i.e. two-day batch culture system). Rotifers are often cultured at temperatures and salinities different from the larval rearing tanks. So they have to be acclimated for at least 6 hours to larval rearing conditions before introducing into larval rearing tanks.

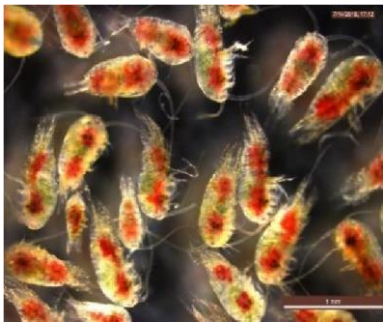
Ideal water quality parameters for rotifer culture

Salinity	10 - 35ppt
Temperature	20- 28ºC
Dissolved Oxygen	above 3 ppm
pH	7.5-8.5
Ammonia	below 1 ppm

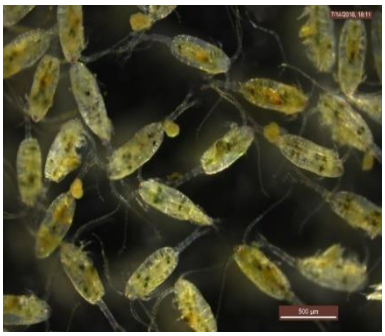
3. Copepods

Copepods are the most common planktonic crustaceans that occur in almost all kinds of water bodies on the earth's surface. In the marine environment, copepods are present in all types of water bodies from pelagic to deep sea and from seashore to deep hydrothermal vents. Copepods form important food for many marine fishes and invertebrates. Certain fishes and fish larvae were evolutionarily adapted for feeding on copepods. Copepods are nutritionally superior to almost all live feeds. Many fishes, especially those with weak fish larvae, totally depend on copepod nauplii for their survival at least for the initial few days. Due to their smaller naupliar stages and nutritional superiority, copepod cultures became an integral component in marine finfish hatcheries. Feeding marine fish larvae with copepods increases their survival, growth rates, reduces deformities and enhances pigmentation and stress tolerance more than almost all other popular live feeds.

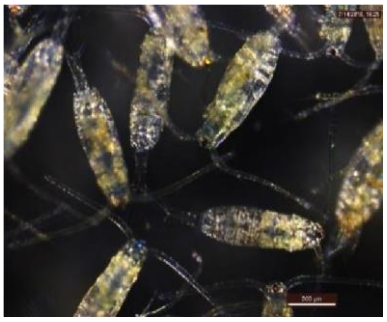
Among the planktonic copepods, three major groups are very important in terms of live feeds- calanoids, cyclopoids, and harpacticoids. Calanoids have smaller pelagic larvae and can be more easily produced on a large scale in hatcheries. Copepods that scatter their eggs are ideal for large-scale cultivation in hatcheries. Pure stock and mass cultures of 12 species of copepods that have been identified as suitable for larval rearing are maintained at Vizhinjam Research Centre of CMFRI. Calanoid copepods (*Temora turbinata, Pseudodiaptomus serricaudatus, Acartia spinicauda, A. bilobata, A. southwelli, A. tropica, Parvocalanus crassirostris, Bestiolina. coreana, B. similis*), Cyclopoid copepods (*Oithona brevicornis* and *Dioithona oculata*) and Harpacticoid copepod (*Euterpina acutifrons*) are being produced in CMFRI. *Apocyclops cmfri* is a promising new species identified from Karwar waters and cultured here.



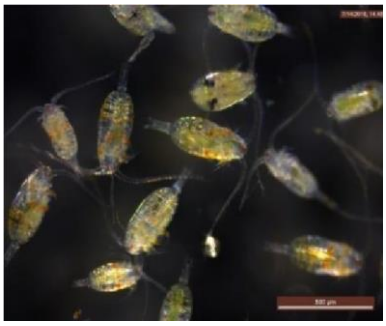
Temora turbinata



Pseudodiaptomus serricaudatus

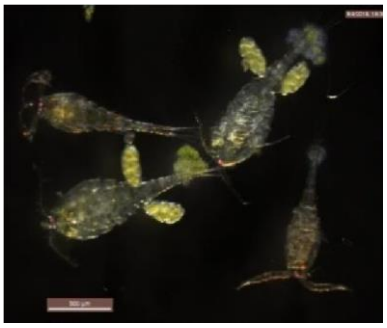


Acartia southwelli



Parvocalanus crassirostris

Bestiolina similis



Apocyclops cmfri

Stock culture

Stock culture of copepods can be done in tanks of 50-500 litre capacity or even in bigger tanks. Tanks of plastic, HDPE or fibre are ideal. A few hundred copepods are sufficient to inoculate in stock culture tanks. Tanks attain maximum density within 1020 days depending on the species cultured. Normally the stock culture can continue for

2-3 months with proper maintenance. There are basically no differences in the maintenance of stock and mass culture.

Mass culture

For the mass culture of 1000-5000 litres, 50-100 litres of inoculum is required. Inoculum needs to be cultured in 1000-litre tanks for inoculating 5 tonne or 10 tonne tanks. Up to 75% of the stock can be used for culture. The inoculum will be ready again within 810 days and the tanks will be ready for harvest within 10-25 days period. Thus, a series of tanks starting from 100 litre, 500 litre, 1000 litre and 5 tonnes/ 10 tonnes are necessary for establishing a large-scale production system. Mild aeration is essential in all tanks. Mass culture tanks of any capacity can be used for large-scale production. Mild aeration needs to be provided accordingly the entire area of the tanks needs to be aerated but there should not be any turbulence or strong flow of water. The inoculum needs to be introduced into 4-5 times higher volume and slowly increase the water level. In most of the species, we can reach maximum volume within 7-15 days.

Sieves of different mesh sizes made from plastic pipe connectors and bolting silk

4. Artemia

Among the live diets used in the larviculture of fish and shellfish, nauplii of the brine shrimp *Artemia* constitute the most widely used food item. It is also called as brine shrimp or sea monkey. The widely used species of *Artemia* is *A. salina*. The females can produce eggs either as a result of mating or via parthenogenesis. The thin shelled eggs hatches immediately, and thick shelled eggs can remain in dormant state and forms cysts. These cysts are metabolically inactive, and do not further develop as long as they are kept dry and can be stored up to 2 years.

The freshly hatched nauplius I stage (Instar I) (length of 400-500µ) is popularly used for feeding the larvae.

Each gram of *Artemia* cyst contains 200000 to 300000 eggs and atleast 50% will hatch within 20-24hrs on proper hydration. To estimate the amount of *Artemia* required one must consider both the volume of the tank and the expected number of *Artemia* the larvae will consume. Based on the stage or the age of the larvae, estimate a daily *Artemia* requirement per ml.

Weight of *Artemia* cyst required =

$$\frac{\text{Total volume of all rearing tanks (in ml) X No. of } \textit{Artemia} \text{ required per ml}}{\text{Percentage hatch rate X No. of cysts per gram}}$$

Procedure for hatching *Artemia* cysts in hatchery

Artemia cysts are hatched into nauplii following the standard procedure involving the following steps

1. Hydration of cyst

   Artemia cysts (<100 g/l) are put into container containing low salinity water or freshwater at 25ºC for 1 hour with aeration. After an hour, hydrated cysts are filtered through 100- 125 µm sieve.

2. Decapsulation

   Decapsulation procedure ensures disinfection of cysts, complete removal of shell from the hydrated cysts, minimize illumination requirements for hatching, reduces hatching time and increases nutritional value of nauplii. Decapsulation can either be done by sodium hypochlorite @ 15 ml for every 1 g cyst or using calcium hypochlorite having 200-250 ppm of chlorine. The decapsulated cysts should be thoroughly washed in tap water or seawater for about 10 minutes until no chlorine smell can be detected. To ensure complete removal of chlorine, the cysts are dipped in 0.1% sodium thiosulphate solution or 0.1N hydrochloric acid.

3. Hatching/ Incubation of decapsulated cyst

Decapsulated *Artemia* cysts are hatched in a cylindroconical FRP tanks/jars having transparent bottom with continuously aerated from the bottom with airlines. Decapsulated cysts are stocked @ 5 g/l of seawater in smaller volume tanks (< 20 L) to 2 g/l of seawater in tanks with large volumes. The optimum water quality parameters required for hatching of cysts is 27-30ºC temperature, 8-8.5 pH, 25-35 ppt salinity, 1000- 2000 lux light and saturated dissolved oxygen concentration

4. Harvesting of nauplii

The decapsulated cysts hatch out after a period of 16-24 hrs. Harvesting is done by taking advantage of phototactic movement of *Artemia* nauplii. The top of the cylinder is closed with a lid and illumination is provided at the bottom transparent part. After 5-10 minutes, the nauplii gets accumulated at the bottom. The outlet of the tank at or near bottom is opened and water is sieved through 100-125 µm net to harvest the hatched out nauplii. Then harvesting net should be submerged in water all the time so as to prevent physical damage of the nauplii. They are then rinsed thoroughly with water to remove possible contaminants and hatching metabolites.

Culture of marine finfishes

Sea cage farming has been successfully used for marine finfish culture for many years. The rising consumption of marine finfish has driven the demand for their culture, consequently increasing the global demand for marine aquaculture. Recognizing the importance of cage culture, the Central Marine Fisheries Research Institute (CMFRI) initiated cage culture as a research and development activity in 2006-07 to identify appropriate designs and suitability of cages in the Indian context. The first open sea cage was launched in the Bay of Bengal off the Visakhapatnam coast in May 2007. After several trials and refinements, 6m diameter cages were designed for ease of operation and economic efficiency. Recently, ICAR-CMFRI projected that utilizing even 1% of inshore waters for cage farming could accommodate 820,000 cages with a production potential of 3.2 million tons. ICAR-CMFRI continues to promote open sea cage culture across all maritime states through cage culture demonstrations of marine fishes. CARCMFRI has also begun experimenting with marine finfish culture in larger diameter sea cages. Cage culture can be undertaken in open seas, sheltered bays or lagoons having suitable water quality in 6mx4m diameter GI or HDPE cages.

6mx4m diameter GI cage

Cage culture in the sea requires a fish variety that meets criteria such as suitability for marketing, commercial importance, consumer acceptance, easy to culture, adaptability to the cage environment, acceptance of formulated feeds, faster growth rate and resistant to common diseases. Disease free quality of fish seed is of vital importance for the success of grow-out culture in cages. Uniform size seeds appropriate for the mesh size of the fish net cage should be stocked to prevent their escape. This will also help in selecting the correct sized feed for fishes, avoid wastage of feed and reduce cannibalism. Presently seed of cobia, pompano, seabass and groupers are being produced in a few hatcheries in the country. Apart from these species, seeds of fishes like snappers, mullets, milkfish, etc. collected from the wild can also be used for cage farming. Stocking appropriate size and number of fish seed in cages is very crucial for the success of cage farming. After allowing the hatchery produced spawn to grow for a period ranging from 30 to 60 days, fish seed can be stocked in cages. Nursery rearing of seed is essential for all species and it can be done as a separate activity, in landbased nursery ponds or hapas held in ponds or in floating nursery cages, by individuals or groups at different localities to support sea cage farming with ready to stock fingerlings.

Feeding cage cultured fishes

Marine fishes require higher protein (35-40%) feed for their optimal growth. Based on growth of the fish, size of the feed pellet should be adjusted. Normal feeding rate is 10% of the body weight for juvenile fishes which can be reduced to 3% body weight as farming progresses. A feed with an FCR of 1:2 is advisable.

Only recommended ration should be given to fishes since overfeeding leads to wastage and environment pollution. Farming duration usually ranges from 7 to 8 months for cobia, 8-0 months for pompano while it is 6-8 months for seabass, to attain optimum marketable size while grouper requires 12-16 months to harvestable size. Salinity above 25 ppt is essential for optimal growth of cobia; whereas silver pompano tolerates even salinity of 10 ppt. In addition to cage culture, Indian pompano and silver pompano culture has also been demonstrated in coastal cages and ponds with good growth, survival and FCR.

Table: Details of growth of marine fishes in sea cages

Species	**Stocking size**	**Stocking density**	**Culture period**	**Harvest size**
Cobia	12-15 cm	9-10 no./m^3	7-8 months	2.5-3 kg
Grouper	10-12 cm	22-25 no./m^3	12-16 months	0.8-1.2 kg
Silver Pompano	10-12 cm	22-25 no./m^3	8-10 months	0.5-0.6 kg
Indian Pompano	10-12 cm	22-25 no./m^3	8-10 months	0.7-0.8 kg
Seabass	10-12 cm	22-25 no./m^3	6-8 months	0.8-1 kg

Cage cultured Indian pompano

Marine cage culture in India represents a significant advancement in aquaculture, offering the potential to boost fish production and contribute to food security.

ICAR-CMFRI has been at the forefront of promoting cage culture. CMFRI conducts demonstration projects across maritime states to showcase the benefits and techniques of cage culture. These projects aim to encourage local fishermen and farmers to adopt cage culture. CMFRI offers training programs and workshops to educate stakeholders on best practices in cage culture, including site selection, cage design, species selection, and management. Under Pradhan Mantri Matsya Sampada Yojana

(PMMSY), significant investments are made to develop infrastructure for cage culture, including the construction of hatcheries, feed mills, and cold storage facilities. The scheme also offers subsidies and grants to fish farmers for setting up cage culture units. This financial aid aims to reduce the initial investment burden on farmers and encourage them to adopt this practice. PMMSY includes provisions for skill development programs to train fishermen and entrepreneurs in modern aquaculture techniques, including cage culture. The development of cage culture in India is being driven by a combination of research, financial support, technical assistance, and policy initiatives from both central and state governments. These efforts aim to boost fish production, enhance the livelihoods of coastal communities, and contribute to the overall growth of the aquaculture sector in India. With proper management practices and supportive policies, marine cage culture can become a cornerstone of sustainable aquaculture development in India.

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