Feeds and Feed Management in Mariculture

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Feed is defined as the mixture or compound of various ingredients that accomplish the nutritional requirements of any organism. The intensification of aquaculture has necessitated a more substantial supply of food from external sources. In this context, artificial feeding is the only option available to satisfy the nutritional requirements of cultured aquatic species. As the fish become more dependent on prepared feeds, the need for nutritionally complete feeds becomes more critical. In cultured organisms, proper nutrition is one of the most critical factors affecting their ability to reach their genetic potential for growth, reproduction, maintenance, and longevity. Better feed management is essential to ensure the better performance of cultured organisms. In sum, feeds and their management are essential parts of any mariculture method, and there are different types of feeds are available for fish farming.

Different types of Aqua-Feeds

Diets provided to aquatic organisms could vary in form. Different forms of aqua feed are described below. Each type of feed has some specific purpose, regardless of its advantages or disadvantages.

Feed can be classified based on different factors such as,

- Origin
- Moisture content
- Life stage of fish

Based on the origin

Natural feeds: These are produced by nature in the form of live food organisms in natural water bodies. For many aquaculture species, they act as an appropriate starting feed. Live feeds are "living capsules of nutrition" since they consist of essential macro and micronutrients. Free swimming nature and their jerky motions cause a feeding response in larvae and allow them to nourish themselves effortlessly. Examples of live feeds are microalgae and zooplankton.

Artificial feeds: Formulated feed prepared based on the requirements of the cultivable species. As per the feed formula, the ingredients are weighed and made into dough, conditioned with steam and feed manufactured via pelletization process. The pelletization can be done in two ways, via compression, produces a dense pellet that sinks rapidly in water and extrusion is a process through which the feed material is moistened, pre-cooked, expanded, extruded and dried, producing a low-density feed particle which floats in water (FAO, 2015).

The size manipulation, top coating of additives etc. also can be done on pelleted feeds. Example of artificial feed is powdered feed, micro bound feed, pellet feed etc.

Farm-made feeds: Feeds in pellet or other forms, consisting of one or more artificial and/or natural feedstuffs. Produced for the exclusive use of a particular farming activity. Simple ingredients are used, which are easily available at a low price and can be made into hand-formed dough balls for small feed mills. Farm-made feed is an alternative to commercial feed. They may be composed of single or many sources of raw materials and processed by cooking or grinding to some extent. The success of certain farms in using farm-made feeds is usually determined by the availability and cost of raw materials.

Based on moisture content

Wet / Moist feed: The feed contains 35-75 % moisture and is made by mixing well-ground dry ingredients with well-ground wet materials and then extruding/pelletizing the mixture through a food processor equipped with the optimum size holes. Many fish species find soft diets more palatable than dry, dense diets. In preparation of farm-made wet feeds, heating and drying are avoided, which may prevent nutrient loss. Feeding fresh or preserving wet feed against microbial spoilage is necessary. The cost of frozen or refrigerated wet diets is very high.

Semi-moist feed: This type of feed contains 12 – 35 % moisture level. The wet and dry ingredients should be combined in the correct proportions to achieve the desired moisture level and consistency. A semi-moist formulated feed uses natural/ wet ingredients as its main ingredient and other additives with graded lipid levels that can be accepted by culturing organisms like crabs (Aqillah-Amr *et al*., 2022) and broodstock fish. For long-term storage, the feed can be refrigerated.

Dry feed: The moisture level in this type of feed is 6-12 %. A mix of more dry ingredients and wet ingredients is used for the preparation of feed and to achieve the desired moisture and nutrient levels. Dry pellets do not require refrigeration, and room-temperature storage is sufficient for at least 90 days with adequate preservatives, after manufacture.

Types of Dry feed

- Pellet feed
  - Compressed pellets
  - Expanded pellets
  - Extruded pellets
- Flake Feed
- Micro – encapsulated Feed
- Micro – bound diet
- Micro – coated diet

Pellet feed: Feeds that are compressed into a defined shape, generally by mechanical means. Pelleting can be defined as the agglomeration of small particles into a larger solid with a given shape and texture. This is done using a mechanical process in combination with moisture, heat and pressure. Pellets can be classified into compressed pellets, expanded pellets and extruded pellets.

Compressed pellets: Steam pelleting is used to produce this kind of feed, which produces a dense pellet that sinks quite rapidly. The compressed pellets are called sinking pellet feeds. The amount of lipid included in the pellet mix does not exceed 10%. Additional lipid can be sprayed onto the feed after pelleting, and lipid levels of 16-20% can be obtained. The bulk density of compressed pellet feed will be 0.45 - 0.6 g/cc.

Expanded pellets: The feed is manufactured based on high pressure conditioning of feed mixtures within an angular expander and it will be slow sinking in nature. It is possible to increase the lipid content of expanded pellets up to 20-22 % via top dressing (coating) with oil. The amount of starch gelatinization obtained by expansion exceeds 60% and the microbial content of the mixture can be reduced significantly. In addition, it is possible to add additives such as oils and molasses. The bulk density of expanded pellet feed will be 0.3-0.4 g/cc.

Extruded pellets: Fish feeds may be pelleted by the "extrusion" process, thereby expanding rather than compressing the various ingredients. The extruded feed will be floating in nature. Due to the porosity of the extruded pellet there is the possibility of increasing lipid incorporation by top – dressing with oil up to 30%. The bulk density of extruded pellet feed will be 0.25 - 0.35 g/cc.

Flake feeds: Flake feeds are the most common type of feed fed to aquarium fish. The most common method of manufacturing flake feed is the double-drum drier. The ingredients are ground to an extremely fine particle size with an attrition mill. They are blended with water to form a slurry that is spread over the surface of a heated rotating drum to turn into a thin dry sheet. The dried sheet is continuously scraped off the rotating drum and crumbled into flakes. By adjusting the distance between the drums, the thickness of the flake can be adjusted. Drying conditions may influence the nutritional value of the product.

Microencapsulated feeds: The process of microencapsulating involves surrounding and coating another substance (the payload) with a material (the wall). The process involves coating a small particle or granular feed with a thin layer of compound that will reduce dissolving and leaching of nutrients. Nylon (N-N bonds) cross–linked proteins, calcium alginate, and lipids have been used as encapsulation materials. As a larval feed technology, this technology has been developed and adapted.

Microbound feeds: In microbound diets, nutrients (both particulate and dissolved) are bound within a matrix containing binding material such as agar, gelatine, alginate or carrageen. Dietary ingredients are mixed with the binder to form a slurry, which is then dried, ground and sieved to produce food particles of the desired size. There is no barrier between dietary ingredients and culture water so there is a chance for nutrient leaching and they are susceptible to direct bacterial attack.

Micro-coated diet: A micro-coated diet refers to the miniature feed surrounding the micro-coherent feed within a capsule. To improve its quality and water stability, these feeds are prepared by coating microbound diet with zean, cholesterol, and lecithin.

Feeds based on the life stages of fish

According to **life stage of fish** the feed can be classified as *starter feed, fry feed, fingerling feed, grow-out feed* and *broodstock feed*. These feeds are generally called as phase feeds. Generally, the **Larval feeds** mainly mash feed, microencapsulated diet, microbound diet, micro coated diet, flakes and crumble feed.

The starter feed: Starter feeds are those fed to first-feeding larvae when their endogenous food supply (i.e yolk) is exhausted or about to be exhausted. They are very crucial feeds that usually come in the form of crumbles, flakes, and paste. They are generally in dry or semi-moist. It differs in composition and type depending on the nutritional requirements and size of the organism at first feeding. It should be nutritionally complete, easily digestible, water stable with the appropriate particle size. The particle size may vary from 50 µm – 70 µm, and is generally in the form of fine crumbles or flakes. Microencapsulation is the most effective technique for preparing this type of feed. However, in many cases, most notably shrimps and some cultured marine finfish, the first feeding of larvae is based on live foods rather than on formulated starter diets.

Fry feeds: They are the feeds for fry stage of fish (0.5 – 0.75 g) and which come in flake or pellet form. The feed size ranges from 0.8 – 1.2 mm. The feed generally contains high levels of protein because the protein and energy requirements on a unit mass basis are much higher in the early stages of life. The highest relative weight gain (specific growth) is achieved in the fry stages with better nutritional quality in fry feed with high feed cost. It is also imperative to ensure that full growth potential is realized during this stage of development for all culture systems.

Fingerlings feeds: The fingerling stage is defined as that between metamorphoses to a growth /weight of about 1-2g to10-20g. Fingerling diets vary from in crumble or pellet form with a size range of 1.2 – 2.4 mm, depending on the species cultured and their size. It also tends to contain less protein (about 10-15% less) and energy than fry and starter diets. Growth rates are higher during this stage than in later stages of the life cycle. Thus, it is essential to ensure that the growth potential of the fish is realised by feeding a diet that is slightly over - fortified with limiting amino acids and vitamins.

Grow-out feeds: Grow-out feeds are formulated to promote efficient and economical growth of fish up to the market size. These are the feeds for adult fish up to maturity. During grow-out stages, weight increase usually occurs at a uniform rate, decreasing slightly as the fish increases in weight and appears to have nutritional requirements that are relatively constant. During these stages, the biomass of the culture system increases considerably, and consequently the total quantity of feed needed is at its maximum. Feed cost and feed conversion ratios (FCR) are critical factors to consider when selecting grower diets since small changes in feed cost or FCR can have a major impact on the profitability of a fish farm. Therefore, the greatest feed cost-saving could be made at this stage of the culture. Grow-out feeds are in pellets larger than 4 mm in diameter.

Broodstock feeds: This feed is only meant for broodstock which promotes the sexual maturation and gonadal development of the organism. Feed quality during this period is known to affect the quality of the offspring; therefore, broodstock feeds should be formulated to meet the nutritional needs of the reproducing fish. For example, some species require omega-3 fatty acids carotenoid pigments, such as astaxanthin, during ovarian development and to ensure viable offspring. Generally, formulations contain higher levels of protein, energy and specific vitamins associated with converting maternal tissue nutrients to egg nutrients e.g Ascorbic acid. The feed consists of special nutrients and essential nutrients like eicosapentaenoic acid (EFA), docosahexaenoic acid (DHA), cholesterol etc. for gonadal maturation and superior-quality egg production.

Based on **contents of ingredients and nutrients**: *High energy feeds* (crude fat 15-36%), *Low pollution feeds* (low phosphorus content), *Medicated feeds* (immunostimulants, therapeutics etc.) and *Pigmented feeds* (colour enhancers).

Based on the **nature of the ingredients** used: *Purified feeds, Semi-purified feeds* and *Practical feeds*.

Based on **buoyancy**: floating feed, slow sinking feed and sinking feed.

Factors to be considered while formulating diet

1. Nutrient requirement of species under culture; 2. Knowledge on nutrient composition of the diet; 3. Digestibility and nutrient availability; 4. Minor dietary components; 5. Anti-nutritional factors; 6. Level of inclusion of each ingredient; 7. The unit price of ingredients and additives; 8. Dietary interaction: micro nutrient-macro nutrient, vitamin-vitamin, mineral-mineral, vitamin-mineral interaction and 9. The culture environment.

Feed manufacturing techniques

Fish feed manufacturing technology will differ based on the types of feeds produced. Aquafeed manufacturing is often a challenging task that involves the production of feed with good water stability, manufacturing difficulties due to high-fat content, good keeping quality due to high unsaturated fatty acids and protein content and protecting the water-soluble vitamins and minerals from leaching. Though several kinds of feeds are available in the market basically two methods are employed to produce most of the commercial feeds. They are steam pelleting and extrusion pelleting techniques. For both of the techniques, most of the preparatory procedures and equipment are common except the pelletizer and extruder, respectively in steam pelleting and extrusion pelleting. The basic steps in feed manufacturing are 1. Grinding/particle size reduction; 2. Batching; 3. Mixing; 4. Pre-processing or Pre-conditioning 5. Pelleting process; 6. Drying, cooling and crumbling of compressed pellets; 7. Drying, oil coating and cooling of extruded pellets; and 8. Bagging and storage


(a)

(b)


(c)


(d)

(d)


(e)

Common machinery in a feed mill (a) Pulverizer/ hammer mill, (b) Homogenizer, (c) Twin-screw extruder, (d) Spheronizer, (e) Sieve shaker assembly, (f) Extruded feed pellets, (g) Weighed and packed feeds of different pellet sizes.

Guidelines for good feed management

It is generally accepted that the highest recurring cost in aquaculture comes from feeds. Feed accounts for about 60-80 % of operational costs in intensive aquaculture. Therefore, feed management plays a huge role in the success of the mariculture sector.

Feed handling and storage: All feeds, whether moist, semi-moist or dry, are susceptible to degradation time. Semi-moist feeds will degrade once removed from their vacuum packs even though they are highly stabilised. The moist feed should be stored in a freezer. Dry feeds are perhaps the most stable, but they are subject to degradation in several ways. Feed storage should protect against high temperature, humidity, moisture and insect and rodent infestations to prevent nutrient loss. During storage, feeds deteriorate since they contain perishable materials, especially lipids and fatty acids. Therefore, it is always better to minimise storage time.

Storage of feed ingredients and finished feeds (pellets, granules or flakes) is an essential step in maintaining the quality of the feeds. Moist and semi moist feeds and feed ingredients, if possible, should be used immediately after preparation. A manufactured feed requires storage at least at the place of manufacture and on the farm.

To proper storage, feed should be stored in such a manner that the feed sacks do not touch the floor or the sidewalls. The store needs to be 100% waterproof and damp-proof. If a facility is ideal, stacks should be arranged so that the feeds purchased earlier are readily accessible (well-labelled with the date of purchase and expiry date). A larger stack tends to reduce or minimise insect damage. However, these have a negative impact, as more heat tends to be generated, resulting in deterioration. The feed should be stored on wooden pallets not more than 5 bags high to maintain adequate air circulation. Proper ventilation ensuring a continuous flow through the store is most desirable. Remember, storage never enhances feed quality, but proper storage reduces the rapidity at which feed deteriorates. The feed should not be stored in direct sunlight, which may cause respiration and affect the quality of feeds. This would adversely affect the vitamin and lipid quality of the feed. Feed should not be stored for a longer period and should be used within 2-3 months.

Feeding management

- Fish under culture should be fed according to their nutrient requirement.
- Feed should be given in more frequencies to reduce feed waste.
- Feed pellet size should be appropriate to the mouth size of fish.
- The quantity of feed should be offered as per the demand of the fish (satiation).
- Feeding may be avoided if the fish is infected acutely and unable to consume the feed.
- Feeding schedule may be changed as per the prevailing climate in the region.
- Feeding holidays may be practiced for better metabolism of fish.
- Alternate feeding strategies may be followed.
- Immunostimulant incorporated feed may be given at the onset of climate change before any expected disease outbreak.
- Excess feeding will increase production costs and pollute the environment.

Conclusion

Adequate nutrition through formulated feeds is an inevitable factor for optimum productivity in aquaculture by way of improved growth, health and nutritional and meat quality. There is room for improvements in feed formulation and feed management in mariculture practice. Therefore, the future of marine fish nutrition aims at the development of well-balanced, species-specific, cost-effective, low-polluting feeds using ingredients which are sustainable for the growth of the mariculture industry.

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Alternative Feeding Strategies for Marine Finfish Production

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Introduction

Marine aquaculture is one of the emerging food production sectors globally. With a vast coast line of more than 8000 km, India is having unlimited potential for mariculture activities. ICAR-Central Marine Fisheries Research Institute have actively involved in the popularisation of marine and coastal cage farming all along the coast line of the country. Several new candidate fishes such as cobia, orange spotted grouper, silver pompano and Indian pompano have been introduced for this purpose by standardising the hatchery and culture technologies for these fishes.

Nutritionally balanced Feed and good quality seed are the major prerequisites for any aquaculture practice. The economic profit of the culture practice is mainly determined by the quality and quantity of the fish feed used. In addition, nutritional status of the feed is one of the crucial factors influencing the growth and immune function of any organism.

Basics of fish nutrition

Basically there are two types of feeds, being used in marine fish farming such as formulated feed and low value fishes. Among them the formulated feed are more appropriate for successful farming of marine finfishes due to the nutritional quality, storage convenience, lesser price and continuous availability. Quantity of the feed is determined by the nutrients present in the feed. The major macronutrients in fish feed includes proteins, carbohydrates and fats. Protein is considered as the building blocks of any living organism and in addition it helps in the growth of the organism. Amino acids are the basic units of proteins. There are mainly 10 essential amino acids which cannot be synthesized by the fish and 10 non-essential amino acids that need not be supplemented through the feed. Carbohydrates are feed ingredients that are mainly meant for supplying energy for the routine physiological activities of the fish. They are having less importance in marine fish feed formulation, but may help in gelatinization and pellet formation in extruded pellets. Fat is another major energy yielding component in fish feed. Fatty acids are the basic units of fat. Essential fatty acids are mainly required for fish growth. Fats yield 2.5 times more energy than carbohydrates and are thus the major source for the energy inputs for fish feed. Vitamins and minerals are the important micronutrients required for the feed formation. Fat soluble vitamins and water soluble vitamins are the major vital inputs for any organisms. Macro minerals like Calcium and Phosphorus are required in higher quantity and micronutrients such as Copper, Cobalt, Iron, Sulphur, Iodine, Magnesium, Manganese and Zinc are required in micro level in fish diet.

Feed Management

The major factors associated with any feed management practice are quality of feeding and the quantity of feed provided to the system. Proportion of the nutrients, stability of the feed and palatability are the major criteria that can determine the quality of the feed. Feeding rate, Feeding frequency and the time of feeding are important for determining the quantity of feed to be provided for the fishes. Generally when the fish size increases, feeding rate need to be reduced. In usual practices the juveniles are provided with the feed @ 10% of body weight initially which can be reduced to 2 to 3% as the fish grows. The feeding rate is also affected by the water quality parameters such as temperature, salinity, ammonia etc. Time of feeding is also an important factor that determines feed utilization in cage culture practices. The total ration for each day need to be split into 2 to 4 portions for better utilization of feed. Generally for fishes, feeding is restricted in the day time. Periodic sampling and growth measurements are at most important for feeding and feed calculations. Weekly or biweekly samples can be done by collecting 30 to 50 number of fishes for noting the increment in weight and length of the fish. The total biomass of the cage farm can be calculated by considering the average weight of the fish, total number of fish stocked and the approximate survival. From the total biomass obtained, the daily ration of the feed can be depicted.

Alternative feeding strategies

For mariculture practices, the fishes were fed routinely with a ration based on the body weight at a regular interval daily. But in order to enhance the production with minimum usage of feed, alternative feeding strategies have been experimented and some of the strategies are being implemented in farming. The most important strategy is to utilize the capability of the fish to attain compensatory growth after a specific period of ration restriction followed by re-feeding. This technology is having two phases such as ration restriction or stunting phase and a compensatory growth or re-feeding phase. The study on different feeding regimes resulted in developing different feeding protocols that are economically sustainable and cause less environmental damage by minimizing fish feed and total operational costs. Compensatory growth studies based on partial or complete starvation periods in different fish species are gaining importance in recent years. The compensatory growth pattern varies from species to species and depends on mode of growth deprivation,

Ration restriction or stunting phase

This phase is characterized by restriction of feeding for reducing the growth or physiological functions so that the growth compensation will elucidate in the compensatory growth phase. Several feed deprivation methods have been experimentally tried such as stunted fingerling production and cycles of deprivation and the compensatory growth pattern varies for each method.

Stunted fingerlings production

Good quality stocking material is one of the important prerequisite for open water cage farming. Success of any aquaculture venture depends on year round availability of quality seeds and price of the stocking material. Even though seed production technology is available for many of the economically important species, continuous seed availability is a major bottle neck in expanding the commercial mariculture activities. Stunted fingerlings are better stocking material for culture because of their higher survival rate and ability to compensate the growth. They are less vulnerable to predation and diseases and are more tolerant to environmental fluctuations; require less time to reach marketable size leading to higher production. More over production of stunted fishes ensure the availability of seed for a longer duration since the fishes can be maintained in the nursery facilities with minimum cost and effort. Compensatory growth in stunted fishes has been commercially adopted in the farming of several freshwater fishes such as Indian Major Carp, Big Head carp, Nile Tilapia etc. Even though compensatory growth pattern is observed in marine finfishes such as European seabass, gilthead sea bream, Atlantic halibut, Atlantic cod, and Alaska yellowfin sole; commercial level adoption of this technology in mariculture has not been reported yet.

Commercial experience in freshwater fishes and experimental evidences in marine finfishes indicated that the stunted fishes attained compensatory growth when shifted to a favourable condition with adequate feeding. Survival rates obtained by stocking stunted fishes is at par or more than that of the normal fishes since during the stunting process many of the weak and unhealthy fishes may be eliminated from the stock. Since the size and growth rate of the stocking material after long term stunting is greater than the normal fingerlings generally stocked, usual problems such as cannibalism and predation will be reduced. Generally stunted fishes are found to be hardy, more tolerant to environmental fluctuations and diseases. Stunted fingerling production is more economical since the quantity of feed utilised for this purpose is minimal (only for the subsistence of the fishes) during stunting. Above all, long term stunting protocols ensures the maintenance of these animals for a longer duration which will help to extend the seed availability for a longer period.

Cyclic feeding

Cyclic feeding regimes (periods of feed deprivation followed by refeeding) in fish production is based on the principle that mimic the natural phenomenon of variations in prey availability that leads to automatic feed restriction which leads to compensatory growth. But the ideal feeding cycles need to be identified for each fish species. More over this strategy depends on various factors such as sex, state of maturity, diet composition and severity of feed restriction. Hence, cyclic feeding regimes to elicit the desired CG response will likely need to be specific to the culture situation of interest. In cyclic feeding method the feed will be deprived for certain period followed by refeeding the fish for certain period in a cyclic manner. The cycle is usually represented as ratio of days feed deprived and days fed (days feed deprived : days fed) for example the cycle is for 1: 6 indicates 1 day feed deprived followed by 6 days fed. One cycle may include few days to weeks and the same pattern of cycle will be repeated several time. Cyclic feeding strategy as management tool is to reduce production cost, enhance feed efficiency and minimize waste loading into the water environment. Cyclic feeding, a feeding scheme that involves feed deprivation followed by a period of refeeding, can elicit compensatory growth.

Compensatory growth or re-feeding phase

Compensatory growth (CG), or "catch-up" growth, has been defined as a physiological process whereby an organism accelerates its growth after a period of restriction, to attain the weight of cohorts whose growth was never hampered. Compensatory growth (CG) is a phase of accelerated growth when favorable conditions are restored after a period of growth depression. CG is important to fisheries management, aquaculture and life history analysis because it can offset the effects of growth arrests. Compensatory growth has been recorded in fish after growth deprivation induced by complete or partial food deprivation. Partial, full or over-compensation is reported in fish. This compensation in growth is achieved through the phenomenon of hyperphagia (excess feeding).The degree of compensation attained is classified as no compensation, partial compensation, and complete compensation or over compensation depending on the method and species selected for stunting.

Individually housed fish have shown that CG is partly a response to hyperphagia when rates of food consumption are significantly higher than those in fish that have not experienced growth depression. The severity of the growth depression increases the duration of the hyperphagic phase rather than maximum daily feeding rate. In many studies, growth efficiencies were higher during CG. Changes in metabolic rate and swimming activity have not been demonstrated yet to play a role.

Periods of food deprivation induce changes in the storage reserves, particularly lipids, of fish. Apart from the strong evidence for the restoration of somatic growth trajectories, CG is a response to restore lipid levels. The advantages of CG probably relate to size dependencies of mortality, fecundity and diet that are characteristic of teleosts. These size dependencies favour a recovery from the effects of growth depression if environmental factors allow.

Experimental stunting on Silver pompano as a model

Compensatory growth pattern in Silver Pompano, *Trachinotus blochii, a* potential candidate species for commercial marine cage farming has been evaluated in both high saline (> 30 ppt) and low saline conditions (<15 ppt) at Mandapam Regional Centre and Karwar Regional Station of ICAR-CMFRI respectively. The fishes were stunted for 30, 60 and 90 days duration followed by post stunting rearing for 30, 60 and 90 days respectively. During the stunting period high stocking density (100 / $m^{3)}$ and low feeding rate (3 % body weight) were maintained and during the post stunting period stocking density were reduced to 20 / m^3 with increased feeding rate (15 % of body weight). The fishes during stunting and post-stunting were fed using a commercial floating pellet feed (45 % crude protein). In the marine condition the 90 day stunted fishes have shown over compensation and in the low saline condition the 60 days stunted fishes have shown near complete compensation.

In another experimental farming, effect of stunting by feed and space deprivation on compensatory growth (CG) in silver pompano (*Trachinotus blochii*) was investigated in coastal water cages with two treatments such as stunted fish and normal fish. A commercial pellet feed (45 % crude protein and 10 % crude fat) was fed two times (morning 9 am and evening 4 pm) for the entire experiment. The 270 days experiment was having a nursery stage carried out in 4 x 2 x 2 m^3 rectangular galvanized iron (GI) cages consisting of a 60 days stunting phase and a 60 days post-stunting phase and the grow-out farming (150 days) was carried out in 3 m diameter GI cages. During stunting phase, the normal fish (in triplicates) was stocked at lower stocking density and fed at 10 % of body weight (BW), while stunted fish (one replication) was stocked at about three times higher stocking density and fed at a three times lower feeding rate (3 % of BW) for feed and space deprivation. During the post stunting phase, the stunted and normal fish were reared in triplicates at uniform stocking density with feeding at higher rate for stunted fish and normal feeding rate (8 % of BW usually adopted for third month farming) was adopted for normal fish. During the grow-out stage each replication from post stunting phase were shifted to 3 m circular cages with same feeding rates. Growth sampling was done once in a month and 30 % of the stock was sampled to record the length and weight of individual fish. There was a growth lag during the stunting phase in stunted fish, but the higher feeding rate during the post-stunting phase compensated the growth. Due to the substantial difference ($p < 0.05$) in the total feed provided and the lower unit cost for stunted fingerling production, their farming resulted in a higher net operational revenue and benefit cost ratio. In conclusion, the stunted fish farming approach can be successfully applied for increasing profitability.

As a part of a research project the institute has initiated to explore the possibilities of application of compensatory growth in stunted marine finfish, even though this technology is already popularized in fresh water carp culture. No studies have been taken up regarding these aspects in marine fishes. Exploration of compensatory growth in stunted fishes for farming have several advantages such as faster growth, higher survival and continuous availability of seed even during off-season. On 01st October 2021 the station has conducted a harvest mela for the farmed Silver Pompano which was stunted for two months in the initial period.

Experiments on other marine finfishes

In order to standardize the stocking density of mangrove red snapper *Lutjanus argentimaculatus* fingerlings for stunting trials, experiments were conducted at Calicut Research Centre of ICAR-CMFRI. Red snapper fingerlings (wild collected) were stunted for 30 days at different stocking densities (@ 25, 50, 75 and 100 numbers / m^3) providing low value fish as feed at 5 % of body weight. The results indicated that high stocking density stunting is not possible in red snapperfingerlings due to aggressive behavior of the fish. The ideal stocking density observed was 50 nos./ m^3 for stunting *Lutjanus argentimaculatus* fingerlings.

In order to find out the compensatory growth pattern in stunted fingerlings of Mangrove red snapper, *Lutjanus argentimaculatus*, thirty days stunting experiments were conducted in high saline (35 ppt) and low saline (15 ppt) conditions. The fishes were stunted for 30 days at a stocking rate of 50/ m^3 providing trash fish at 5 % of body weight and were further reared (post-stunting) for 30 days at a stocking rate of 20/m^3 providing feed at 15% of body weight. Control was maintained at a stocking rate of 20/m^3 providing feed at 10 % of body weight and the fishes were reared for 60 days. *L. argentimaculatus* fingerlings exhibited partial compensatory growth compared to normal in low and high saline condition after one month stunting with higher degree of compensation in low saline condition. Further stunting trials are in progress by increasing the stunting and post stunting durations to see whether complete compensation in growth could be achieved in *Lutjanus argentimaculatus* fingerlings.

A preliminary experiment was conducted with hatchery produced *Trachinotus mookalee* (Indian pompano) fingerlings at Vishakapatnam Research Centre of ICAR-CMFRI. The 45 days stunted fishes has shown indications of compensatory growth in the refeeding period.

Conclusion

The experiments on silver pompano reveals that the long term stunted fish can be employed for the commercial cage culture practices in both low saline and marine condition. Stunting practice can be adopted even in the carnivorous fishes such as red snapper and other species such as Indian pompano.

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