Culture of Marine Ornamental Fishes with reference to Production Systems, Feeding and Nutrition

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Coral reefs support over 4000 species of fish, about 800 species of reef building corals and a great number of other invertebrates and sponges. The ornamental animals are the highest value added product that can be harvested from a coral reef. The annual global marine ornamental trade is estimated at US $ 200 – 330 million. Unlike freshwater Ornamental species where over 90% of the species are produced in farms, almost the entire ornamental species in the trade are collected from the coral reefs and adjacent habitats. Hence the long term sustainability of the industry is a controversial aspect. The damaging techniques such as the use of sodium cyanide are non-selective methods used to capture fish and it adversely affects the health of the fish and also kills the non-target organisms. The over-harvesting of target organisms is another aspect of concern. The ultimate solution to a long term sustainable trade of marine ornamental fishes can be achieved only through the development of culture technologies. At present tank reared species contribute only 1-2% of the trade. Culture of marine ornamental fish is well accepted as an environmentally sound way to increase the supply of such organisms by reducing the pressure on wild populations and producing juvenile and market size of a wide variety of species year round. In addition, hatchery produced fish are hardier which fare better in captivity and survive longer. The list of marine ornamental fishes reared in captivity today the world over contains more than 84 species. But the species that can be reliably reared in large quantities include only a dozen anemone fishes, seven species of gobiids, five species of cardinal fishes and eight species of pseudochromids.

In India, till recently much attention was not focused on the culture of marine ornamental fishes. During the past few years the Central Marine Fisheries Research Institute has intensified its research on breeding, seed production and culture technologies for marine ornamental fishes. One of the milestones in this programme is the recent success in the hatchery production technology of clownfish. Another significant achievement is in the seed production of sea horse. Experimental success was also obtained on the broodstock development and larval rearing of five species of damselfishes.

Production Systems

Hatchery Production of Clownfish

Clownfishes continue to be the most demanded marine tropical fish and the technologies available at present on marine ornamental fish breeding are mainly centered around clownfishes. There are 27 known clownfish species. They are distinguished and taxonomically separated from other damsel fish by their dependence on anemones for protection. They are further distinguished from other damsels by their large capsule- shaped eggs and large larvae at hatch. Their swimming pattern consists of exaggerated lateral fluxures and alternating paddling of their pectoral fins. Clownfishes are distributed throughout the Indo-West pacific region. Anemonefish as their name defines, live in a mutualistic relationship with anemones. In nature, selection of preferred anemones is species specific. Primary benefits to clownfish from anemone association are protection of the pair, their nests and a portion of their progeny from predation. The fish achieves protection from stinging of anemones by means of the development of a special external mucus layer. Clownfish appear to be monogamous, pairing for life. There is also a possibility that some species may be polygamous.

Age of the fish is the most important factor determining sexual maturity. Sexually matured adult clownfish are usually 9-18 months old. While selecting or establishing a pair, it is not advisable to purchase or use full grown adult fish. Firstly adult clownfish in good condition will be costly. Secondly the fragile characteristics of newly captured adult clownfish make them a high risk. While selecting possible pairs or purchasing fish for pairing, it is best to buy sub-adults. Sub-adults do not form immediate pairs or fully display adult colouration, but they will quickly adjust and mature in good environmental conditions. Eventhough they are younger than adult pairs, they will only take about 3-6 months for initial spawning. A distinct advantage when pairing clownfish is their ability to change sex. The best and easiest approach in pairing clownfish is purchasing 3 or 4 fish of equal size, 2.5 to 5cm in total length. Put all the fish in one established aquarium with no other fish. Since sex reversal is prevalent in clownfish, they simply decide which will become the male and which will become the female. Eventually, two fish will tend to stay together, chase others from specific areas, and attempt to destroy others. Sometimes a pair will accept and allow a few smaller individuals to remain in a reserve situation. Utilization of reserve fish is a unique adaptation in clownfish. When the female of a pair dies, the original male will become female and one of the reserve fishes will become the new male. Within a pair, the female is usually the first to die. Colouration can be used for sexing many species of clownfish. Colour differences are found only on sexually matured adults.

Size can be another criterion determining males and females of many species of clownfish. In general females are largest individuals. In older established pairs, size differences between a male and female are not very conspicuous. Under aquarium conditions, these fishes are maintained under ideal environmental parameters, receive food *ad libitum* and grow at about equal pace. As they reach sexual maturity, tank-raised individuals normally show more dimorphic size differences.

Behaviour is another criterion for selecting males and females from adults or sub-adult fish. The best way to use behaviour is by introducing one adult after another to the tank. With net in hand, lower the new introductions slowly into the aquarium and let them go into the aquarium water. Stand back and observe for about 15 minutes. They will either accept each other or start to fight each other. A good possible pair will act basically gentle. Even though you have established a possible pair, there is a strong possibility of rejection later in the day or at night. Hence when using the introduction pairing technique make it start early in the morning and make continuous routine observations throughout the day. Established, dominant individuals often seem to respond instinctively and without provocation, and often injure the newly introduced fish. Hence it is better to put both fish in new environment. Placing both in a new environment greatly reduces dominance of established individuals and puts both fish on a more equal basis. Placing both fish on an equal basis often helps to slow down the initial instinctive aggressive behaviour. Two females will often accept each other and hence it is confusing to find out whether we have a pair or not. Test the possibility of two females within a pair, split the suspicious pair, and introduce a known male. Usually within a very short time you will receive fertilized eggs. Since there is no way that two females can reverse their sex and form a productive pair, it is better to stop trying to get the biggest fish for making a breeding pair which may be probably two females.

Conditioning the fish is a prerequisite for spawning any fish. Conditioning is a term used to describe the utilization and manipulation of a combination of environmental factors to induce gonadal maturation and spawning. The factors may include light intensity, light duration and possibly wave length, temperature, water current, water quality, nitrogen, phosphate, ammonia, p^H, type of food, tank size and shape, aeration and habitat.

Broodstock diets are virtually the main keys to successful spawning. Eggs contain considerable lipids which are high and long lasting energy resources needed for the protracted development of the embryos within the eggs. These deposits are reserves to be incorporated within the eggs and provide energy to the female during her fasting period. Hence suitable diets and enough food must be fed to the broodstock fish. If brood stock fish are not properly fed, the results are directly reflected in the number of eggs laid, fertilization rate, hatch rate and the quality of hatched larvae. Poor quality eggs develop slowly, hatch late and often result in significant early larval mortalities. Conditioning food should be administered routinely to the brood stock clownfish three times a day – early in the morning, noon and around 5 O'clock.

From larvae to sexual maturity and spawning takes from 9-15 months (normally 12) for clownfish. Some species like *A. ocellaris* reach maturity earlier. Sub adults generally take about 6 months to reach sexual maturity. Full size adults obtained from the wild usually take 2-3 months to begin spawning again. If a consistent spawning pair is severely disrupted, such as tank change, illness, treatment, etc., they usually take 1-3 months to begin spawning again. Clownfish displays several common characteristics that indicate as spawning. Often the female takes the initial lead role in forming a new pair and in spawning. She will clean several hard surface areas and often pushes the male on his side or belly. Head shaking, standing on their heads, nipping and chasing are common prior to spawning, especially in new pairs. Excessive digging in the bottom substrate for cleaning of many areas usually occurs. As the pair matures, the male becomes more aggressive. Eventually the male assumes most of the nest cleaning and tending of the eggs. The clownfish normally spawn during forenoon. Once spawning commences, females press their body towards the substrate and slowly move in a rowing fashion using their pectoral fins. She moves in a circular path depositing a continuous spiral of eggs from the central outward. The male swims behind the female, releasing sperm over the newly deposited eggs. After spawning the males assume a more dominant role. Although both tend the nest, the male becomes the real caretaker. He intermittently fans the nest with his caudal or pectoral fins. He also cleans the eggs by gently mouthing them without removing them. Dead and fungal infected eggs are routinely removed and eaten. Substrate around the nest is also often cleaned. While a nest is present, males do not feed aggressively. The male spends an average of 30-60% of its time during the day for tending the nest. Fanning the eggs is frequent on the day after spawning and diminishes considerably about mid way in the incubation period. On the day of hatch, fanning increases again. Nest will be located on any hard surface. Placing substrates usually helps to minimize spawning on the sides of the tank. Dirty spawning substrates should be avoided since it makes nest location harder to detect.

A key factor in regard to success and failure of the spawn is nest pigmentation. Egg pigmentation of benthic spawners is very common. Pigmentation has a direct relationship in the success of hatch and initial larval survival. Healthy, well fed clownfish pairs produce orange to bright red nests depending on the species. The degree of intensity of colour is directly proportional to the amount of pigments within their diet. Highly coloured nests hatch better than pale whitish coloured nests. Addition of the pigment astaxanthin to the diet resulted in bright coloured nest within two weeks. In addition, nests became tighter, more compact, nests and eggs larger, hatches more regular, less initial larval mortality, brighter larval colouration and faster larval metamorphosis. The egg colouration has a direct correlation with juvenile survival and growth. As fertilized clownfish eggs mature, they change daily from initially yellow orange or red colour to a vivid black. Using these colour changes, it is possible to determine when the spawn occurred and when it will hatch. During early development, the larva's head is located at the attached edge of the eggs. When about to hatch, they rotate inside the eggs so that their head is at the unattached tip. At hatching they push forward with their tails, breaking the unattached tip of the egg. Unfertilized or diseased eggs turn opaque within 24 hours.

During incubation, eggs may die due to improper development, fungus, physical damage, severe water quality changes, lack of parental care and / or parasitic attack. Overall nest size depends more on the species, size and age of the female. Eggs range in size from 2.0-2.4mm and 0.9mm wide. The newly hatched larvae measure around 4mm in total length.

The clownfishes live for longer periods. The age of captive *A. frenatus* is recorded as 17 years, *A. clarkii* as 14 years, *A. ocellaris* as 14 and *A. perideraion* as 21years. Clownfish are protracted spawners and produce one nest per month or less in the wild. Under controlled conditions and ideal consistent diets, they can be easily induced to spawn an average of 2.1 times per month. In captivity most pairs spawn a minimum of 11 months a year, regardless of the species. Individual pairs of clownfish seem to reach a typical reproductive pattern which remains fairly consistent for an extended period of time.

Eventhough adult clownfish pair for life, this does not mean that they will remain good commercial pairs throughout their lives. When a pair is no longer productive, it should be replaced or separated for repairing. The criteria that can be adopted for culling pairs include (1) A pair that remains as a possible pair over eight months (2) Pairs producing less than two spawns a month over the last four months. (3) Old pairs with greater than 50% of the nest gone over the last four months (4) Old pairs with consistently loose, scattered nest of small nests. (5) Pairs that continuously spawn on the side of the tank and (6) Unpopular species or overstock of a species.

Nests can tolerate more mechanical and chemical changes than newly hatched larvae. While within the egg, larvae can adjust more easily to water changes than after hatch. Determination of the time of hatch is dependant on visual appearances, temperature during incubation and the species. Hatching is also dependant on brood stock health, quality of the eggs, initial colour of the eggs, water quality and light. The longer the larva remains in the egg beyond the normal incubation, the weaker it will be at hatch. The duration of hatching of clownfish eggs from the day of egg laying for the common species generally ranges from 6th day evening to 9th day evening, at a temperature range of 26-28°C. Hatching of clownfish eggs normally commences from 1-2 hours after dark. Hatching takes between 15-20 minutes. If larvae are allowed to remain in broodstock tanks overnight, numbers of larvae are significantly reduced due to predation or due to the filtration in the broodstock tanks. Scooping and siphoning hatched larvae is very impractical. The use of a net for removal of larvae is prohibitive due to the chance of severe mechanical injury to the delicate larvae. Whatever means are used, it is important to realize that larvae cannot tolerate being touched by a solid object like a net. Common practice is to allow the larvae to hatch within the broodstock tank, which is suitable for small scale operations. Since clownfish larvae are phototrophic, they can be drawn to a specific spot for removal by using a flash light. The accumulated larvae can be collected by using buckets along with water. More sophisticated siphoning bucket includes using large diameter plastic tubes mounted above the nest area and equipped with a small light source at the top.

Hatching nests can be done remotely outside the broodstock tanks also. Remote hatching is more advantageous especially to commercial operations. Larvae within the eggs are more tolerable than newly hatched larvae to physical, chemical and water quality change. Hatching nests within broodstock tanks may yield 100% hatch, but not 100% recovery of the larvae. Many larvae are consumed, drawn into the filters, become entrapped or die before being captured. Removing the nest and placing it into a flow-through hatchery that was connected to the flow on the adult broodstock tank has been attempted. To keep the eggs moving and well aerated, they were either aerated or incoming water flow was directed on to the eggs. When hatched, the larvae were trapped in the compartment containing the spawning substrate. This method works but allowing the larvae to remain in hatchers overnight resulted in high mortalities. Physically removing intact nests just prior to hatch and placing them directly in larval rearing tanks is also found to yield successful hatching.

Larval rearing is the most critical, time consuming phase of marine fish culture. The major requirements are (1) to provide a simple, adequate stable environment that can be easily manipulated and maintained (2) to provide adequate, quality foods on a consistent basis and (3) to provide strict maintenance procedures on a daily basis. Water quality is key environmental factor but can be easily controlled with simple water exchanges. Typically the bio-load in larval rearing tanks is insignificant when compared to broodstock or juvenile rearing tanks. Therefore deterioration of the water environment is easier to control. Success or failure in larval rearing is closely associated with availability of quantity and quality of live feeds and how they are administered. With out a ready, plentiful, nutritious live feed source your larval rearing attempts will be futile, erratic and very discouraging. To rear clownfish larvae, about 300-600 rotifers per larvae per day for a period of 5-10 days are required. In addition, the rotifers must be completely nutritious and balanced with essential fatty acids and micro algae. Larval rearing is not simply putting fish larvae in the tank, feed them and watch them grow. It will be necessary to clean the tank daily of detritus and uneaten food. Water exchanges and air flows must be watched. Since benthic larvae like those of clownfish normally hatch with well developed functional eyes and fair swimming ability, there is no chance of larvae becoming trapped in the corners of the tank and hence rectangular or square tanks can be employed. Benthic larvae may feed from vertical surface areas of water column, but not normally from the bottom. Therefore deeper tanks are usually preferred. One of the extremely important criteria for selecting tank size is knowing the quantities of live feed we can provide on a daily basis and how many larvae you intend to rear in each tank. Larvae do not normally actively seek food but tend to be opportunistic feeders, patiently waiting for a food particle to come within striking distance. Placing 300 larvae in a 400 litre tank makes it difficult to provide proper densities of live feeds / dry feeds with out polluting the water. Opportunistic contact between food and larva diminishes drastically when few are reared in a large tank. Forcing larva to swim considerable distances to seek food tends to drain their potential power supply quicker than it is replenished and results in eventual death or slow growth. Concentrating early stage larvae and food supplies minimizes production cost to provide sufficient live food organisms per unit area. By assuring more adequate food particles per unit area, energy expenditure of larvae to find food is minimized. This ensures faster growth rates and higher survivals.

The clownfish reach the juvenile stage, which can be transferred to grow out tanks around 13mm size when they are about 30 days old. Generally it takes a total of 4 months to rear to a marketable size of around 38mm. Juvenile growth and development are strongly influenced by water quality, food quality and the amount of food fed. A significant portion of juvenile culture facilities should be dedicated towards filtration. It is during juvenile grow out that filtration capabilities become critical. Increasing bio-load, consisting of growing fish constantly demanding more food, increases biological oxygen demand required for respiration and oxidation of wastes. A conventional submerged undergravel filter is not advisable in grow out tanks. Gravel, crushed coral, etc. is hard to clean and maintain and can easily clog, which can result in 'toxic tank syndrome'. It is advantageous to use a bare tank with a single large airlift sponge filter. The juveniles can be transferred very carefully with fine meshed net, to grow out tanks. Clownfishes are territorial at very early age. The territorial problems can be prevented by (1) providing each fish with its own tank (2) providing a highly diverse habitat (3) increasing the tank volume so that each fish has several litres of water and (4) crowding them so that there is no territory to defend. The last method is preferred due to practical reasons of cost, space requirements and maintenance problems. Juveniles should be fed a minimum of 3 times a day to obtain maximum growth. Uneaten food and faecal matter should be removed each morning by siphoning. Excessive handling in order to remove a few salable fish is not advised. Harvesting large individuals from a single tank can go on for several weeks and then it is advisable to cull remaining fish and condense them for a final growout. Sufficient pigmentation of juveniles is dependent on how they are maintained prior to hatch and during metamorphosis. Intense colouration is primarily developed through food. Fish grown in a very large tank (low density) have better colour than those in crowded conditions. Fish that grow slower than normal usually have more intense colouration. Fish grown in dark backgrounds develop dark colouration while those in light coloured have light pale colouration. Fish with excellent colouration that are moved to clear glass aquaria often become dull or light in colour in a matter of weeks. Stress plays a very important role in colouration. Pigment cells expand and contract according to light intensity and background colouration. Wild caught fish often have brighter colouration but when maintained in the average aquarium the colour becomes dull. This has been attributed to colour changes but sometimes a combination of diet, tank background, lighting and/ or water quality is responsible. It has been proved that astaxanthin is the key pigment in clownfish. Products containing significant amounts of astaxanthin are most effective in enhancing pigmentation in clownfish. Frozen, freeze dried and meals of the planktonic krill are some of the best food sources for astaxanthin. Lobster eggs, freshwater crayfish eggs and *Macrobrachium* eggs are also good sources. Manipulation of diet, exterior environments, lights, water quality and maintaining healthy and unstressed fish can all contribute to colouration.

Hatchery Production of Damselfishes

The damselfishes are very popular among aquarists due to their small size, bright colours, quick acclimation to captivity and interesting behaviour. The majority of species inhabit the Indo-Pacific region and about 100 species and 18 genera have been recorded from the Indian Ocean. More than 30 species belonging to the genera *Pomacentrus, Neopomacentrus, Chromis, Abudefduf* and *Chrysiptera* are commonly available from Indian coral seas. A technology for breeding and rearing of five species of damselfishes *viz.* the filamentous tail damsel (*Neopomacentrus filamentosus*), the yellow tail damsel *(Neopomacentrus nemurus*), the blue damsel (*Pomacentrus caeruleus*), the peacock damsel *(Pomacentrus pavo)* and the one spot damsel *(Chrysiptera unimaculata)* was developed at CMFRI.

The species investigated are protogynous hermaphrodites in which the larger fishes establish territories and finally become the males. The mating system is promiscuous in which both males and females spawn with several mates. Polygamous mating behaviour was noted. The male parent drove out fishes other than its mate intruding into its territory. The egg laying was mainly during early morning hours, rarely extending upto noon. The clutch size of eggs ranged from 2400-5200, 1500-6300, 3500-4000 and 1500-5000 for *N.filamentosus, N.nemurus, P.caeruleus* and *P.pavo* respectively. The eggs were attached either to earthen pots placed in the tanks or to the sides of the broodstock tank. Females deposited the eggs in the territories occupied by males and one male fertilized one or more batches of eggs and guarded them simultaneously. The male parent continuously guarded the eggs and fanned the eggs with its fins and mouth.

The freshly laid eggs were yellowish and translucent. The eggs were stalked and capsule shaped. The average lengths of eggs were 1.15mm, 1.08mm, 0.96mm and 1.15mm for *N.filamentosus, N.nemurus, P.caeruleus* and *P.pavo* respectively. The eggs were allowed to hatch in the broodstock tanks. The yellowish colour of freshly laid eggs became whitish translucent from the second day. The duration of incubation ranged from 82 to 106 hrs. On the day of hatching the egg capsule became very thin and transparent. The time of hatching was between 1900 to 2100 hrs. The larvae broke the egg capsule and came out. Normally the hatching rate was almost 100%. But sometimes partial hatching or no hatching was noted mainly in clutches deserted by the male parent.

The length of newly hatched larvae ranged from 1.62 to 2 mm (average length 1.90 mm) for

N. filamentosus, 1.50 to 2mm (average 1.72mm) for *N. nemurus*, 1.6 to 2.1mm (average length 1.85mm) for *P. caeruleus* and 2.42 mm (average) for *P.pavo.* The mouth gape of freshly hatched larvae ranged from 117 to 188 μm (average 158 μm) for *N. filamentosus*, 76 to130 μm (average 110 μm) for *N.nemurus*, 115-167 μm (average 144 μm) for *P. caeruleus* and 189 μm (average) for *P. pavo*. The newly hatched larvae were carefully transferred by buckets to circular FRP tanks of five tonne capacity each. 'Greenwater technique' was employed for larval rearing. A microalgal bloom was developed in the larval rearing tanks prior to introduction of larvae and a mixed culture of copepods was maintained in the tank. The copepods were maintained at productive phase so that nauplii were continuously available for the first feeding of the larvae. After one week, the rotifer *Brachionus rotundiformis* was also supplied for larval feeding. After two weeks, the larvae were fed *ad libitum* with freshly hatched *Artemia* nauplii. The larvae metamorphosed and the characteristic colour pattern of adults appeared within a range of 30-40 days. The length of freshly metamorphosed fish ranged from 18-20 mm

Marine Angel fish

All angel fish species so far studied are protogynus hermaphrodites – all individuals begin life as females, with mature larger individuals becoming male. All are also haremic, with a single male defending their territory containing 2-5 females. Spawning was noted with the pair engaging in a courtship ritual that terminates in a rush towards the surface, at which point eggs and sperm are released. Spawning occurs at sunset, and the microscopic larvae that hatch out the next evening swim in the plankton for about a month. Members of the genus *Centropyge* which are the best choices for aquarium fish, routinely form pairs and spawn often daily in captivity. Maintaining 2-3 females with a single male or rearing 3 small fish together is sufficient for obtaining spawning. The first case of artificial breeding of angel fish was achieved in Blue moon angel fish *Pomacanthus maculocus* in China. Very recently, the Hawaiian Masked angel fish *Genicanthus personatus* and Flame angel fish *Centropyge loriculus* were successfully bred and reared in captivity.

Cardinal fish

Breeding and rearing of Banggai cardinal fish *Pterapogon kauderni* is reported recently. Typically cardinal fish incubate their eggs orally until they hatch, at which point the fry swim away and enter the water column. The Banggai cardinal fish is different in that the male shelters the young for the first weeks of post hatching. In the broodstock tank, a pair starts courtship behaviour usually late in the afternoon and continues to the night. After breeding the pair becomes very aggressive to the other tank-mates. At first the male would drive the other fish away from the female, but after the male was carrying eggs, the female was very aggressive driving away the others. The male continually refuse to food for the next 2 weeks, while it was incubating the eggs in the mouth. From 23rd to 25th day after refusing food, the male spit out the fry. The fry are quiet large about ¼th of an inch. They feed immediately after release and they can accept newly hatch nauplii of brine shrimp (*Artemia)*. The fry require large amounts of living food and at two and a half months, can eat adult brine shrimp.

Neon goby & Royal gramma

The Neon goby *Gobiosoma oceanops* and Royal gramma *Gramma loreto* are species that readily reproduce in the aquaria and have hardy eggs and early larvae. Both the species can be bred by the same method as employed for the clownfish. The male is usually the larger of the pair in both Neon gobies and Royal grammas, and the abdominal fullness of the active female is the prominent sexual difference.

Neon gobies attach their eggs to the substrate very much like clownfish, but their nests are more secretive. They place their eggs under shells and rocks and the presence of nest is seldom known until the tank is suddenly filled with tiny, transparent hatchlings. Hatching usually takes place at night, but it is not uncommon for a nest to hatch in the day time. The male is in-charge of the nest and spends much time working over the eggs. Presence of a nest can be suspected if the male is observed entering and leaving the same small opening with great frequency.

Royal grammas are also secretive nest builders. The male selects a nest sight hidden deep in some crevice or under a rock. It actively cleans these hidden areas or shell until the nest site meets its specifications. Algal strands are also brought into the nest area until it appears filled, with a small entry visible. The female lays 20-100 large eggs that have numerous long, sticky filaments extending from their surface, that serve to bind the eggs to each other and to the surrounding algal mass. The egg is about 1mm in diameter and has 6 or more small oil droplets. It is not transparent, but has an yellowish translucent appearance. The male cares the eggs in the nest periodically. Eggs develop to larvae in about 5-7 days. Hatching takes place with in a few hours after dark. The larvae are relatively large and hardy and are ready to feed on the day after hatching and grow very fast under the right conditions.

Feeding and Nutrition

Feed management of aquarium fish is as vital as water quality management in aquarium. In nature, fish are adapted physiologically and ecologically to certain types of food organisms. These natural diets provide the amount and balance of proteins, fats, carbohydrates, vitamins and minerals that each species needs to maintain good health and reproductive capability. Most marine aquarists do not employ feeds according to the exact composition but feed their fish with commercially prepared diet or a fish food mix.

Fish with broad, unspecialized dietary requirements usually adjust easily to foods and conditions of captivity, while fish with highly specialised diets may have difficulty. A fish may be limited by its adaptive behaviour patterns to certain food organisms, but still be capable of digesting and utilizing other foods. There are two problems that must be overcome in feeding captive marine fish – the first is to get the fish to accept a substitute for the natural diet and the second is to provide all the nutritional requirements in the substitute food.

Natural foods: Natural foods are obtained fresh, frozen or freeze dried and fed fresh, thawed or cooked. Typical natural foods are leafy green vegetables fed fresh or thawed after freezing, cooked or fresh fish and invertebrate flesh and, freeze dried brine shrimp or other zooplankton.

Green Leafy Vegetables: Raw leafy green vegetables are composed mostly of water and are low in energy, protein and lipid, but contain relatively high concentration of carbohydrate, ash, fiber and certain vitamins.

Fish and Invertebrate flesh: Captive fishes can be fed a variety of seafoods either fresh, thawed or cooked. Cooking does not alter the proximate composition much and the energy per gram actually increases because the percentage of tissue water is lowered. Raw foods have been implicated in the transmission of certain infectious diseases to captive fishes and their use is not recommended.

Freeze-dried foods: Freeze dry involves Freeze dried adult brine shrimp is commercially available. Freeze dried and vaccum dried brine shrimp nauplii retain the same fatty acid composition and approximately the same total lipid concentration as freshly killed brine shrimp nauplii.

Moist feeds: Moist have a texture close to natural foods and sometimes are readily accepted by fishes. Factors to be considered are (i) digestibility of the ingredients (ii) acceptability to fishes (iii) physical stability and natural retention in water (iv) nutrient balance and (v) ease of mixing and storage.

Proteins: The purpose of adding proteins to feeds is to supply EAAs. Protein quality is a measure of the relationship between the amino acid composition of food and the amino acid content of the animal to which it is fed. The highest quality protein contains an aminoacid composition that most closely matches that of the recipient. The proximate composition of the whole fish is similar among species and hence fish meal provides the highest quality protein available for fish feeds.

Lipids: Dietary lipids in excess of physiological requirements are deposited in tissues, resulting in reduced activity and abnormal fatty acid ratios. Fatty acids of *n-3* series are required by all fishes. Fish oils are high in PUFAs of the *n-3* series. Direct addition of C20 and C22 *n-3* PUFAs to feeds is the best procedure and this is accomplished easily by using fish oil as the sole source of lipid. Lipids should make upto 10-20% of the diet.

Carbohydrates: Sea water fishes apparently do not require carbohydrates and hence their addition to feeds is unnecessary. Energy can be provided easily and more effectively in the form of lipids.

Vitamins: Vitamins are added to moist feeds as premixes. Vitamin deficiencies are less likely if live feeds are fed regularly as dietary supplements.

Carotenoids: The normal skin colouration of some fishes can be intensified by adding carotenoids to feeds. As dietary supplements only canthaxanthin and astaxanthin appear capable of intensifying red skin colouration in fishes. Several cartenoids are available as powder for addition to feeds.

Live Animal Foods:

Most coral reef fish consume animal food as the major portion of their diet, thus animal foods are most important to the marine aquarist. Fish consume entire live prey organisms when feeding. This gives them access to minerals in hard parts and shells plus vitamins from internal organs and proteins and food energy in the flesh and fat. Obviously a variety of live feed organisms is the best possible diet for most fish.

Brine shrimp: Brine shrimp (Artemia) is the most common live food marine aquarists offer their fish. Although live, clean and well-fed adult brine shrimps are generally considered as attective and nutritious food for most marine tropicals, some aquarists fear introduction of bacteria and parasites from unclean cultures of brine shrimp. Adult brine shrimp can also be obtained in frozen and freeze dried forms. Frozen brine shrimp can lose much of its nutritive value if they are not handled properly. Thawing and freezing or slow initial freezing causes ice crystals to form in the tissues. Ice crystals rupture cells and internal organs and cause most of the fluids to leave the shrimp as it is thawed before freezing. Thus the nutritional value of thawed and frozen brine shrimp is limited to the protein in the exoskeleton.

Newly hatched brine shrimp can be very valuable to the marine aquarist. They can be used to feed small plankton feeding fish such as damselfish and young ones of many species.

Live Fish: A number of popular marine aquarium fish viz. lionfish, groupers, snappers, Sargassum fish feed on small live fish. It is best to feed with small freshwater fish because they are less expensive than marine fish and they do not carry marine diseases and parasites.

Small shrimps and other crustaceans: Small shrimps, amphipods etc. are excellent live food organisms for many marine aquarium fishes. These organisms may be given a quick dip in freshwater for incapacitating the organisms so that fish can snap them before they find shelter in the bottom of the tank.

Tubifex worms: One very useful method of feeding Tubifex worms is to press a small ball of worms deeply into a coral skeleton and then place it in the tank. Hard to feed fish such as butterflyfish are often attracted by the movement of the worms and begin to feed quickly. Tubifex worms can quickly foul a tank if overfed to marine fish.

Dead Animal Foods

Shrimp: Shrimp is a good substitute for the natural diet. Shrimp should be peeled and washed to remove the hard exoskeleton and excess fluids. Then freeze the washed shrimp into a fist sized ball and keep it in a plastic bag in a freezer. Select a metal grater that shaves particles of the proper size for the fish to consume in one bite.

Molluscs: Molluscs such as mussels, clams and oysters can be utilized by marine aquarists in the same manner as shrimp.

Fish: Boneless fish flesh can be prepared and fed like peeled shrimp. Care should be taken for not overfeeding because fish has a greater tendency to foul in the aquarium than shrimp or mussel. All fish products should be hard frozen before feeding to reduce the possibility of parasite introduction.

Other Meats: An occasional feeding of other meats like lean beef, beef liver etc. is helpful if sea foods are not available.

SUGGESTED READING

Martin A.Moe,Jr. 1995. Marine Aquarium handbook – Beginner to Breeder., Green Turtle Publications, P.O. Box 17925, Plantation, Florida 33318.

Frank.H.Hoff.Jr. 1996. Conditioning, spawning and rearing of fish with emphasis on Marine clownfish. Aquaculture Consultants Inc., 33418 old Saint Joe Rd., Dade City, FL 33525.