2002

Management of feeding aquaculture species

Alava, Veronica R.

Aquaculture Department, Southeast Asian Fisheries Development Center

Alava, V. R. (2002). Management of feeding aquaculture species. In O. M. Millamena, R. M. Coloso, & F. P. Pascual (Eds.), Nutrition in Tropical Aquaculture: Essentials of fish nutrition, feeds, and feeding of tropical aquatic species (pp. 169-208). Tigbauan, Iloilo, Philippines: Aquaculture Department, Southeast Asian Fisheries Development Center.

http://hdl.handle.net/10862/3322

CHAPTER 7

Management of Feeding Aquaculture Species

VERONICA R. ALAVA

Introduction

Production targets, environmental conditions, and socio-economic considerations determine the level of management in aquaculture production systems. The contribution of natural food as a source of nourishment is important in producing fish with few inputs. However, more inputs such as complete high quality feeds are required to increase fish yield per unit area.

The use of cost-effective feeds, proper feeding management, and maintenance of good water quality are critical for a successful aquaculture enterprise. As the stocking density increases, feed requirement and metabolic wastes also increase. Feeding must be regularly monitored and continuously adjusted so as not to overfeed or underfeed the fish. The success of an artificial diet is dependent on the management of the feed on the farm. Feeding practices must therefore be directed towards optimizing feed utilization to prevent pollution of the culture environment and the coastal vicinity.

This chapter teaches the reader to: differentiate the different feeding strategies in pond culture; learn feeding management methods such as stock sampling and record keeping, calculating daily feed ration, choosing appropriate feed size, and methods of applying feeds; understand the impact of feeding management on water quality and environment and on the cultured animal's growth, survival, and feed conversion ratio; and describe the different feeding schemes used to culture fishes (milkfish, tilapia, rabbitfish, bighead carp, native catfish, sea bass, orange-spotted grouper, and mangrove red snapper; and crustaceans (tiger shrimp and mud crab). Other species for aquaculture stock enhancement (donkey's ear abalone, seahorses, window-pane oyster) are also discussed.

Feeding strategies in pond culture

Fish production depends on the stocking density and feeding strategy used. At lower stocking density as in the extensive culture system, natural pond productivity is important. As stocking density increases as in the semi-intensive and intensive systems, artificial feed becomes more essential (Figure 7.1).

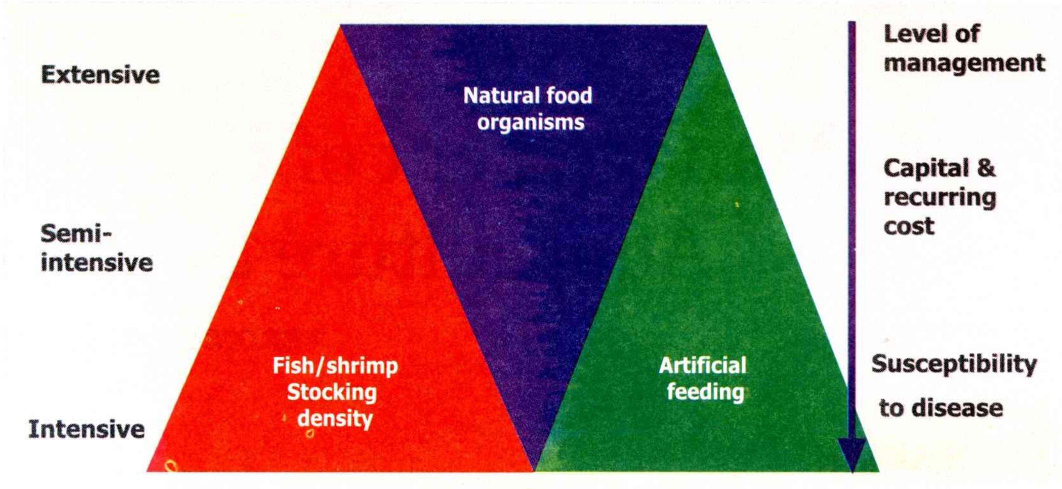

Figure 7.1
Range of aquaculture practices in relation to inputs.
Source: Tacon 1998

In pond aquaculture, the feeding strategies used are:

A. Production of natural aquatic food

During the early growth stages of the cultured animal and at low stocking density, the role of natural aquatic food, as the only source of nutrition is very important. The natural food bases in ponds are: *lablab* (a complex of blue-green and green algae, diatoms, rotifers, crustaceans, insects, roundworms, detritus, plankton (Figure 7.2A), and *lumut* (fibrous filamentous green algae) (Figure 7.2B). Organic or inorganic fertilizers are periodically applied as sources of carbon, nitrogen, and essential minerals. With sunlight, fertilizers enhance the growth of phytoplankton thereby increasing the natural productivity and hence fish production. An integrated system using various species in different trophic levels such as seaweed, shellfish, and herbivorous and omnivorous fish species such as milkfish and tilapia are also used to efficiently utilize various forms of nutrients and to obtain high productivity. In extensive culture systems, inputs and production costs are generally lower than in semi-intensive and intensive systems, but yields are also lower.

Figure 7.2
Natural aquatic food in ponds: lablab (A) and lumut (B).

B. Feeding a supplementary diet

When stocking density and standing crop of cultured animals is increased, the natural productivity can no longer support adequate growth. Supplemental feeds become necessary. The commonly used supplemental feeds are rice bran, chicken feed, breadcrumbs, boiled corn, cooked cassava, and chicken entrails. These are nutritionally incomplete and would be inadequate if used as the only source of food. When supplemental feeding is applied, higher stocking densities are possible resulting in higher production per unit area. The most cost-effective way of producing aquatic animal is to grow natural food and to provide supplemental feed when natural food becomes inadequate. As natural food decreases with increasing standing crop, the quality of the feed should be improved to sustain fish growth.

C. Feeding a complete diet

At higher stocking densities typical of intensive culture, a complete diet is necessary to provide the nutrients required by the animal for growth and survival. Production does not rely on natural food. Since the aim of high level of production is to maximize yield per unit area in a shorter period, highly effective artificial feeds are used.

Feeding management

Sampling and record keeping

Regular sampling of cultured stocks is essential in order to assess the effectivity of feeding management. Sampling involves weighing or measuring a representative group (sub-sample) of animals. These data can then be used to determine the total biomass, and the changes in weight or length from previous sampling data. All sampling methods should be carefully designed to avoid bias, and to minimize any stress on the animals. A work schedule should be set prior to sampling, and all equipment and materials should be on hand before animals are collected and measured. It is important that the fish handling and measuring procedures are consistent and repeatable.

To estimate biomass in the pond, tank or cage, fish are sampled by using a cast or lift net (Figure 7.3 A,B). When fish in large ponds are

Figure 7.3
Sampling by cast net (A) and lift net (B).

sampled, the nets are cast in several areas of the pond in order to get a better sample of biomass. For example, in a one-hectare pond, a net may be cast in the middle, and one or two in each side of the pond. The samples are then weighed individually or in bulk. A good estimate of survival rate is necessary to calculate total fish biomass but this is often difficult to obtain in the ponds. In practice, most farmers assume a certain value for survival based on data from previous culture operations in the same pond or other ponds with similar conditions. This value is modified by observations of actual mortalities, water quality, and occurrence of diseases.

Data on fertilizers, animal stock, feed, water quality, and other useful parameters listed in Table 7.1 must be recorded. Accurate records are necessary to enable the farmer to assess the efficiency of feeding and farm management during the past and current culture runs.

Table 7.1 Some useful parameters that must be recorded in the farm

	Parameters
Pond	Pond number, area, depth
Fertilizer	Source, date of fertilizer applications, type and quantity of fertilizer used
Animal stock	Date of stocking, source of stock, species, behavior, stocking density, average initial weight or length, date of sampling, date of harvest, average final weight or length, kg harvested, weight gain or growth, survival at harvest, size distribution at harvest
Feed	Date of purchase of feeds, feeding rate and amount, type of feed used, date each feed type is given, feeding frequency, feeding time, feeding location in the pond, presence of left-over feeds, feed conversion ratio
Water quality	Secchi disk reading (water transparency), water exchange rate, salinity, dissolved oxygen level, date of water change, water temperature, water color, time and duration of paddlewheel operation if used
Others	Disease or abnormalities of stock, predators in pond, weather conditions during the growing cycle, unusual events, costs of inputs, investment returns

Feeding Ration

The amount of the daily feed ration, and the frequency and timing of feeding are important factors affecting growth and feed conversion. Each cultured species has a dietary feeding rate optimal for growth and feed efficiency. The optimal feeding level varies with age, fish biomass, dietary nutrient requirement, water quality, and natural food availability. Fish lose weight when their feed intake falls below the required level for maintenance. As ration size and feed intake increase, the growth rate increases up to a certain limit. The larval stages of aquatic animals have very high metabolic activity and rapid gastro-intestinal evacuation rates. Thus, it is critical that their high energy requirements are met by continuous feeding to satiation. Frequent feeding is recommended when fish are small, when natural food is inadequate, and when the feeds are less water-stable.

Optimal growth and feed efficiency can only be attained if sufficient amount of feed is provided, completely ingested, and digested. Pond-reared shrimps must be fed frequently on small amounts, with the bulk of the feed given during the night when the feeding activity is highest. Increasing the frequency of feeding reduces leaching and feed loss, and improvement of growth and feed efficiency. Normal feeding patterns in crustaceans are interrupted during molting. Immediately before and during actual molting, crustaceans stop feeding. This usually lasts for two days after which feeding levels increase. Thus, an adjustment in feeding levels is needed.

Various methods are used to estimate feed ration. These include calculations based on the use of feeding charts, feed equations, and growth predictions. Feeding tables are calculated from estimates of growth, survival, and feed conversion. Tabulated feeding levels for various species are commonly provided by feed manufacturing companies. Daily feeding rate is expressed as percent of body weight per day. The percentage of feed consumed in relation to body weight decreases as the fish grow and their metabolic rates decline. Feeding charts provide only a general guide to feed intake. These do not take into account the short- or long-term fluctuations in appetite in response to many physiological and environmental factors. However, they are useful in estimating feed requirements. These baseline values, later modified as feeding and growth data from the various culture batches, are collected. Clearly, optimal feeding rate and frequency must be determined for each feed and pond by careful monitoring of feed consumption, growth, and feed efficiency over several growing cycles.

In order to calculate the daily feed ration of the cultured animal, data on average body weight and the estimated survival rate at a given time are needed, and these two are obtained by sampling the stock. The feeding rates recommended for the different species at various stages of culture are given in the section on Feeding Schemes. The formulas to compute for average body weight, survival rate, and daily feed ration are:

$$\text{Average body wt (g)} = \frac{\text{total wt of sampled stock (g)}}{\text{number of sampled stock (pcs)}}$$

$$\text{Survival rate (\%)} = \frac{\text{number of fish at a given time (pcs)}}{\text{original number of fish stocked (pcs)}} \times 100$$

$$\text{Daily feed ration (kg/day)} = \frac{\text{original number stocked (pcs)} \times \text{average body wt (g)} \times \text{estimated survival rate (\%)} \times \text{feeding rate (\%)}}{1{,}000}$$

Feed Particle Size

Feed particles must be of a size that can be readily ingested and this increases as fish grow. Large fish can ingest small particles but requires more energy to capture an adequate amount resulting in reduced feed efficiency. Unlike fish feed, the particle size of crustacean pellet is not related to the mouth size because crustaceans physically break down pellets prior to ingestion. However, the pellets must be of an appropriate size that crustaceans can carry and nibble on using their feeding appendages.

Feed application methods

Feeding fish is the most important daily activity at fish farms requiring a considerable amount of time. The choice of feeding methods will depend on the following factors: labor costs, scale of farm operation, species being farmed, type of holding system (ponds, cages, or tanks), hatchery and grow-out operation. Manual feeding includes broadcasting the feeds into the pond as well as placing feeds into floating frames (for floating feeds) or feeding trays (for sinking feeds). Feeding trays are used either to monitor actual feeding or to serve as feeding areas (Figure 7.4). Manually broadcasting feeds in the middle of a big pond requires the use of a small banca. Mechanical means of partially replacing hand feeding include: automatic feeders which can be set to release controlled amounts of feed when activated, and demand feeders which can release a few pellets each time a triggering mechanism is bumped by the fish (Figure 7.5). These mechanical feeders can save time, however, these must be calibrated and adjusted regularly.

Figure 7.4
Use of feeding tray to monitor feeding.

Figure 7.5
A demand feeder.

Whether manual or mechanical, the feeding method used should be economical and allow some control and reliability in dispensing feeds. The method should minimize feed waste, provide a way to monitor fish appetite and feed consumption, and should distribute feeds widely in order to promote uniform feeding and growth. If carried out carefully, manual feeding can closely monitor the appetite, feeding behavior, and abnormalities if any, of the animal. However, it is labor intensive and time consuming.

Mechanized feeding requires high capital and operating costs but can be offset by the reduction of labor costs associated with manual feeding. With timing controls, automated systems can be set to deliver feeds at any time, at any given frequency in accurate amount, and spread feed more evenly and over large areas, than is possible when broadcasting by hand. Manual feeding may be combined with the use of mechanical feeding systems to effectively control feeding routine, thereby reducing waste.

Feeding, Water Quality, and the Environment

Nutritional and economic success of an aquafeed is based upon a variety of interlinked factors and that no one factor can be considered by itself. These are presented in Figure 7.6. Feeds that are uneaten within a certain period can deteriorate the water quality of the culture system. Hence, proper feeding strategies and good water quality management are very important factors.

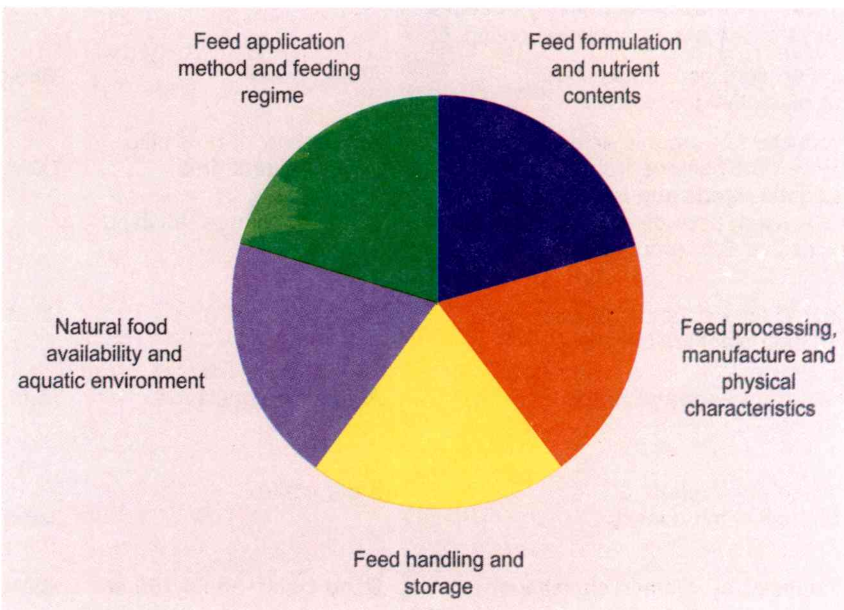

Figure 7.6
Interlinked factors that are critical for the success of an aquafeed.
Source: Tacon 1993

A. Feeding, oxygen requirements, and water quality

Oxygen, together with an organic substrate, is required for all oxidative metabolic processes. The rate of oxygen consumption rises to a peak after feeding, and then slowly falls back to the pre-feeding level.

Low water exchange rates, photosynthesis in plants, and the respiratory activity of the pond biomass create fluctuations in dissolved oxygen (DO) levels. Low DO depresses the feeding activity of aquatic animals. When DO level is low, feeding should not be done. Giving less feed at each feeding while increasing the frequency of feedings helps prevent low DO problems. Careful monitoring of DO levels, combined with observations of the behavior of the aquatic animal, is essential and should be routinely done. Oxygen depletion can be alleviated by increasing water exchange (at least 30% of total volume) and the use of mechanical aerators such as a paddlewheel aerator. Other water quality parameters should be carefully monitored so that conditions that adversely affect growth and survival can be minimized. Some water quality problems in brackishwater ponds and methods to manage them are given in Table 7.2.

Table 7.2 Water quality parameters, method of measurement, water quality problems and possible causes, scheme/ method of management, and target water conditions in brackishwater pond culture

Parameter	Method of measurement	Water quality problem	Possible causes of problems	Scheme/method of management	Target water condition
Dissolved oxygen (DO)	DO meter, titration	Low DO	Increased DO demands due to: over-abundance of plankton and benthic organisms, and subsequent die-offs of plankton or animal, waste accumulation in pond bottom Slow O_2 diffusion from atmosphere Limited photosynthesis during overcast days or the algal population collapses	Aeration if DO is < 4 ppm Water change 30-50%, flushing of bottom wastes and detritus	> 4 ppm
		DO stratification	Limited light penetration due to high plankton density	Algal control	No stratification
pH	pH meter, pH paper	Low pH	Production of organic acids by anaerobic bacteria from uneaten feeds and metabolic wastes Acids leach from dikes of acid sulfate soil Excessive CO_2 production	Application of dolomitic or agricultural lime Water exchange/ flushing	7.0 to 8.5 pH
		pH stratification	Limited light penetration due to high plankton density	Algal control	No stratification
Salinity	Refractometer, hydrometer	Salinity stratification	Rain and freshwater runoff	Aeration / circulation	15 to 30 ppt
Temperature	Thermometer	Temperature	Limited penetration due to high plankton density	Algal control	No temperature stratification
		Unstable water temperature	Influenced by climatic conditions	Deep water, about 150 cm	Stable, 26 to 33°C
Ammonia-N	Ammonia test kit	High NH_3-N	Excess feed, metabolic wastes and decaying matter; phytoplankton die-off	Water change/ flushing Aeration	< 1.0 ppm
Nitrite-N	Nitrite test kit	High NO_2-N	Excess feed, metabolic wastes and decaying matter	Water change/ flushing Aeration	< 0.5 ppm
Alkalinity	Alkalinity test kit, titration	Low alkalinity	Excess feed, metabolic wastes and decaying matter	Water change/ flushing Aeration	> 20 ppm
Hydrogen Sulfide	Sulfide test kit	High H_2S	Excess feed, metabolic waste and decaying matter	Water change/flushing Aeration	< 0.003 ppm
Transparency	Secchi disk visibility	Turbid	Increased suspended solids, erosion of dikes, turbid water source, excessive and rapid plankton bloom	Coagulants Water change	30 to 45 cm
		Clear	Absence of good plankton bloom, plankton die-off	Fertilizers: urea, chicken manure	Golden brown, light to brownish green color

Source: Modified from Chiu 1988

B. Fish farm wastes

The impact of aquaculture on the environment is primarily related to feed management. The composition of feeds and feed conversion affect both the physical and chemical nature of waste materials and the amounts produced. Wastes produced during the culture of aquatic animals fall into two groups: solid wastes resulting from uneaten feed, dust and feces, and soluble excretory products, primarily ammonia and urine, dissolved organic materials, and carbon dioxide. These materials are potentially harmful to both the immediate farm environment and water bodies receiving the farm effluents.

If organic materials accumulate to high levels on the bottom of the ponds or in the sediment below floating cages, the sediment will become anaerobic, releasing toxic hydrogen sulfide and methane gas. Suspended solid materials have a harmful effect on the gills of aquatic animals, affect respiratory function, and provide potential sites for bacterial and fungal infection. Long-term effects may result from the release of phosphates and nitrates from fish farm effluents leading to eutrophication or enrichment of the receiving water. In extreme cases, these may lead to the occurrence of potentially harmful plankton blooms.

Performance Measures

The success of feeding operations is reflected in overall production and profit. Growth, survival, and feed conversion ratio, the major indicators commonly used by farmers to measure performance are computed at the end of each culture cycle (See Chapter 6).

Biomass. This refers to the total weight of species being cultured, expressed in terms of a given area or volume of the habitat, e.g., per hectare.

$$\text{Biomass (kg/ha)} = \frac{\text{original no of stock (pcs) x ave body wt (g) x survival (\%)}}{1{,}000}$$

Feed conversion ratio (FCR). Many farmers use FCR as the indicator of the effectiveness of both feeding practices and overall husbandry. FCR can only be accurately determined if the amount of feed consumed is accurately monitored and recorded. To compare the FCRs of feeds, moisture values must be corrected when calculating the weights of feed fed. Poor or variable FCRs may reflect problems with feed or feeding methods, or may be indicators of problems such as the occurrence of disease in stocks or worsening water quality. Low FCR of 1.1 means that it only takes 1.1 kg of feed to produce 1 kg of fish. High FCR of 2.5 is considered as poor since it takes 2.5 kg of feeds to produce 1 kg of fish. The lower the FCR value, the better is the feed utilization.

$$\text{Feed conversion ratio (FCR)} = \frac{\text{amount in dry wt of feed given (kg)}}{\text{wet wt gained within a feeding period (kg)}}$$

Feeding Schemes

A. Milkfish

Milkfish (*Chanos chanos*) (Figure 7.7) is a major protein source in the Philippines. It is omnivorous and grows in a wide range of salinity. The traditional low-density culture in brackishwater ponds has expanded to high-density culture in freshwater lakes, brackishwater ponds, marine pens, and offshore cages. High quality feeds and good feeding management become more critical in these culture systems. Milkfish are harvested and marketed as fresh, chilled, or processed into value-added products, such as deboned, marinated, 'choice cuts' packs, smoked, and canned.

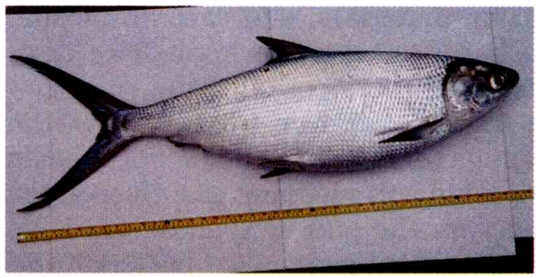

Figure 7.7
Milkfish *Chanos chanos*.

1. Feeding milkfish broodstock in floating cages and tanks

The milkfish broodstock rearing facilities used at SEAFDEC AQD are floating marine net cages and concrete tanks (Figure 7.8A, B). A formulated broodstock diet (Table 7.3) is broadcast twice daily (0800 to 0900 h and 1400 to 1500 h) at 2 to 4% of biomass. Milkfish anticipates feeding time and can swallow whole pellets measuring 1 cm diameter x 2 cm long. Mature milkfish can spontaneously spawn during the season with nutritionally adequate feeds and proper feeding management.

Figure 7.8
Floating marine net cages (A), and concrete tanks (B), for broodstock.

Table 7.3 Practical diet formulas (g/kg dry diet) for milkfish at various stages of culture

Ingredient	Broodstock diet [1]	Larval diet [2]	Fry freshwater diet [3]	Fry seawater diet [4]	Grow-out diet [5]
Fish meal	200	330.0	566.0	300	110
Soybean meal	430	180.0	114.0	200	308
Squid meal	-	100.0	-	-	-
Shrimp meal (*Acetes* sp.)	-	120.0	90.0	-	-
Shrimp head meal	-	-	-	160	-
Rice bran	255	-	87.0	115	492
Bread flour	40	66.9	-	150	50
Sago palm starch	-	-	50.0	-	-
κ-carrageenan	-	50.0	-	-	-
Cod liver oil	20	80.0	25.0	30	20
Soybean oil	-	-	25.0	-	20
Lecithin	-	10.0	-	-	-
Vitamin mix	15	30.0	6.9	10	-
β-carotene	-	2.5	-	-	-
DL-α-tocopherol acetate	-	0.1	-	-	-
Mineral mix	-	30.0	36.0	35	-
Dicalcium phosphate	40	-	-	-	-
Butylated hydroxytoluene	-	0.5	0.4	-	-
Proximate composition (% DM):					
Crude protein	37.6	46.3	43.9*	37.6	26.7
Crude fat	8.7	11.4	10.3*	8.7	10.9
Crude fiber	3.9	5.6	3.6*	3.9	8.4
Nitrogen-free extract	36.4	27.3	16.8*	36.4	45.1
Ash	13.4	9.4	16.2*	13.4	8.9

Sources: [1] Marte & Borlongan in FDS Manual 1994; [2] Borlongan et al. 2000; [3] Santiago et al. 1983; [4] Alava and Lim 1988; [5] Sumagaysay 1998
*as-fed basis

2. Feeding milkfish larvae in hatcheries

In intensive production, milkfish larvae are reared in concrete tanks (3 to 10 m^3 capacity, Figure 7.9) at high stocking rates (30,000 to 50,000 larvae per m^3). Milkfish larvae are pelagic feeders, thus their feed should be buoyant and remain suspended in the water column until eaten. A feeding scheme is developed with the use of artificial diets to reduce the need for natural food production in hatcheries (Figure 7.10). A nutritionally-balanced, flaked microbound diet or MBD (Table 7.3) may be fed to milkfish larvae in combination with *Brachionus* starting day 2 or day 7, and used solely as feed from day 15 onwards. The natural foods are given once daily (0900 h), while formulated larval diets are dispensed three times a day at 0800, 1100, and 1300 h.

For a semi-intensive hatchery system, milkfish larvae are fed initially with *Brachionus*. At later stages, copepod *Acartia* and *Pseudodiaptomus* nauplii and MBD are provided. MBD is given at 2 g/m^3/day, four times daily (0800, 1100, 1400, and 1700 h) until harvest.

FIGURE 7.9
Intensive larval rearing tanks.

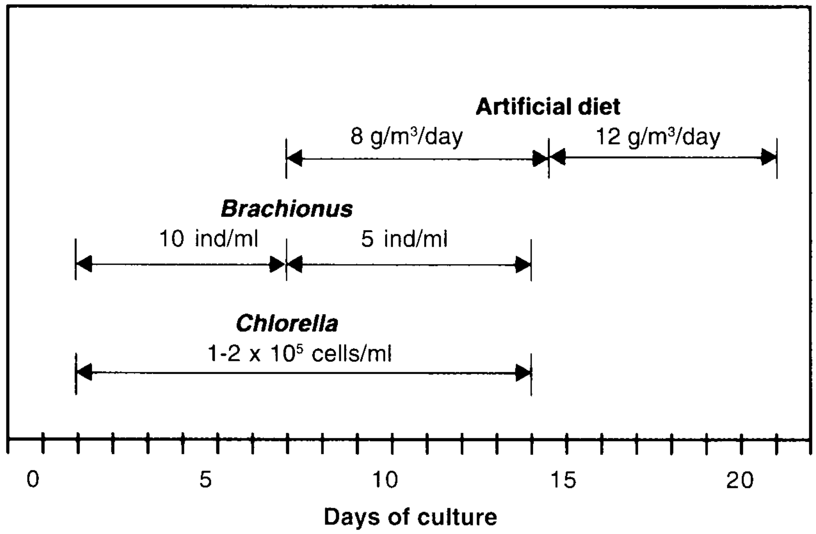

Figure 7.10
Feeding management scheme for larval rearing of milkfish.
Source: Borlongan et al. 2000

3. Feeding milkfish fry in nursery tanks and ponds

Traditionally, milkfish fry obtained from the wild are reared in fertile nursery ponds with abundant natural food. Hatchery-bred fry are also stocked into nursery ponds. The natural food bases for milkfish in ponds are *lablab*, plankton, and *lumut*. *Lablab* is cultivated during the dry season and plankton during the wet season in deep-water ponds (70 to 100 cm).

Wild-sourced fry metamorphose and has good growth and survival in freshwater when fed on an artificial diet (Table 7.3) at 15 to 10% of biomass four times daily (0900, 1200, 1500, and 1800 h) for 35 days in tanks. Likewise, wild-sourced fry reared in seawater tanks and fed artificial diet (Table 7.3) three times daily (0900, 1300, and 1700 h) at 20 to 15% of the body weight per day attain good growth and excellent survival in one month.

4. Feeding milkfish in grow-out ponds

Milkfish grow-out culture started from the traditional shallow water straight culture of uniform-sized fish stock in ponds to multi-size stocking and harvesting using modular, and deep-water plankton methods.

Milkfish depends on natural food grown in the ponds during the first and second months of culture (Figure 7.2). Artificial feeds (Table 7.3) can be fed at 3 to 4% of body weight per day when natural food is low. There is no common feeding table for supplemental feeding; feeding depends on total fish biomass, the amount of natural food, and on water quality. Feed can be broadcast always in the same area of the cage or pond (Figure 7.11A, B). Before feeding, the fish are conditioned to sound to make feeding easier and more effective because the fish gather in one area.

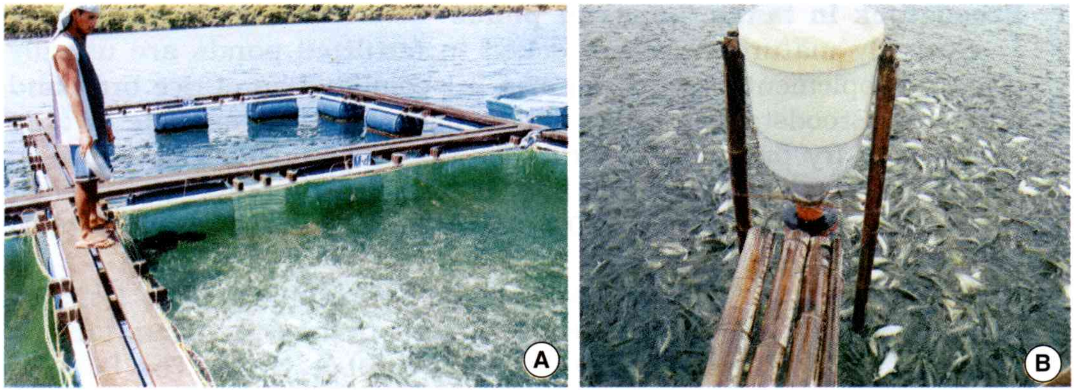

Figure 7.11
Feed can be broadcast in the same area of the cage or pond since fish gather in same area for feeding (A,B).

Milkfish are daytime feeders. Feeding is done twice a day, at mid-morning (when DO is not less than 3 ppm) and late afternoon. At mid-day, milkfish prefer to feed on natural food. Thus, high plankton density should be maintained through periodic application of fertilizers. For example, 25 kg of 16-20-0 monoammonium phosphate may be applied per hectare every 15 days.

When feed is the major source of nutrients, feeding is increased to three times a day; 0800 to 0900, 1200, and 1600 to 1700 h. The feed ration could be higher at noon and in the afternoon (3/4 of the daily ration) than in the morning (1/4 of the daily ration).

Milkfish feeding activity is affected by abrupt changes in environmental factors such as temperature, salinity, and DO. The daily feed ration is reduced by 25% when the temperature drops from 32°C to 25-28°C, and by 50% when the temperature falls from 26-33°C to 21-24°C, when salinity is more than 36 ppt, or when DO is less than 3 ppm.

B. Tilapias

In the Philippines, tilapias (*Tilapia nilotica* or *Oreochromis niloticus*, *T. mossambica* or *O. mossambicus*, *T. aurea* or *O. aureus*, red tilapia *Oreochromis* spp. (Figure 7.12A, B, C, D) rank second to milkfish in economic importance. Tilapias are omnivorous; they feed on phytoplankton, zooplankton, bottom organisms, and detritus. Tilapias are ideal for culture because of their flexible feeding habits. They can readily take a variety of feeds, in meal form, and in sinking and floating pellet form. Tilapias feed continuously and they respond well to frequent feeding. They prefer small pellets, and chew rather than swallow them whole. For high survival and efficient feed conversion, dry pellet crumbles are better utilized than the non-pelleted mixture of the same diet.

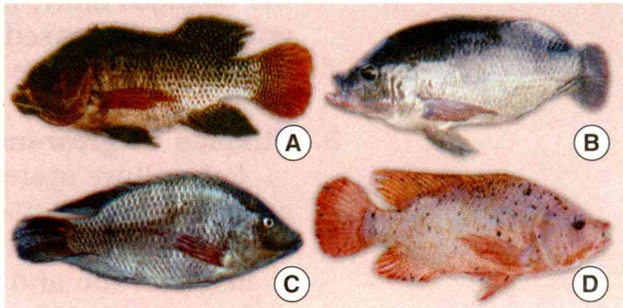

Figure 7.12
Tilapia nilotica (A), *mossambica* (B), *aurea* (C), red tilapia (D).

1. Broodstock in tanks, hapas or ponds

Sexually mature tilapias stocked in fertilized ponds are usually given a supplement of rice bran or a 3:1 combination of rice bran and fish meal. Broodstock in tanks and in hapas are fed complete diets to obtain high fry production. A diet for tilapia broodstock is shown in Table 7.4. This diet is given at a feeding rate of 1% of the body weight twice daily at 0900 h and 1500 h and is sufficient to increase growth and fry production.

Tilapias spawn asynchronously. The females deposit their eggs at the bottom of the pond, tank or hapa where the males fertilize them. The females incubate their eggs and shelter the larvae in their mouths until the fry are free-swimming (Figure 7.13). During this time they eat very little or none at all.

Restricted feeding is suitable for broodstock. Tilapia that have been fed to satiety at temperatures 28 to 30°C can be stimulated to reproduce by reducing the feed ration by 25 to 50%. It is important not to overfeed the broodstock. Frequent cleaning of tanks and hapas disturbs the brooders, causing them to spit out or swallow the eggs and larvae.

Figure 7.13
Larvae released from mouth-brooding female.

2. Larvae or fry in nursery ponds, tanks, and hapas

Nursery ponds are fertilized to grow plankton. Tilapia fry are stocked in ponds or in hapas inside the pond. Natural foods differ in nutritional value for tilapia fry. The diatom *Navicula* and cyanobacterium *Chroococcus* are more acceptable and are better assimilated than the green alga *Chlorella* and the phytoflagellate *Euglena.*

When natural food starts to decline in ponds, the nursery operator introduces feed which may be fine rice bran or a 7:3 combination of fine rice bran and fish meal. In nursery tanks and hapas where natural food is scarce, a formulated diet (Table 7.4) is given to fry as soon as they start feeding. Fry are fed to satiety, or at about 30% of the biomass daily, four times a day. As they grow, the feeding rate is gradually decreased to 15%. The feed is broadcast over areas in the nursery so that the fry do not have to swim far to search for food.

3. Tilapias in grow-out tanks, ponds, and cages

Polyculture systems of tilapias with fish of different food preference are used to maximize the utilization of natural foods. The manures of chicken, ducks, or pigs are used to fertilize the ponds. Locally available crude and inexpensive feedstuffs such as rice bran, pollard, and copra meal, leftover bread and biscuits, and commercial poultry feeds are given as supplemental feeds twice a day at 2 to 3% of biomass.

Table 7.4 Practical diet formulas (g/kg dry diet) for tilapia at various stages of culture

Ingredient	Broodstock diet [1]	Larvae/fry diet [2]	Grow-out diet [3]
Fish meal	362	301.7	182.5
Corn gluten meal	204	-	-
Soybean meal	177	259.5	250.0
Copra meal	118	114.8	100.0
Ipil-ipil meal	-	81.0	-
Cassava flour	-	-	364.2
Rice bran	75	149.7	60.0
Starch	32	30.0	-
Cod liver oil	5	10.0	-
Vegetable oil	5	10.0	-
Vitamin-mineral mix	22	43.3	43.3
Proximate composition (% DM):			
Crude protein	44.0	38.1	28.1
Crude fat	5.5	8.7	3.8
Crude fiber	9.1	5.6	3.6
Nitrogen-free extract	29.6	30.8	54.6
Ash	11.8	16.8	9.9

Sources: [1,2,3] Santiago et al. 1985,1986,1987, respectively

Broadcasting by using a cup or a ladle is the most common feeding method. The feed is distributed evenly or in several sites so that all fish have easy access to feed. Water temperature, fish size, the quality of the feed, and the presence of natural food affect the feed consumption of tilapias. Thus, the daily feeding ration is adjusted, depending on fish appetite.

Intensive culture of tilapia has gained popularity in recent years. This method of farming requires the use of high quality feeds and modern management tools. Fish are stocked at high densities in concrete tanks, earthen ponds or floating net cages (50 to 74 fingerlings per m^3). For grow-out cages in lakes (Figure 7.14), feeding trays or a second fine-mesh net at the bottom of the cage are installed to help minimize the loss of feeds. A diet with 28% protein (Table 7.4) is given three times daily at 5 to 6% of biomass. Daily feeding rate can be decreased to about 2 to 3% as the fish size increases from 30 g to more than 100 g. The daily ration is given in three feedings 3 to 4 h apart, at 0900, 1200, and 1600 h. During cool months, when metabolic rate is low, feeding frequency can be reduced to twice a day at 0900 and 1500 h. The appetite is generally poor when water temperature is low, and highest in the afternoon, when the water is warmer.

Figure 7.14
Grow-out floating net cages in a lake.

Figure 7.15
Rabbitfish *Siganus guttatus* juveniles.

C. Rabbitfish

Rabbitfishes are widely distributed in the Indo-Pacific region. The local species *Siganus guttatus* (Figure 7.15) is an economically important food fish in the Philippines. It breeds in captivity, spawns regularly, and grows in brackishwater ponds feeding only on algae.

1. Broodstock in tanks

Rabbitfish spawns naturally every month the whole year round. Broodstock are fed with an artificial diet (Table 7.5) at 3% of the body weight per day, morning and afternoon. This diet enhances reproductive performance, and egg and larval qualities of rabbitfish.

Table 7.5 Practical diet formulas (g/kg dry diet) for rabbitfish broodstock and fry

Ingredients	Broodstock diet [1]	Nursery diet [2]
Fish meal	100.0	145.0
Shrimp meal (*Acetes* sp.)	-	145.0
Squid meal	100.0	134.0
Shrimp meal	100.0	-
Soybean meal	80.0	-
Corn gluten meal	80.0	-
Wheat germ	80.0	-
Brewer's yeast	60.0	-
Cellulose	187.3	28.5
Bread flour	22.5	376.0
κ-carrageenan	-	50.0
Cod liver oil	100.0	71.0
Soybean oil	15.0	-
Soybean lecithin	45.0	-
Vitamin mix	20.0	30.0
Mineral mix	10.0	20.0
Butylated hydroxytoluene	0.2	0.5
Proximate composition (% DM):		
Crude protein	38.4	39.2
Crude fat	17.4	9.9
Crude fiber	13.1	5.5
Nitrogen-free extract	23.6	37.8
Ash	7.5	7.6

Sources: [1] Duray et al. 1994; [2] Parazo 1991.

2. Larval rearing and nursery

In the hatchery, rabbifish larvae (day 1 to 21) can grow and survive well with feeding either highly unsaturated fatty acids (HUFA)-enriched rotifer at 15-20 ind/ml, HUFA-enriched rotifer supplemented with artificial diet (0.5 g/m^3/day), or *Chlorella*-fed rotifers supplemented with artificial diet. Good growth and survival are also obtained when larvae (day 25 to 45) are fed an artificial diet (Table 7.5). Feeding rate is at 23% of initial biomass daily, given at 0900, 1030,1200,1300, 1500, and 1700 h. A feeding scheme from day 1 to 45 outlined in Figure 7.16 yields consistently fair survival.

3. Culture in ponds and floating netcages

The natural food recommended in the rearing pond are filamentous algae such as *Cladophora linum*, *Chaetomorpha* spp., and *Enteromorpha tubulosa*. These algae are planted uniformly in small clumps in the entire pond, done during the late afternoon to prevent them from floating the next day. Rabbitfishes reared in floating cages and in ponds are also fed supplementary feeds or commercial tilapia feeds.

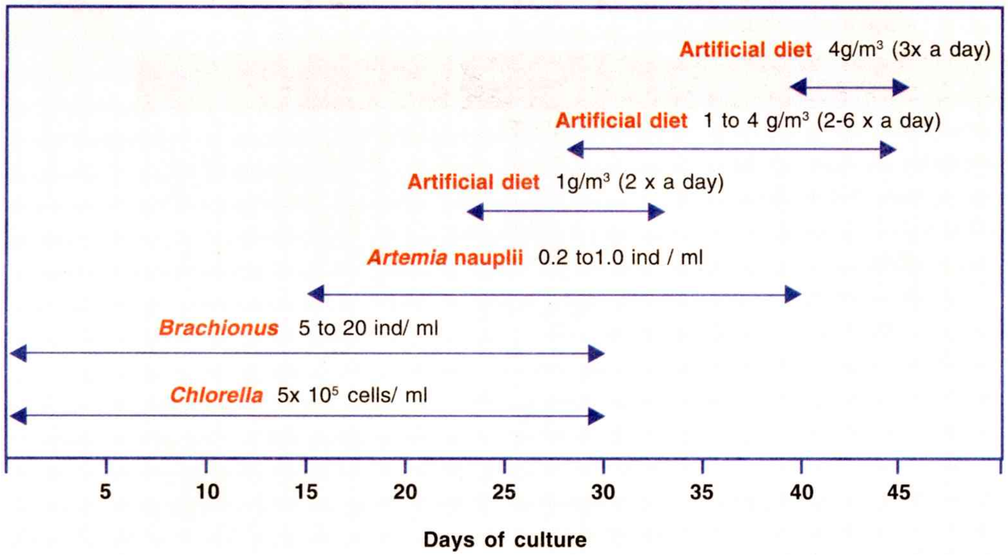

Figure 7.16
Feeding scheme for rabbitfish larvae.
Source: Hara et al. 1986

D. Bighead Carp

Carps are among the most commercially desirable freshwater fish species in Asia and the Indo-Pacific region. Bighead carp (*Aristichthys nobilis*) (Figure 7.17A) has a high reproductive capacity and fast growth rate, feeds low on the food chain, and can be grown in monoculture in ponds, cages and fish pens or in polyculture with milkfish and tilapia in pens.

1. Broodstock in fish pens and cages

Bighead carp mature in cages in the lake without supplemental feeding, but fry production and survival are enhanced when the broodstock are fed supplemental diets. Broodstock diet (Table 7.6) is fed at 2 to 0.8% of body weight per day at 0930 and 1500 h. Artificial diets positively influence the onset of gonad maturation and enhance the hatchability of eggs.

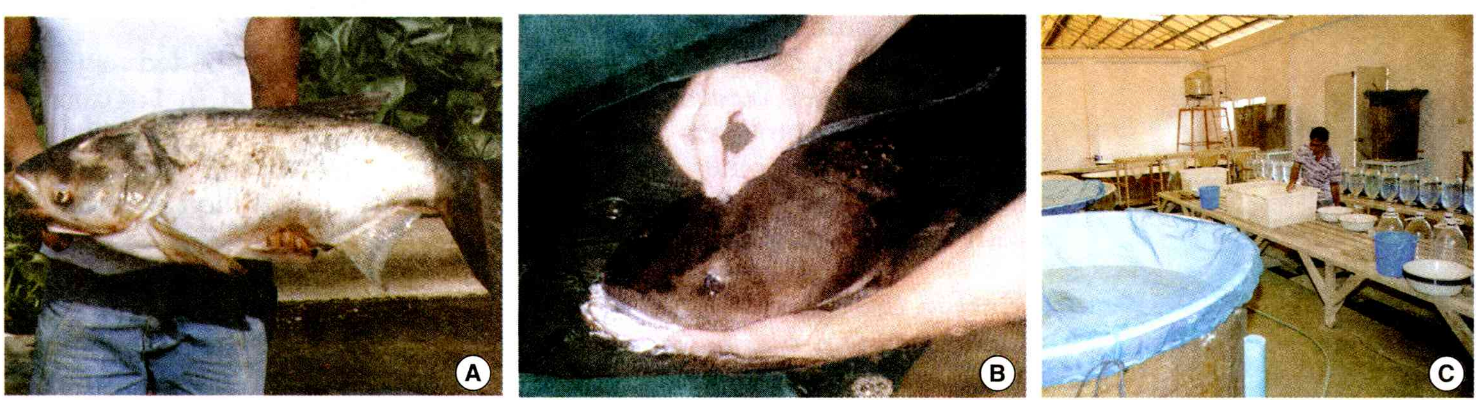

Figure 7.17
Bighead carp *Aristichthys nobilis* (A), induced to spawn using hormonal injection (B), and indoor larval rearing facilities (C).

Table 7.6 Practical diet formulas (g/kg dry diet) for bighead carp at various stages of culture

Ingredients	Broodstock diet [1]	Larval diet A [2]	Larval diet B [3]
Copra meal	200.0	-	-
Fish meal	150.0	406.0	566.0
Shrimp meal (*Acetes* sp.)	-	-	90.0
Rice bran	25.0	150.0	127.0
Soybean meal	320.0	361.3	114.0
Corn gluten meal	-	-	-
Meat and bone meal	224.0	-	-
L-lysine	1.0	-	-
DL-methionine	5.0	-	-
Starch	26.9	-	10.0
Cod liver oil	5.0	32.7	25.0
Corn oil	5.0	-	25.0
Vitamin-mineral premix	38.1	50.0	43.0
Proximate composition (% as-fed):			
Crude protein	41.5	40.2	41.5
Crude fat	5.1	6.8	11.9
Crude fiber	3.9	no data	no data
Nitrogen-free extract	30.4	26.5	24.5
Ash	14.6	no data	12.5

Sources: [1] Santiago and Gonzal 2000; [2] Fermin and Recometa 1988; [3] Santiago and Reyes 1989

2. Larval and nursery rearing

Induced spawning of the broodstock using hormones (Figure 7.17B) produces bighead carp larvae. In the nursery (Figure 7.17C), the combination of live food organism and artificial diet enhances the growth of bighead carp larvae. The combination of *Moina* and larval diet A (Table 7.6) fed daily to satiation at 0900, 1100, 1300, and 1600 h gives the best growth of bighead carp larvae (day 5 to 12 weeks). Similarly, the combination of *Brachionus* and larval diet B (Table 7.6) has a positive effect on growth. Bighead carp larvae can grow well on artificial diet given initially at 100% of the body weight per day, and finally at 30% of the fish biomass daily. These larvae are reared in indoor nursery tanks for 30-45 days before they are harvested for stocking in grow-out cages.

3. Grow-out culture

Cultured in fish pens, bighead carps do not have to be fed artificial feeds, since they thrive well on abundant natural food in Laguna de Bay. Carp farming has already expanded to upland and landlocked areas in the Philippines. Bighead carps are reared together with tilapia in fertilized ponds where they rely mainly on natural food organisms, with occasional supplemental feeds.

E. Native Catfish

The native catfish *Clarias macrocephalus* (Figure 7.18A) is an important indigenous freshwater food fish in Malaysia, Thailand, and the Philippines. At SEAFDEC AQD, catfish is induced to breed in captivity in order to arrest the decline of the natural population, and ensure a sufficient supply of fry and fingerlings for stocking.

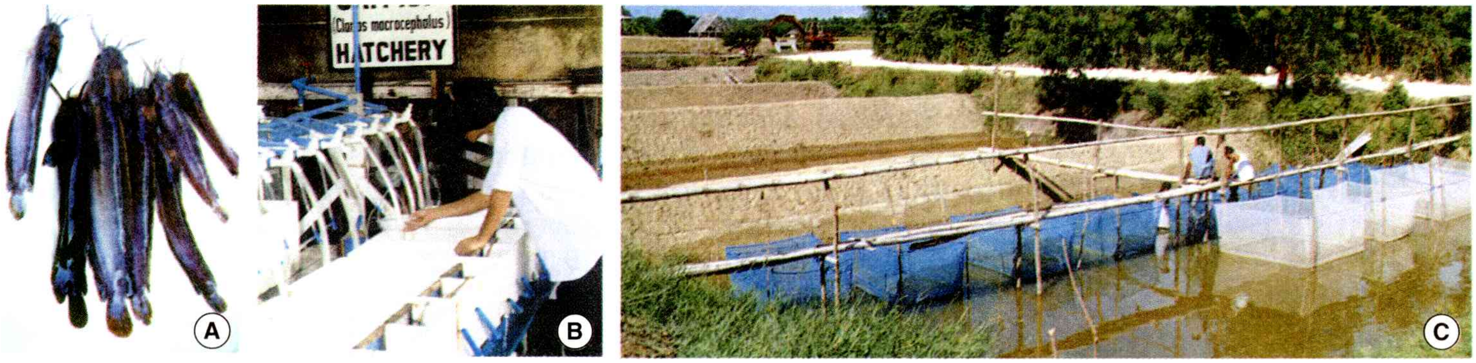

Figure 7. 18
Native catfish *Clarias macrocephalus* (A), reared in hatchery (B), and in net-cages in pond (C).

1. Broodstock

Traditionally, raw fish alone or in combination with artificial diet is used as feed to condition the broodstock for induced spawning. Live foods like *Tubifex* worms are also used to supplement the dry broodstock diet. Without supplementation of natural food, two artificial diet formulations enhance the reproductive performance of catfish and can be used in production and maintenance of broodstock (Table 7.7). Broodstock are fed two times a day to satiation or about 8 to 10% of the fish biomass daily.

Table 7.7 Practical diet formulas (g/kg dry diet) for Asian catfish at various stages of culture

Ingredient	Broodstock diet A[1]	Broodstock diet B[1]	Larval diet [2]	Grow-out diet [3]
Fish meal	250.0	150.0	73.8	200
Soybean meal	350.0	350.0	380.0	300
Shrimp meal (*Acetes* sp.)	-	-	77.5	-
Meat and bone meal	53.3	224.0	-	-
Squid meal	-	-	71.3	-
Rice bran	-	156.1		310
Copra meal	261.2	34.4		-
Ipil-ipil leaf meal	-	35.5		-
Bread flour	-	-	191.4	90
Starch	20.0	-		-
κ-carrageenan	-	-	10.5	-
Cellulose	-	-	14.7	-
Cod liver oil	-	-	80.8	-
Soybean oil	30.0	20.0		50
Vitamin mix	35.5	30.0	50.0	-
Vitamin-mineral mix	-	-		10
Mineral mix	-	-		10
Dicalcium phosphate	-	-	50.0	30
Proximate composition (% DM):				
Crude protein	42.5	43.1	39.9	34.2
Crude fat	7.2	7.9	10.6	9.5
Crude fiber	4.2	3.4	1.5	5.8
NFE	33.4	30.2	40.2	36.3
Ash	12.7	15.4	7.5	14.2

Sources: [1]Santiago and Gonzal 1997; [2] Fermin and Bolivar 1996; [3]Coniza et al. 2001

2. Larval and nursery rearing

Live zooplankton feed (*Artemia* or *Moina*) is required for successful larval rearing (Figure 7.19B) of catfish. During the first week of rearing, newly hatched *Artemia* are fed to fish at 10 individuals per day and artificial diet at 50% of body weight. At the second week of culture, *Artemia* is given at 20 individuals per day and artificial diet at 25% of body weight per day. The daily ration is divided into four feedings given between 0900 and 1500 h. Weaning of catfish larvae to dry artificial diet can be started four days after feeding live zooplankton. A combined diet of *Artemia* and a dry artificial feed (Table 7.7) improves the growth and survival of catfish larvae.

Hatchery-bred catfish fry stocked in net cages installed in tanks and in ponds (Figure 7.18C) grow well on artificial diet. In ponds, natural food (copepods and cladocerans) also serves as food source for catfish juveniles.

3. Grow-out culture

Traditionally, catfish feeds on decaying organic matter in the pond with kitchen refuse as supplement. Feeding catfish blanched chicken entrails and rice bran (80 : 20) at 10% of the fish body weight per day is also practised.

Cultured in pens inside a pond (Figure 7.18C), catfish fry are fed an artificial diet (Table 7.7) at 5, 4.5, 4, and 3.5% of fish body weight per day for the 1st, 2nd, 3rd and 4th month of culture, respectively. Feeds are given at 0800 and 1600 h with the crumble diet for the first two months and about 2.5 mm diameter pellets thereafter until harvest.

F. Asian sea bass

Figure 7.19
Asian sea bass *Lates calcarifer.*

Sea bass (*Lates calcarifer*) (Figure 7.19) is an important aquaculture species in Thailand, Hong Kong, Singapore, and Malaysia. Called "barramundi" in Australia and Papua New Guinea, sea bass is an important resource, forming the basis of their commercial and recreational fisheries. Sea bass is an opportunistic predator throughout its life cycle.

1. Broodstock in seacages and tanks

Sea bass reared to maturity in floating net cages and tanks spawn naturally. Sea bass are fed raw fish at 3 to 5% body weight once daily and reduced to 1 to 2% body weight during the peak of the spawning season.

2. Larval and nursery rearing

The phytoplankton *Chlorella*, *Tetraselmis* or *Isochrysis* are added to larval rearing tanks as water conditioners and as food for rotifers. Sea bass begin to feed 50 h after hatching but feed is given earlier at 36 h. Larvae are weaned gradually to each new feed type by increasing

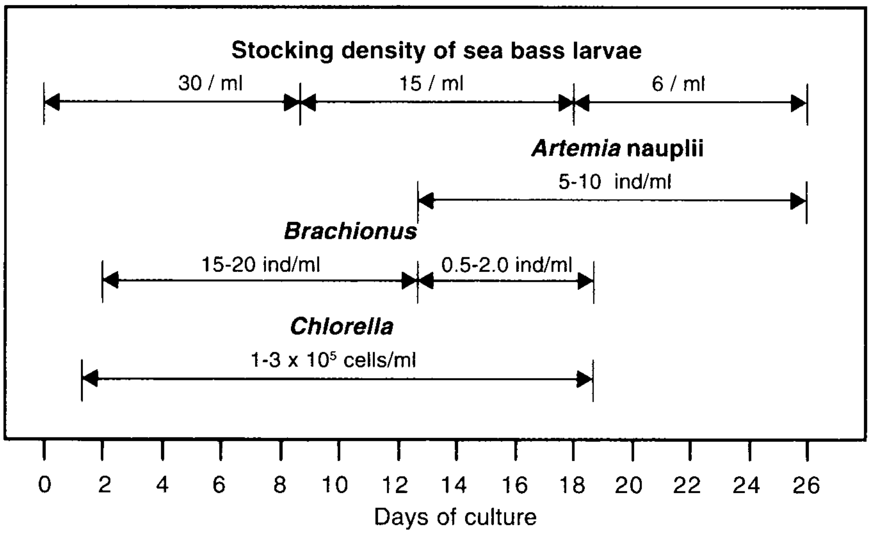

Figure 7.20
Feeding management scheme for the larval rearing of sea bass.
Source: Parazo et al. 1998

the daily proportion of the new feed type while gradually decreasing that of the preceeding feed. (Figure 7.20)

As a partial or complete replacement of *Artemia*, the freshwater cladoceran *Moina* may be fed to sea bass larvae starting with 17 to 20 day old larvae at a feeding rate of not less than 1 ind/ml. *Moina* are first sieved to obtain small adults and neonates before feeding to 17-day old larvae. Unsieved *Moina* can be fed directly to 20-day old larvae. When feeding with *Moina*, the salinity of rearing water is gradually lowered to about 10 ppt within a 24-h period. Larvae are fed at least four times daily. The brackish water cladoceran, *Diaphanosoma*, is also a potential live food for sea bass larvae. It can be fed once a day to 15-day old and older larvae at 2 ind/ml at 32 to 35 ppt.

Sea bass larvae and juveniles can be reared in nursery cages installed in open waters using night-light to attract zooplankton (mostly copepods) as food. A stocking density of 600/m^2 can be used when fish feed on zooplankton alone but minced fish flesh given *ad libitum* during daytime is needed when stocking density is increased to 1200/m^2.

Table 7.8 Practical diet formula (g/kg dry diet) for juvenile sea bass

Ingredients	Amount [1]
Fish meal	420.0
Soybean meal	90.0
Shrimp meal (*Acetes* sp.)	100.0
Squid meal	50.0
Bread flour	77.5
Cellufil	145.0
Cod liver oil / soybean oil (1:1)	57.5
Vitamin mix	40.0
Mineral mix	20.0
Proximate composition (% DM):	
Crude protein	43.2
Crude fat	9.3

Source: [1]Catacutan and Coloso 1995.

3. Grow-out culture

Sea bass juveniles respond well to dry artificial diet as long as they are trained to feed an artificial diet are early in the nursery. In tanks, juveniles fed an artificial diet (Table 7.8) at 17 to 14%, 12 to 8%, and 8 to 5% of the body weight for the first 20 days, next 20 days, and last 14 days, respectively. Daily ration is given in three equal portions at 0930, 1300, and 1600 h. In ponds and in sea cages, sea bass grow well on raw fish alone or in combination with artificial feeds.

G. Orange-spotted grouper

Groupers are among the most valuable species for export markets. Their demand is mostly in countries with high seafood consumption or with high economic growth. Groupers spawn readily in captivity but larval survival is still low. At present, the grow-out industry relies on fry taken from the wild.

1. Broodstock in sea cages and tanks

Orange-spotted grouper (*Epinephelus coioides*) (Figure 7.21) first mature as females at around 3 to 4 kg body weight, some of the fastest growing females change into males when they reach more than 6 kg. Broodstock held in tanks or cages spawn monthly, usually within a week before or after the last quarter moon phase. Broodstock maintained in sea cages and in tanks are fed a variety of species of raw fish every other morning at satiation level.

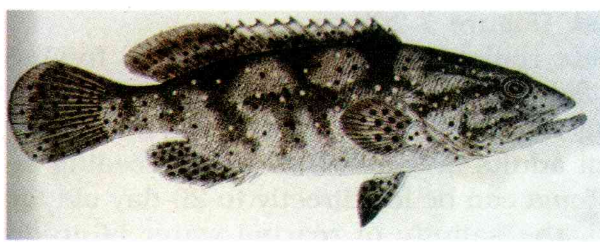

Figure 7. 21
Orange-spotted grouper *Epinephelus coioides.*

2. Larval rearing

In intensive larval rearing, the rearing protocol involves feeding young larvae (day 2 to day 15) with screened rotifers previously enriched with high *n*-3 HUFA boosters. Older larvae (day 20 to 50), are fed enriched *Artemia* nauplii or *Artemia* meta-nauplii until metamorphosis to the juvenile phase (Figure 7.22).

In semi-intensive larval rearing, grouper larvae stocked at low densities (10 larvae/l) with minimal water exchange feed on copepod nauplii during the early rearing phase. Copepods are collected from brackish water ponds and inoculated in the larval tanks 2 to 3 days before stocking of larvae. First-feeding larvae prefer copepod nauplii than rotifer.

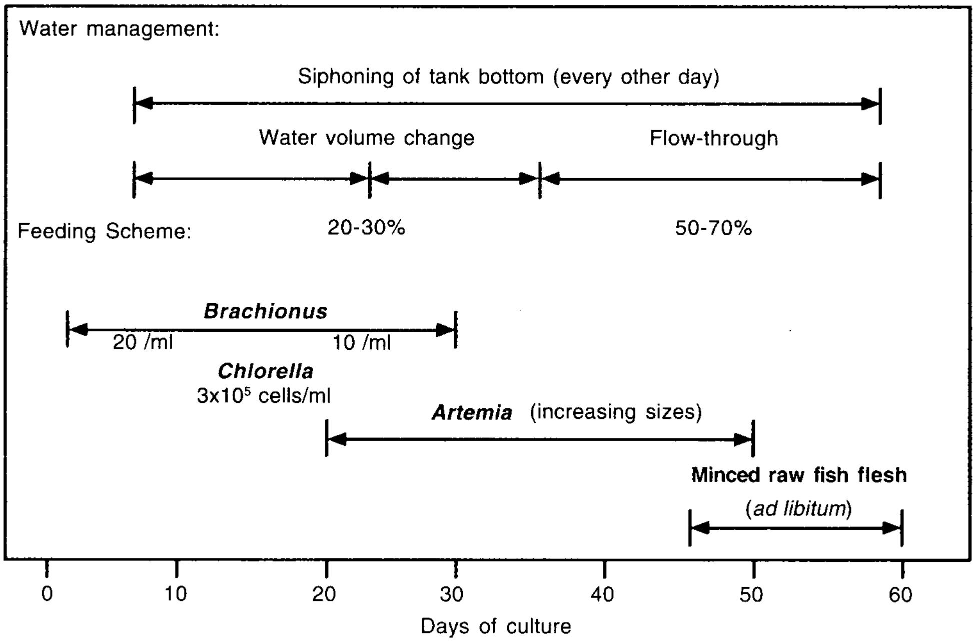

Figure 7.22
Feeding and water management scheme for intensive rearing of grouper larvae.
Source: Duray et al. 1997

3. Grow-out culture

Generally, raw fish is used as feed for groupers farmed in sea cages, ponds, and net-cages in ponds. Another feeding strategy is to initially stock adult tilapias (5,000 to 10,000 per hectare) in ponds and allow them to reproduce. Tilapia fingerlings are then used as food for grouper juveniles. In addition, chopped raw fish is given every other day at 5% of grouper biomass. Half of the ration is given in the morning and half in the afternoon, some are placed in feeding trays for monitoring purposes and the rest are broadcasted. If raw fish is the sole feed, groupers may be given up to 10% of biomass daily.

Hatchery-bred grouper juveniles accept dry artificial pellets as long as they are trained to feed on the pellets early in the nursery. Artificial feed (Table 7.9) is given to groupers cultured in offshore cages and in cages installed inside the pond at 4 to 6% of biomass daily.

Table 7.9 Practical diet formulas (g/kg dry diet) for grow-out culture of grouper

Ingredients	Grow-out diet	Grow-out diet
Chilean fish meal	80	200
Meat and bone meal, local	-	200
Meat and bone meal, imported	320	-
Blood meal	80	80
Shrimp meal	100	100
Soybean meal	60	60
Squid meal	10	10
Wheat flour	150	150
Rice bran	70	70
DHA-Selco		
Cod liver oil	60	60
Vitamin mix	40	40
Mineral mix	30	30
Vitamin-mineral mix	-	-
Butylated hydroxytoluene	-	-
Proximate composition (% DM):		
Crude protein	44.0	44.0
Crude fat	11.5	11.5
Crude fiber	1.8	1.8
NFE	25.8	25.8
Ash	16.9	16.9

Sources: Millamena et al. 2001

H. Mangrove red snapper

Mangrove red snapper *Lutjanus argentimaculatus* (Figure 7.23) is an important food fish in Southeast Asia and is popularly cultured in brackish water ponds and marine net cages. Snappers are opportunistic carnivores and feed mainly on fish and crustaceans.

Figure 7. 23
Mangrove red snapper *Lutjanus argentimaculatus.*

1. Breeding

Wild-caught or hatchery produced fry are sexually mature after 5 (males) and 6 years (females) in floating net-cages or in tanks. Broodstock are fed raw fish every other morning at 5% of body weight. They are sexually mature from April to October and they spawn naturally for up to four consecutive days.

2. Larval rearing

The feeding regime for the red snapper larvae consists of *Chlorella*, rotifers, *Artemia*, and minced fish flesh (Figure 7.24). Growth and survival of red snapper larvae are best when fed screened rotifers (<90 μm) during the first 14 days and *Artemia* nauplii (2 per ml) given four times a day starting on day 22. Day 21 to 35 larvae have similar survival with *Artemia* alone, artificial diet alone, or combination *Artemia* and artificial diet.

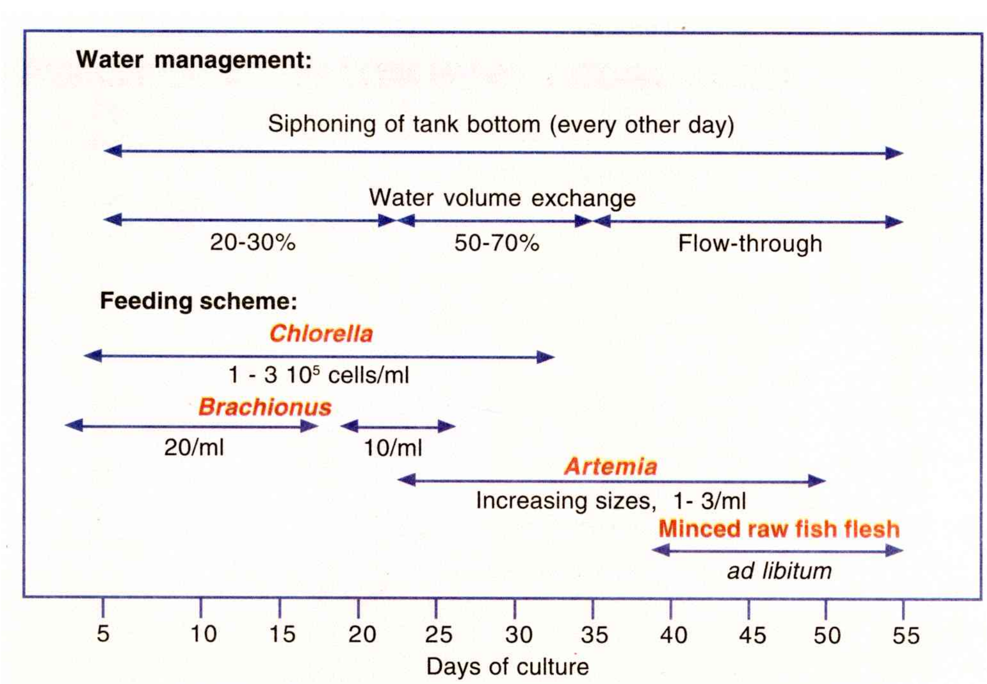

Figure 7.24
Feeding and water management during larval rearing of the mangrove red snapper.
Source: Duray et al. 1994

3. Grow-out culture

Snappers are usually fed raw fish in floating net-cages but they also respond well to artificial diet. In tests done in 250 l tanks the feed (Table 7.10) given twice a day at 0930 and 1600 h at 3.5 to 4.5% of body weight per day enhances growth and survival.

Table 7.10 Practical diet formula (g/kg dry diet) for red snapper

Ingredients	Amount[1]
Peruvian fish meal	430.0
Squid meal	80.0
Shrimp meal (*Acetes* sp.)	54.0
Defatted soybean meal	80.0
Bread flour	200.0
Rice bran	58.0
Cod liver oil	38.0
Soybean lecithin	5.0
Vitamin and Mineral mix	50.0
Ascorbyl monophosphate	0.2
Dicalphos	5.0
Proximate composition (% DM):	
Crude protein	44.0
Crude fat	10.0
Carbohydrate	26.5
Energy (MJ/kg diet)	18.9

Source: [1]Catacutan et al. 2001

I. Tiger shrimp

The tiger shrimp *Penaeus monodon* (Figure 7.25A,B) is the most widely cultured shrimp species and accounts for over one third of globally farmed shrimp. High-density production is supported by greater use of formulated feeds, where production may yield up to 10 tons/ha/year. Tiger shrimp culture has evolved from traditional extensive to semi-intensive and intensive systems using modern equipment and techniques. The aim is to produce significantly high yield per unit area while minimizing farm waste discharges to the environment.

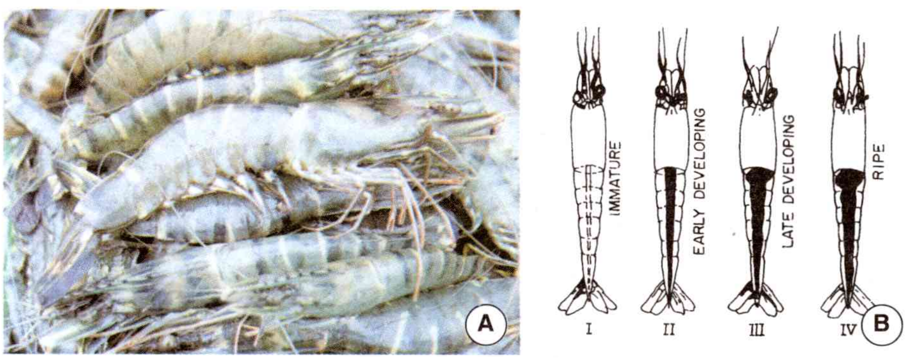

Figure 7. 25
Tiger shrimp *Penaeus monodon* (A), and stages of ovarian maturity (B).

1. Broodstock in tanks

Shrimp broodstock are fed on a variety of live, fresh, or fresh-frozen natural food, such as marine annelids, mussel meat, squid, clam meat, and other meat of mollusks and can be given alternately. These natural food items contain essential nutrients particularly n-3 HUFA that are needed for shrimp maturation (Figure 7.25B). Brown mussel meat and squid are chopped into small pieces. Marine worms are given to shrimps preferably alive. For convenience, they are bought in bulk, weighed, packed, frozen, and thawed as needed for feeding. An artificial diet has been formulated using the fatty acid and amino acid profiles of mature shrimp ovaries as guide. The diet is supplemented with fresh wet feeds in an attempt to ensure an optimal nutrient balance and a full range of essential nutrients. Reproductive performance of pond-reared shrimp broodstock is markedly improved when fed a combination diet of natural food and pellets. A mixture of various feedstuffs is better than a single item in the diet. Most of the females given natural food alone undergo ovarian regression and do not spawn.

The standard feeding regime for shrimp broodstock at SEAFDEC AQD consists of fresh food and pellets (Table 7.11) given alternately. Fresh or frozen natural foods (squid, mussel meat, or marine worms) are given daily at 0800 to 0900 h at 5 to 10% of biomass, and pellets at 1600 to 1700 h at 2 to 3% of biomass. Natural foods are broadcasted into the maturation tank while pellets are placed in feeding trays.

Table 7.11 Practical diet formulas (g/kg dry diet) for tiger shrimp at various stages of culture

Ingredient	Broodstock diet [1]	Larval diet [2]	Grow-out diet [3]
Squid meal	300.0	300.0	-
Shrimp meal	-	-	150.0
Shrimp head meal	200.0	350.0	-
Fish meal	200.0	-	250.0
Soybean meal	-	-	250.0
Bread flour	55.0	110.0	130.0
Rice bran	22.5	-	69.5
Seaweed (*Gracilaria*)	40.0	-	50.0
κ-carrageenan	-	5.0	-
Celufil	-	22.0	-
Cod liver oil	60.0	80.0	25.0
Soybean oil	-	-	25.0
Soybean lecithin	30.0	25.0	-
Cholesterol	5.0	10.0	-
Vitamin mix	27.0	60.0	20.0
β-carotene	-	2.5	-
Mineral mix	60.0	40.0	10.0
Dicalcium phosphate	-	-	20.0
Butylated hydroxytoluene / Ethoxyquin	0.5	0.5	0.5
Proximate composition (% DM):			
Crude protein	52.8	50.3	41.7
Crude fat	12.1	14.2	8.8
Crude fiber	3.8	20.4	5.9
Nitrogen-free extract	13.4	10.1	29.2
Ash	17.9	5.0	14.4

Sources: [1] Millamena et al. 1986; [2] Bautista et al. 1989; [3] Millamena and Triño 1994

2. Larvae in hatchery and nursery tanks

In the hatcheries, the food of shrimp protozoeal larvae up to postlarvae PL_5 consists mostly of planktonic microalgae (*Skeletonema, Tetraselmis, Chaetoceros*) and *Artemia* nauplii. At PL_6 onwards, postlarvae are gradually introduced to minced mussel meat, raw fish, and shrimp meal *Acetes* sp. or pellet crumbles.

Artificial diets that partially replace live food help alleviate the need for large tanks necessary for phytoplankton production. Shrimp larval diets are readily available and are easy to use. Many commercial microparticulate diets can partially replace the natural food requirements of shrimp larvae. At SEAFDEC AQD, a microbound diet (Table 7.11, Figure 7.26) is used to partially replace diatoms and *Artemia* as food for shrimp larvae. However, it needs to be more buoyant and should remain suspended in water longer to be more available to the larvae. Seawater is replaced at the rate of 30% per day from Z_2 to Z_3 stage and 50% per day during mysis and postlarval stages.

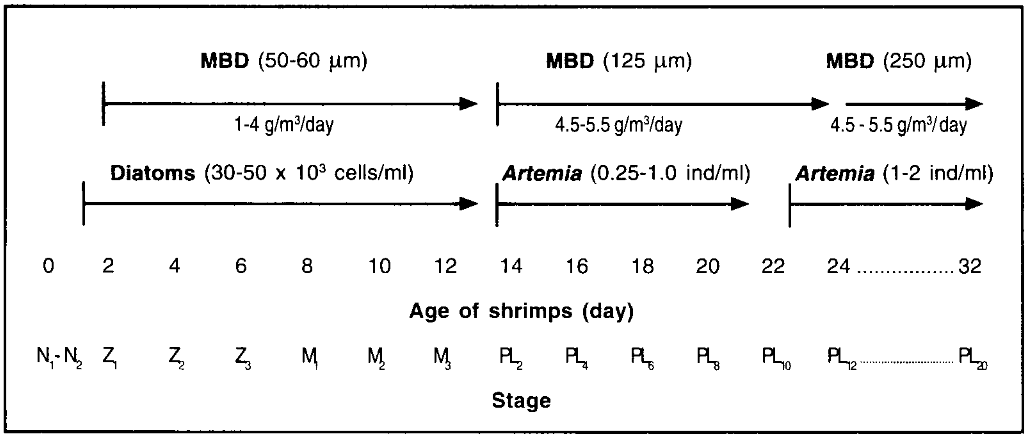

Figure 7.26
Feeding scheme for tiger shrimp larvae Z-zoea, M-mysis, PL-postlarvae at days 1 to 20.
Source: Bautista et al. 1991

3. Shrimps in grow-out ponds

Shrimp postlarvae are released directly into nursery ponds. Farmers propagate natural food organisms such as copepods in the ponds by applying organic (chicken manure) and/or inorganic (monoammonium phosphate 16-20-0, diammonium phosphate 18-46-0) fertilizers. In extensively managed ponds, shrimp feed mostly on detritus, animal remains, diatoms, cyanobacteria, and green algae. The most cost-effective way of producing shrimp is to grow natural food in the ponds and provide artificial feed when necessary. A suggested feeding formula fcr shrimp grow-out culture is shown in Table 7.11. At 50,000/ha, this formulated diet may be given starting 1-1.5 months after stocking depending on the amount of natural food in the pond. At 100,000/ha, this diet is given soon after the shrimps are stocked.

Early juvenile stages prefer to feed in the shallower water along the walls of the dike. As development proceeds through late juvenile into the adult stages, the shrimp feed freely on the benthos of the whole pond. Shrimp are slow bottom feeders and feed continuously and more actively at night. The ingested feed takes about four hours to leave the midgut. Daily feeding is usually done 4 to 5 times (0600, 1000, 1400, 1800, and 2200 h) with about 30% of the total feed given in the morning and 70% in the late afternoon and evening.

Metabolic rates of animals decrease with size. The feeding rate is not fixed, but is lowered as the shrimp grow. Dedicated management and appropriate feeding practices represent a major labor component but is crucial to the success of the culture. Feeding based on biomass alone without adjustment over time may result in underfeeding when shrimp are small, and overfeeding when they are larger.

The most efficient way to feed shrimp is "by demand" rather than by following a feeding table. Daily rate can be adjusted according to how much of the previous day's ration is consumed. Feeding trays are used to observe the size and health condition of shrimp as well as to monitor feeding activity to avoid overfeeding and underfeeding.

Figure 7. 27
A feeding tray for shrimp.

Trays measuring 1 x 1 m can be made from nylon screen and wood or bamboo strips and stone sinkers (Figure 7.27). Usually 1 to 3% of the daily ration allotted to the pond is spread between several feeding trays. Five to twenty feeding trays are usually distributed over one hectare, positioned not too near the dikes or the pond bottom. Feed is placed on trays to monitor feeding activity. Feeding trays should be installed immediately after stocking to permit observation of the condition and growth of the shrimp, and to detect the presence of any pests or predators. The feed allowance can be adjusted based on the amount of feed left on the trays after one to two hours. The next feeding ration is then adjusted accordingly based on the average amount of feed remaining on the trays.

At the end of the grow-out cycle, shrimps avoid very shallow areas during the day to avoid light and those areas where anaerobic sediments and sludge accumulate. Thus, feed is distributed only in deeper areas during daytime and none in areas where sludge deposits are high because shrimp will not consume it.

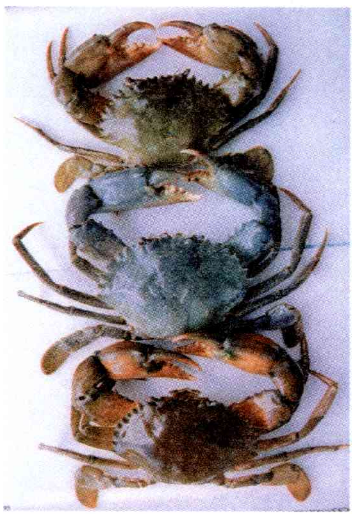

Figure 7.28
Mangrove crabs *Scylla* spp.

J. Mud Crabs

Various species of mud crabs occur throughout tropical to warm and temperate zones. They are highly valued and are important sources of income for fishers throughout the Asia-Pacific region. Extensive mud crab (*Scylla serrata, S. tranquebarica, S. olivacea*) (Figure 7.28) farming has been an on-going industry for many decades but the technology for broodstock, hatchery, nursery, and semi-intensive grow-out culture have been developed only recently.

1. Broodstock in tanks

Mud crabs are provided with flow-through aerated seawater in tanks. They are fed a combination of natural food consisting of mussel meat, raw fish, and formulated diet (Table 7.12). Feeding rate is 3 to 5% of biomass for natural food and 1 to 1.5% for formulated diet. Feed is given twice daily with formulated diet given in the morning at 0800 h, and natural food in the afternoon at 1700 h. Reproductive performance and larval quality are better with this combination diet than on either natural food or formulated diet alone.

2. Larval rearing and nursery

Spawned eggs hatch and are raised to zoea then to megalopa, the highest larval stage. Initially, zoea are fed *Brachionus* at 10 to 15 ind/ml are fed then *Artemia* nauplii are introduced at zoea$_3$ and are gradually increased from 1 to 5 ind/ml as the larvae develop to megalopa (Figure 7.29). As a supplement, a commercial larval diet for shrimp may be given at 1.5 to 2.0 g/m^3 water per day.

Megalopas are nursed until crab stage either in tanks or in net cages installed in ponds. In tanks, food consist of newly hatched Artemia at 3 to 5 ind/ml or adult Artemia, then to minced fish flesh, green mussel meat, or small shrimps given *ad libitum* twice a day as soon as the megalopa metamorphose to crab stage. In net cages

Table 7.12 Practical diet formulas (g/kg dry diet) for mud crab broodstock and grow-out

Ingredients	Broodstock diet [1]	Grow-out diet in pond [2]	Grow-out diet in tank [3]
Chilean fish meal	200	250	335
Shrimp meal (*Acetes* sp.)	-	-	75
Soybean meal, defatted	-	-	110
Shrimp head meal	200	-	-
Brown mussel meat	-	250	-
Squid meal	200	-	65
Wheat flour	170	170	118
Seaweed (*Gracilaria* sp.)	40	50	50
Rice bran	-	125	-
Corn bran	-	100	-
Cellufil -	-	-	162
Carboxy methyl cellulose	-	-	25
Cod liver oil	50	25	14
Soybean oil	-	25	-
Lecithin	30		5
Cholesterol	10	-	1
Vitamin mix	30	-	15
Mineral mix	40	-	5
Dicalcium phosphate	30	-	20
Ethoxyquin	-	5	-
Proximate composition (% DM):			
Crude protein	46.0	40.1	43.3
Crude fat	11.6	11.9	4.7
Crude fiber	4.2	1.4	12.0
Nitrogen-free extract	23.2	38.0	27.1
Ash	15.0	8.6	12.9

Sources: [1] Millamena and Quinitio 2000; [2] Triño and Millamena 2001; [3] Catacutan and Teshima 2001

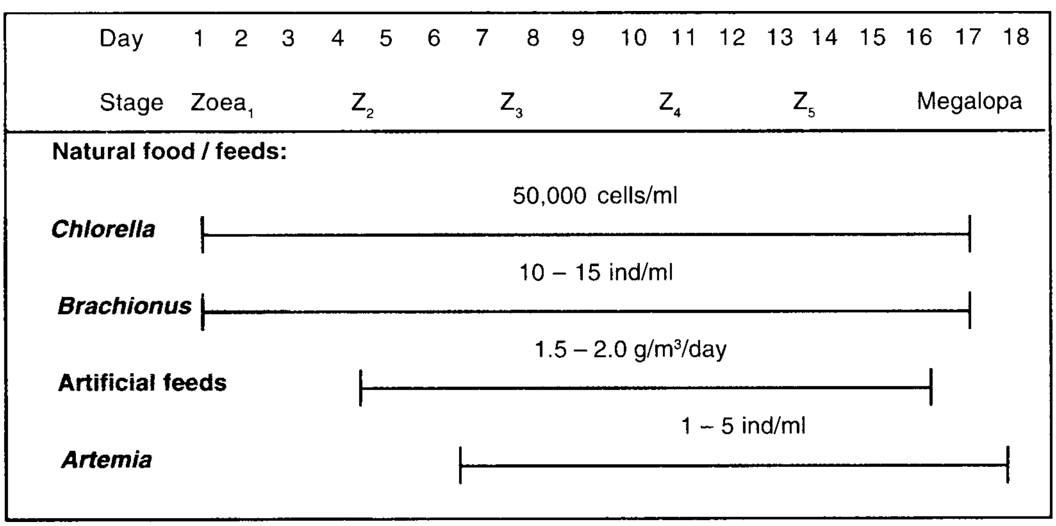

Figure 7.29
Feeding scheme used in the culture of mud crab larvae.
Source: Quinitio et al. 2001

installed in brackish water nursery ponds, crab megalopas are fed macerated brown mussel meat or fish flesh at 30 to 20% of biomass per day. Feed ration is given at 0800, 1300, and 1700 h daily. Stocking 30 megalopas/m^2 in net cages is feasible.

3. Pond culture

Culture of either male, female, or both sexes of mud crab in earthen ponds (Figure 7.30) or in pens installed in tidal flats with reforested mangrove are economically viable. Stocking density of 1/m^2 gives high survival. Raw fish and fresh brown mussel meat are used as feed. Crabs are fed at 10% of their biomass daily when carapace length (CL) is <6 cm and 5% when CL is ≥ 6 cm. The daily feed ration is broadcasted over areas in between mangrove trees of each pen, 40% at 0700 h and 60% at 1700 h. Feed ration is determined by placing 1% of the scheduled feeding ration on feeding trays. When feed on the tray is consumed after four hours, the ration for the next feeding is increased by 5%. Feeding rate is reduced by 5% when 0.5% or more of the feed is left uneaten on the tray while no feed adjustment is made if less than 0.5% feed remains on the trays. Dry artificial diet can also be used as grow-out feed for mud crabs (Table 7.12). This diet is given at 5% of biomass daily when CL is <6 cm and 2% when CL is >6 cm. The daily feed ration is given at 0730 and 1700 h.

Mud crab can also be fed *Acetes*, green filamentous algae, animal hides and entrails, and snails. Crabs are fed at 10% then 6% of body weight as culture progresses. Daily feed allowance is placed on a feeding tray or broadcast twice a day, half of the feed in the morning, half in the afternoon.

A mud crab artificial diet (Table 7.12) has been developed in the laboratory. It is presently used as maintenance feed for mud crab under indoor conditions.

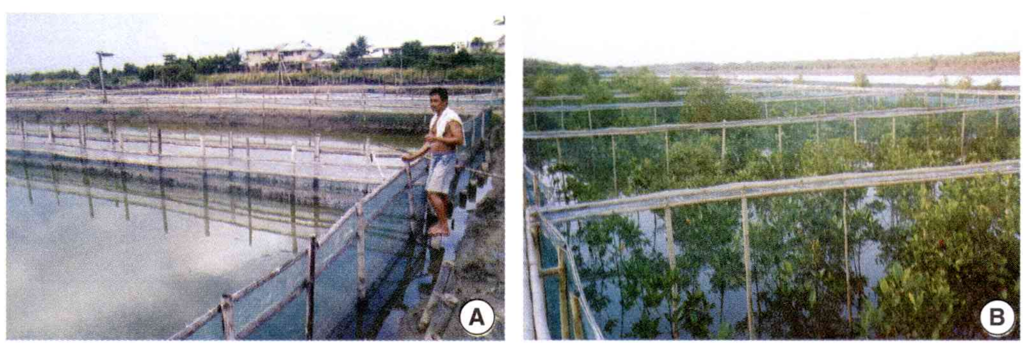

Figure 7.30
Grow-out culture in pond (A) and in pens installed in reforested mangroves (B).

Other species for aquaculture stock enhancement

A. Donkey's ear abalone

Donkey's ear abalone (*Haliotis asinina*) (Figure 7.31A) is a gastropod mollusk that live around algal stands in rocky and shallow sea waters. Abalones are popular in specialty restaurants in the Philippines and other Southeast Asian countries but their declining yield from the wild necessitates intensive aquaculture. Research at SEAFDEC AQD aims to develop seed production and culture techniques in order to produce seed for stock enhancement in the wild. Abalones are herbivores and feed mainly on seaweeds. Among the three naturally occurring abalone species in the Philippines, donkey's ear abalone grows to a maximum size of 100 to 110 mm in shell length (SL).

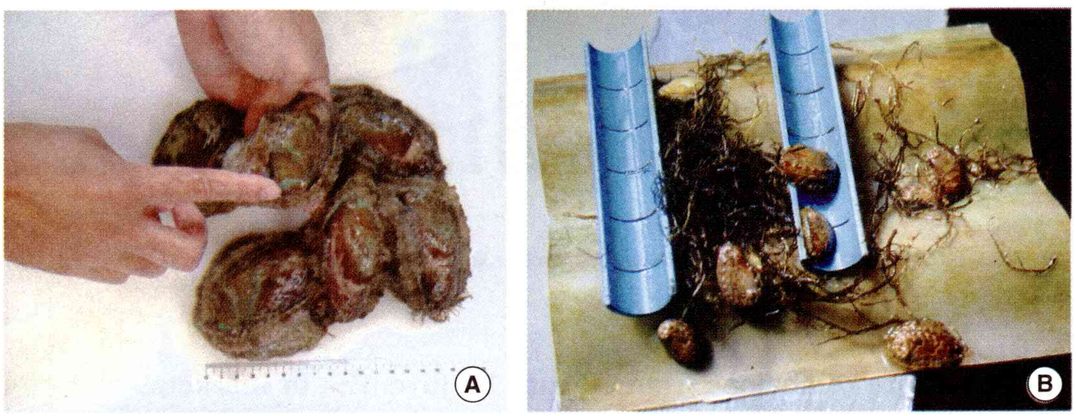

Figure 7.31
Donkey's ear abalone *Haliotis asinina* (A), feeding on red alga (B).

1. Breeding

Abalone breeders are kept in perforated plastic baskets and fed the red alga, *Gracilariopsis* (Figure 7.31B), to satiation replenished at weekly intervals. Captive abalone attains sexual maturity within 6 to 8 months of culture at shell size range of 35 to 40 mm. Artificial diet (Table 7.13) in combination with *Gracilariopsis* improves fertilization rate and spontaneous fecundity in abalones. Abalones are fed 2 to 5% of their body weight per day using the dry diet while the red alga is given *ad libitum*. The dry ration is given once at 1600 h.

Table 7.13 Practical diet formula (g/kg dry diet) for abalone broodstock

Ingredients	Amount
Fish meal	100.0
Shrimp meal	150.0
Defatted soybean meal	200.0
Rice bran	149.5
Wheat flour	200.0
Seaweed	70.0
Cod liver oil	15.0
Soybean oil	15.0
Vitamin mix	30.0
Mineral mix	40.0
Dicalcium phosphate	30.0
BHT	0.5
Proximate composition (% DM):	
Crude protein	27.9
Crude fat	5.8
Carbohydrate	40.4

Source: [1]Bautista-Teruel and Millamena 1999

2. Postlarval settlement and nursery rearing

Settlement tanks are prepared one week before stocking to allow the growth of epiphytic diatoms on the plate substrates (Figure 7.32A, B). Veliger larvae and early juveniles feed on epiphytic diatoms such as *Navicula* and *Nitzschia*, then gradually shift to red alga *Gracilariopsis* when they reach >5 mm SL.

Feeding larvae a commercial feed or the SEAFDEC formulated diet (Table 7.13) is feasible. These feeds are given at 3 to 5% of the body weight twice daily.

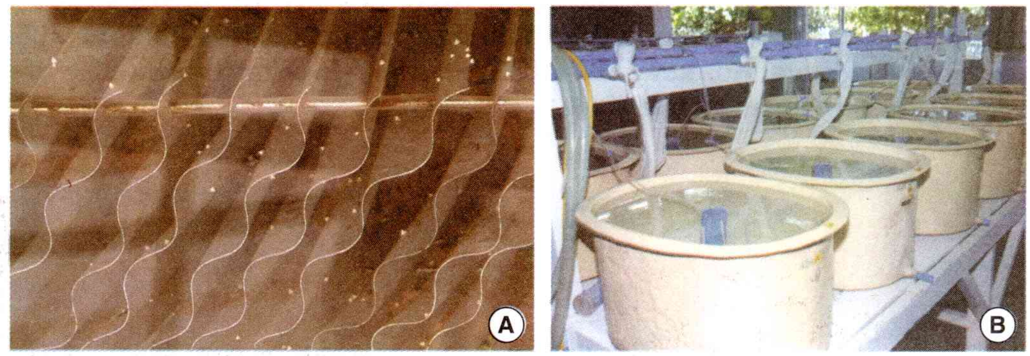

Figure 7.32
Plate substrates (A) for epiphytic diatoms, live food for larvae installed in tanks (B).

3. Grow-out

Culture of abalone from 30 mm SL juveniles to marketable size of 55 to 60 mm is carried out in flow-through tanks and in sea cages for 8 to 10 months. Abalones are fed fresh seaweeds to satiation given at weekly intervals.

In cages, feeding rates as well as growth and survival are higher at lower stocking densities (17 to 35 per cage). The rapidly growing small juveniles (16-20 mm) feed at 35 to 40% of body weight while the bigger abalones (> 50 mm) feed less, only 5 to 10% of body weight.

B. Seahorses

Live seahorses (Figure 7.33A) are traded on the aquarium fish market while the dried ones are highly valued in traditional Chinese medicine. Seahorses came near to extinction due to destruction of their natural habitat and overexploitation. At SEAFDEC AQD, breeding and seed production techniques are being undertaken on *Hippocampus kuda* and *H. barbouri* ultimately for stock enhancement in the wild.

Live food organisms are used as food for seahorses to breed and produce seeds in tanks (Figure 7.33B). The combination diet of HUFA-enriched *Artemia* adults, mysids, or tilapia fry promotes frequent parturition events and great brood size per female in tanks. *Artemia*, mysids, and tilapia fry are given at 15, 6, and 5% of the body weight per day, respectively. A combination diet of rotifers and copepods enhances survival of *H. kuda* larvae.

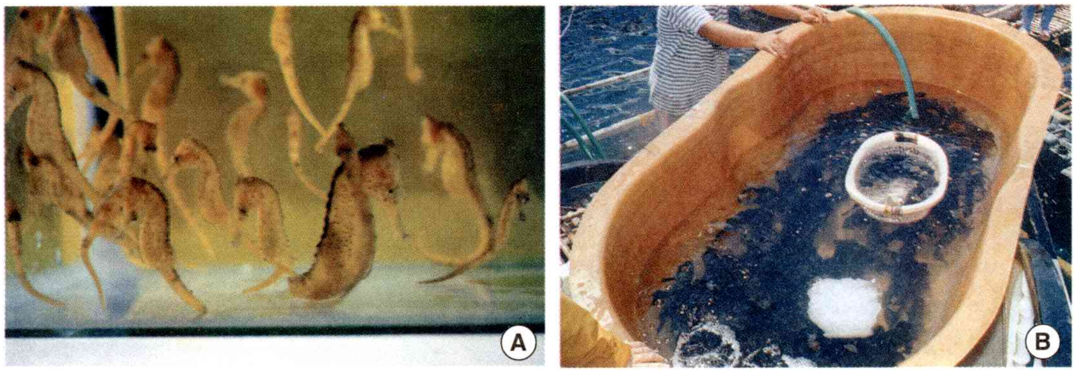

Figure 7.33
Seahorses (A) and a rearing tank (B).

C. Window-pane oyster

Window-pane oyster or *kapis* shell (*Placuna placenta*) (Figure 7.34A) is a bivalve mollusk that is commercially and economically important in the Philippines. Their translucent shells are used as raw materials for the fabrication of beautiful handicrafts like window sills, wall panels, lamp shades, and chandeliers (Figure 7.34B,C). With very high world market demand for these products, they become overexploited and their natural population is nearly decimated. Artificial propagation is carried out at SEAFDEC AQD in order to reseed and enhance the declining natural population in the wild, thus rehabilitating the *kapis* industry.

Figure 7.34
Window-pane oyster (A), and handicrafts using kapis shells (B,C).

1. Broodstock and seed production in tanks

Broodstock fed daily with *Isochrysis* and *Tetraselmis* at 3:1 ratio at 200,000 cells/ml promotes rapid gonad development. Sexual maturity is reached after 4 months, and then induced spawning is done to produce viable gametes. The larvae are reared in fiberglass tanks at a density of 900 larvae per liter. Larvae grow and survive best with *Isochrysis* as food at initial concentration of 10,000 cells/ml, and are progressively increased to 30,000 cells/ml as the larvae grow. Settling is reached after 14 days.

2. Stock enhancement

Kapis shells are filter-feeders and their food consist of plankton, detritus and other suspended materials in the estuary. The natural beds of *kapis* shells are the bluish-soft mud or slightly sandy-muddy substrates in areas with high primary productivity. To rehabilitate the natural beds of *kapis* shell at Tigbauan, Iloilo coastline (Figure 7.35A,B), immature broodstock (72 mm SL, 14.5 g body wt) are stocked at 75 ind/m^2. The broodstock feed on the available natural food in the estuary. Two months after reseeding, they spawn naturally.

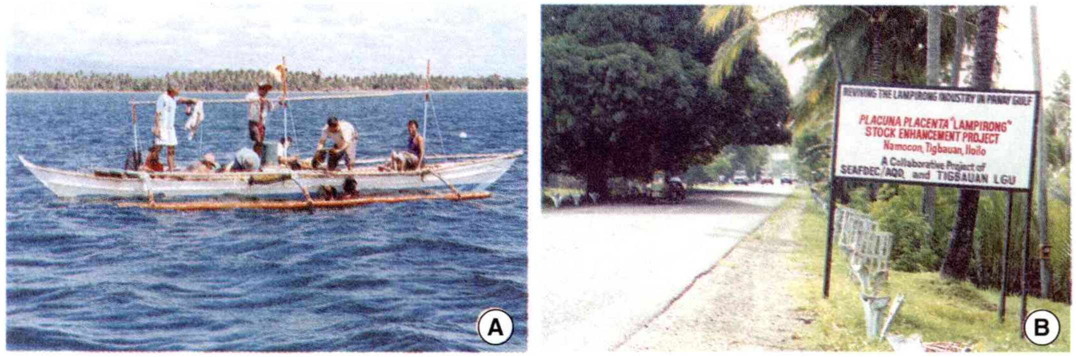

Figure 7.35
Rehabilitation of Iloilo coastline (A,B).

Summary

The objective of feed management is to make available to the animals the most cost-effective, formulated feed in the proper amounts and at the right times and locations. Feeding practices must be continually modified and adapted to account for changes in feeding activity and preferences as the animals grow and as environmental conditions change. Feed management practices are specifically adapted to species, culture system, and area in order to increase production efficiency and minimize environmental impact.

The farmer wants the cultured aquatic animal to grow maximally with a minimum amount of feed waste. Thus, one should have a good knowledge of how much the fish should be fed and then monitor their feeding activity carefully. Feed consumption can vary by species, size/age of animals, intensity level of culture, water temperature, dissolved oxygen, feed attractability and water stability, frequency and times of feeding, and other factors. Feeding rations are based on feed consumption from feeding trays, or survival estimates, average size, and feeding tables developed by the farmer himself using data from several culture cycles. Many biotic and abiotic factors are used to adjust feed quantity, and these criteria include low DO, extreme water temperatures, excessive plankton blooms, feed consumption, molting/lunar cycle, animal size and weather.

How often to apply feed is an important decision the culturist has to evaluate and determine based on experience, season, changing environmental conditions, species, age and size, stocking densities, production system used, stress, available resources, and other considerations. Constant feeding of newly hatched larvae is important for good survival. Particle size should be increased in close relation with growth.

Hand feeding is commonly used and has the advantage of close observation of the fish. There is then an assurance of feeding to maximum effectiveness and minimum waste since the fish culturist is more aware of the conditions and problems if they develop. Automatic and demand feeders have advantages in that they can be labor-saving and can allow fish to be fed many times throughout the day. Automatic feeders can be used as a useful alternative to manual broadcasting, but should not replace regular observation and visual assessment by trained personnel.

Considering the diversity of species and production systems, best management practices, particularly those on feeding management, are important steps towards assuring that aquaculture will grow in a responsible manner and can be sustained.

Guide Questions

1. Compare the different feeding strategies in pond culture.
2. Why is supplementary feeding considered as the most cost-effective feeding strategy?
3. Discuss the importance of sampling and record keeping, adjustments of feeding rations and use of appropriate feed size to optimize the use of feeds.
4. How are feed rations and total feed requirement determined?
5. What are the significant contributing factors in the choice of feeding methods?
6. What are the advantages and disadvantages involved in manual vs. mechanical feed application methods?
7. Why does the high value for FCR indicate poor feed conversion efficiency?
8. What are the main waste products associated with feeding and how are they minimized?
9. What feed nutrients are agents of "eutrophication" in receiving waters for fish farm effluents? Discuss their harmful consequences in the environments.
10. How do we determine the appropriate time and frequency of feeding for fish and crustaceans?
11. Discuss the factors that influence feed consumption of aquatic animals.
12. What are the do's and dont's in feeding management?

Suggested Readings

Alava VR, Lim C. 1988. Artificial diets for milkfish *Chanos chanos* (Forsskal) fry reared in seawater. Aquaculture 71:339-346.

Bautista MN, Millamena OM, Kanazawa A. 1989. Use of k-carrageenan microbound diet (c-MBD) as feed for *Penaeus monodon* larvae. Mar. Biol. 102:169-174.

Bautista-Teruel MN, Millamena OM. 1999. Diet development and evaluation for juvenile abalone, *Haliotis asinina*: protein/energy levels. Aquaculture 178:117-126.

Bombeo RF, Fermin AC, Tan-Fermin JD. 2002. Nursery rearing of the Asian catfish, *Clarias macrocephalus* (Gunther), at different stocking densities in cages suspended in tanks and ponds. (Aquaculture in press).

Borlongan IG, Marte CL, Nocillado JN. 2000. Development of larval diets for milkfish *(Chanos chanos)*. J. Appl. Ichthyol. 14:68-72.

Catacutan MR, Coloso RM. 1995. Effect of dietary protein to energy ratios on growth, survival, and body composition of juvenile Asian sea bass, *Lates calcarifer*. Aquaculture 131:125-133.

Catacutan MR, Pagador GE, Teshima SI. 2001. Effect of dietary protein and lipid levels and protein to energy ratios on growth, survival and body composition of the mangrove red snapper *Lutjanus argentimaculatus* (Forsskal 1775). Aquac. Res. 32:811-818.

Capinpin EC Jr, Toledo JD, Encena VC II, Doi M. 1999. Density dependent growth of the tropical abalone *Haliotis asinina* in cage culture. Aquaculture 171:227-235.

Chiu YN. 1988. Water quality management for intensive prawn ponds. In: Chiu YN, Santos LM, Juliano RO (eds). Technical considerations for the management and operation of intensive prawn farms. UP Aquaculture Society, Iloilo City, Philippines. p 102-129.

Coniza EB, Catacutan MR, Tan-Fermin JD. 2001. Pen culture of Asian catfish *Clarias macrocephalus* juveniles fed four different diets in the Philippines. Paper presented at the 6th Asian Fisheries Forum, Asian Fisheries Society, 25-30 November 2001, Kaoshiung, Taiwan.

Duray MN. 1998. Biology and Culture of Siganids. SEAFDEC Aquaculture Department, Tigbauan, Iloilo, Philippines. 54 p.

Duray MN, Estudillo CB, Alpasan LG. 1997. Larval rearing of the grouper *Epinephelus suillus* under laboratory conditions. Aquaculture 150:63-76.

Duray MN, Alpasan LG, Estudillo CB. 1996. Improved hatchery rearing of mangrove red snapper, *Lutjanus argentimaculatus*, in large tanks with small rotifer (*Brachionus plicatilis*) and *Artemia*. The Isr. J. Aquacult.- Bamidgeh 48:123-132.

Duray MN, Kohno H, Pascual FP. 1994. The effect of lipid-enriched broodstock diets on spawning and on egg and larval quality of hatchery-bred rabbitfish (*Siganus guttatus*). The Philippine Scientist 31:42-57.

Emata AC. 1996. Maturation and induced spawning of the mangrove red snapper, *Lutjanus argentimaculatus* reared in a floating net cage in the Philippines. In: Arrenguin-Sanchez F, Munro JL, Balgos MC, Pauly D (eds). Biology, fisheries and culture of tropical groupers and snappers. ICLARM Conference Proceedings No. 48. p 378-384.

Emata AC, Borlongan IG, Damaso JP. 2000. Dietary vitamin C and E supplementation and reproduction of milkfish *Chanos chanos* Forsskal. Aquac. Res. 31:557-564.

Emata AC, Damaso JP, Eullaran BE. 1999. Growth, maturity and induced spawning of mangrove red snapper, *Lutjanus argentimaculatus*, broodstock reared in concrete tanks. Isr. J. Aquacult.-Bamidgeh, 51:58-64.

Fermin AC. 1991. Freshwater cladoceran *Moina macrocopa* (Strauss) as an alternative live food for rearing sea bass *Lates calcarifer* (Bloch) fry. J. Appl. Ichthyol. 7:8-14.

Fermin AC, Bolivar MEC. 1991. Larval rearing of the Philippine freshwater catfish, *Clarias macrocephalus* (Gunther), fed live zooplankton and artificial diet: a preliminary study. Isr. J. Aquacult.-Bamidgeh 43:87-94.

Fermin AC, Bolivar MEC.1994. Feeding live or frozen *Moina macrocopa* (Strauss) to Asian sea bass, *Lates calcarifer* (Bloch), larvae. Isr. J. Aquacult.-Bamidgeh 46:132-139.

Fermin AC, Bolivar MEC.1996. Weaning of the Asian catfish, *Clarias macrocephalus* Gunther, larva to formulated dry diet. In: Santiago CB, Coloso RM, Millamena OM, Borlongan IG (eds). Feeds for Small-scale Aquaculture. Proceedings of the National Seminar-Workshop on Fish Nutrition and Feeds. SEAFDEC Aquaculture Department, Tigbauan, Iloilo, Philippines. p 83-86.

Fermin AC, Bolivar MEC, Balad-on SBM, Vargas JB. 1995. Improved hatchery rearing techniques for the Asian catfish, *Clarias macrocephalus*. In: Lavens P, Jaspers E, Roelants I (eds). Larvi '95 Fish and Shellfish Larviculture Symposium. European Aquaculture Society, Gent, Belgium. Special Publication No. 24. p 394-397.

Fermin AC, RSJ Gapasin, MB Teruel. 2000. Spontaneous spawning, fecundity and spawning periodicity in the donkey's ear abalone *Haliotis asinina* Linnaeus 1758. Phuket Marine Biological Center Special Publications 21:195-201.

Fermin AC, Recometa RD. 1988. Larval rearing of bighead carp, *Aristichthys nobilis* Richardson, using different types of feed and their combinations. Aquacult. Fish. Management 19:283-290.

Golez NV. 2000. Effect of some environmental factors on the growth and survival of *Penaeus monodon*. In: 4th International Symposium on Sediment Quality Assessment. Approaches, Insights and Technology for the 21st Century. Abstracts. October 24-27, 2000. Otsu, Japan. p 37-41.

Hara S, Duray MN, Parazo M, Taki Y. 1986. Year-round spawning and seed production of the rabbitfish *Siganus guttatus*. Aquaculture, 59:259-272.

Hilomen-Garcia G. 1999. AQD's marine ornamental fish project, In: Castanos MT (ed). SEAFDEC Asian Aquaculture 21 (2), SEAFDEC Aquaculture Department, Iloilo, Philippines. p 31.

Madrones-Ladja JA, de la Pena MR. 2000. Hatchery management for the window-pane shell, *Placuna placenta* Linnaeus, 1758. Phuket Marine Biological Center Special Publication 21:189-194.

Madrones-Ladja JA, de la Pena MR, Parami NP. 2002. The effect of micro algal diet and rearing condition on gonad maturity, fecundity and embryonic development of the window-pane shell, *Placuna placenta* Linnaeus. Aquaculture, 206:313-321.

Millamena OM, Primavera JH, Pudadera RA, Caballero RV. 1986. The effect of diet on reproductive performance of pond-reared *Penaeus monodon* Fabricius broodstock. In: Maclean JL, Dizon LB, Hosillos LV (eds). The First Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines. p 59-596.

Millamena OM. 2002. Replacement of fish meal by animal by-product meals in a practical diet for grow-out culture of grouper, *Epinephelus coioides*. Aquaculture 204:75-84.

Millamena GM, Trino AT. 1994. Evaluation of fish protein concentrate and lactic yeast as potential protein sources for shrimp feeds. In: Chou LM, Munro AD, Lam TJ, Chen TW, Cheong LKK, Ding JK, Hooi KK, Khoo HW, Phang VPE, Shim KF, Tan CH (eds). The Third Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines. p 676-677.

Millamena OM, Quinitio ET. 2000. The effects of diets on reproductive performance on eyestalk ablated and intact mud crab *Scylla serrata*. Aquaculture 181:81-90.

Motoh H. 1980. Field guide for the edible Crustacea of the Philippines. SEAFDEC AQD. Iloilo, Philippines. p. 27.

Parazo MM. 1991. An artificial diet for larval rabbitfish, *Siganus guttatus* Bloch. In: De Silva SS (ed). Fish nutrition research in Asia. Proceedings of the Fourth Asian Fish Nutrition Workshop. Asian Fisheries Society Special Publication 5. Asian Fisheries Society, Manila, Philippines. p 43-48.

Parazo MM, Garcia LMaB, Ayson FG, Fermin AC, Almendras JME, Reyes DM Jr, Avila EM, Toledo JD. 1998. Sea bass hatchery operations. SEAFDEC Aquaculture Department, Extension Manual No. 18. 42 p.

Quinitio ET, Parado-Estepa FD, Millamena OM, Rodriguez E, Borlongan E. 2001. Seed production of mud crab *Scylla serrata* juveniles. Asian Fish. Sci. 14:161-174.

Quinitio ET, Estepa FP, Alava VR. 1999. Development of hatchery techniques for the mud crab *Scylla serrata*: 1. Comparison of feeding schemes. In: Keenan CP, Blackshaw A (eds). Mud Crab Aquaculture and Biology. Proceedings of an International Scientific Forum held in Darwin, Australia. ACIAR Proceedings No. 8. p 125-130.

Rodriguez EM, Quinitio ET, Parado-Estepa FD, Millamena OM. 2001. Culture of *Scylla serrata* megalopae in brackishwater ponds. Asian Fish. Sci. 14:89-93.

Santiago CB, Aldaba MB, Abuan E, Laron MA. 1985. Effects of artificial diets on fry production and growth of *Oreochromis niloticus* breeders. Aquaculture 47:193-203.

Santiago CB, Aldaba MB, Laron MA. 1983. Effect of varying dietary crude protein levels on spawning frequency and growth of *Sarotherodon niloticus* breeders. Fisheries Research Journal of the Philippines 8:9-18.

Santiago CB, Aldaba MB, Reyes OS. 1987. Influence of feeding rate and diet form on the growth and survival of Nile Tilapia *(Oreochromis niloticus)* fry. Aquaculture 64:277-282.

Santiago CB, Banes-Aldaba M, Songalia ET. 1983. Effect of artificial diets on growth and survival of milkfish fry in fresh water. Aquaculture 34:247-252.

Santiago CB, Camacho As, Laron MA. 1991. Growth and reproductive performance of bighead carp (*Aristichthys nobilis*) reared with or without feeding in floating cages. Aquaculture 96:109-117.

Santiago CB, Gonzal AC. 1997. Growth and reproductive performance of the Asian catfish *Clarias macrocephalus* (Gunther) fed artificial diets. J. Appl. Ichthyol. 13:37-40.

Santiago CB, Gonzal AC. 2000. Effect of prepared diet and vitamins A, E and C supplementation on the reproductive performance of cage-reared bighead carp *Aristichthys nobilis* (Richardson). J. Appl. Ichthyol. 16:8-13.

Santiago CB, Reyes OS. 1993. Effects of dietary lipid source on reproductive performance and tissue lipid levels of Nile tilapia *Oreochromis niloticus* (L.) broodstock. J. Appl. Ichthyol 9:33-41.

Santiago CB, Reyes OS, Aldaba MB, Laron MA. 1986. An evaluation of formulated diets for Nile tilapia fingerlings. Fisheries Research Journal of the Philippines 11:5-12.

Sumagaysay NS. 1998. Milkfish *(Chanos chanos)* production and water quality in brackishwater ponds at different feeding levels and frequencies. Journal of Applied Ichthyology 14:81-85.

Sumagaysay NS, Borlongan 1G. 1994. Growth and production of milkfish *(Chanos chanos)* in brackishwater ponds: effects of dietary protein and feeding levels. Aquaculture 132:273-283.

Tacon A. 1993. Feed formulation and on-farm feed management, 61-74. In: New MB, Tacon A, Csavas I (eds). Farm-made aquafeeds. Proceedings of the FAO/AADCP Regional Expert Consultation on Farm-made Aquafeeds, 14-18 December 1992, Bangkok, Thailand. FAO-RAPA/AADCP, Bangkok, Thailand, 434 p.

Tacon A. 1998. The nutrition and feeding of farmed fish and shrimp. A training manual. 3. Feeding methods, FAG Field Document, Project GCP/RLA/075/ITA. Field Document 7/E, FAQ, Brasilia, Brazil, 208 p.

Triño AT, Millamena OM, Keenan C. 1999. Commercial evaluation of monosex pond culture of the mud crab *Scylla* species at three stocking densities in the Philippines. Aquaculture 174:109-118.

Triño AT, Millamena OM, Keenan C. 2001. Pond culture of mud crab *Scylla serrata* (Forskal) fed formulated diet with or without vitamin and mineral supplements. Asian Fish. Sci. 14:191-200.

Triño AT, Rodriguez, EM. 2002. Pen culture of mud crab *Scylla serrata* in tidal flats reforested with mangrove trees. Aquaculture in press.