Feed management of major carps in India, with special reference to practices adopted in Tamil Nadu

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ABSTRACT

In India, major carps, namely catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus cirrhosus*) dominate aquaculture production. Although Chinese carps such as common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*) and silver carp (*Hypothalmichthys molitrix*) are cultured, their popularity in the market remains low. In some of the emerging commercial culture systems Chinese carps are almost excluded due to marketing and other management constraints. Due to the non-availability of compounded feeds, the majority of farmers in most parts of the country continue to depend on a conventional mixture of rice bran and oil cake as the common supplementary feed. Application of manures and inorganic fertilizers to produce natural food is widely used, even when compounded feeds are employed. With the increased commercialization of carp farming and greater market focus, demonstration of the commercial viability of the use of pelleted feeds is undertaken by feed companies. With a number of innovations made by farmers in evolving suitable culture practices and feeding methods, pelleted feeds are gaining acceptance in some parts of the country. However, although carp farmers desire to use compounded pelleted feeds, due to the highly dispersed nature of carp farms they are confronted with problems in obtaining feeds in small quantities. Faced also with difficulties in obtaining compounded feeds at an affordable cost, farmers have no option but to continue to use rice bran as the major feed input along with oil cakes, even in states like Andhra Pradesh where carp culture is well organized. In Punjab, where a feed manufacturing factory is located, a competitive pricing policy exists; an effective marketing strategy has been adopted by the company and a high percentage of farmers have switched to the use of pelleted feed. In Tamil Nadu, another state where carp farming has gained popularity, particularly in areas such as Thanjavur District where water is not a major constraint, farmers have begun to realize the benefits of feeding floating pellets. However, availability and delivery to farmers are major constraints hindering the expansion of pellet feed-based carp culture

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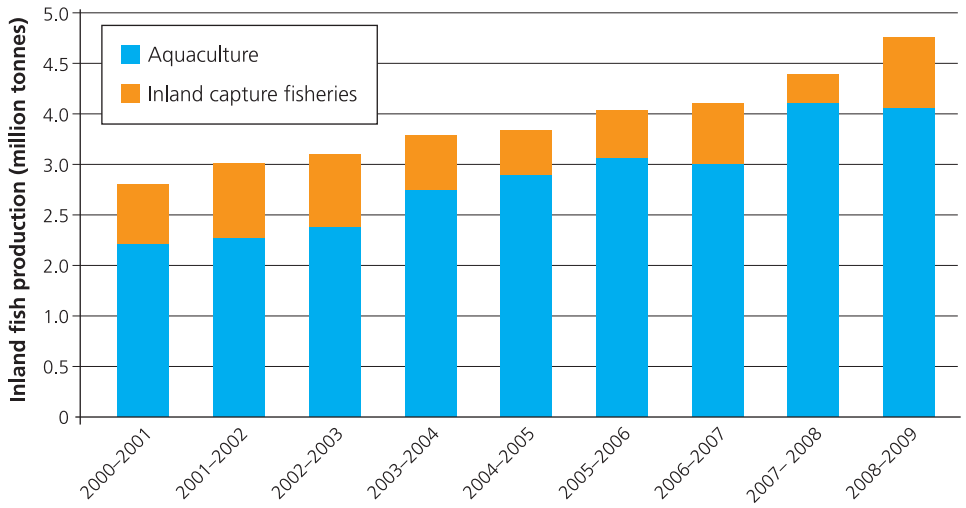
in the state. In this review, an attempt is made to present the general feeding strategies adopted in different parts of India, with a specific case study drawn from the State of Tamil Nadu where farmers have demonstrated the benefits of using floating pellets. The review also covers the current status of feed ingredient availability, the feed manufacturing industries and the strategies that need to be evolved to promote compound feed-based carp culture. A major part of the information used in the preparation of this paper was gathered *via* a country-wide survey on the feeds and feeding practices used in the culture of Indian major carps.

1. AQUACULTURE IN INDIA: CURRENT STATUS AND FUTURE PROJECTIONS

India's freshwater resources consist of rivers and canals (197 024 km), reservoirs (3.15 million ha), ponds and tanks (2.35 million ha), and oxbow lakes and derelict (i.e. ruined and unusable natural waterbodies) waters (1.3 million ha). Carp culture has been promoted in many of these waterbodies for the past four decades. The average fish production from the ponds has been expanded to about 2.5 tonnes/ha/year in several states from an early production level of ~0.5 tonnes/ha/year. However, research results and the accomplishments of progressive farmers indicate the possibility of obtaining ~10 tonnes/ha/year; thus there is good potential to increase present on-farm production levels. To achieve these, feed is recognized as the most important input. As seen in Figure 1, most of the current inland fish production is contributed by the aquaculture sector. By 2007, nearly 50 percent of total national fish production was being contributed by aquaculture (Figure 2), a fact that demonstrates the evolving importance of aquaculture in the current situation of declining capture fishery resources.

FIGURE 1
Inland fish production (million tonnes) in India, 2000–2001 to 2008–2009

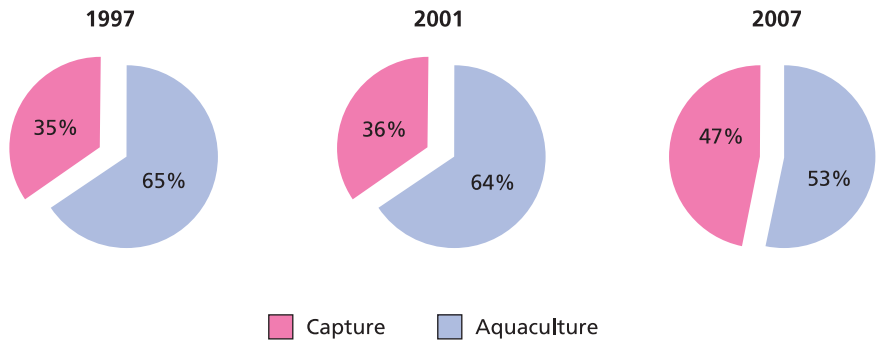


Source: Anon. (2006); data for 2007–2009 courtesy of Paul Pandian, Deputy Commissioner of Fisheries, Planning Commission, Government of India.

In 2006 the combined aquaculture and capture fisheries sectors contributed 1.2 percent to the national gross domestic product (GDP) and 5.3 percent to the national agricultural GDP (FAO, 2008). With a total fish production of 7.13 million tonnes in 2008, the country has become the third largest fish producer in the world.

As mariculture in India is still in its infancy, freshwater aquaculture has been identified as the principal area to cater to the increasing domestic demand for fish. When the entire population of the country is considered, the per capita availability of fish is

FIGURE 2
Changes in the contribution from capture fisheries and aquaculture, 1997–2007



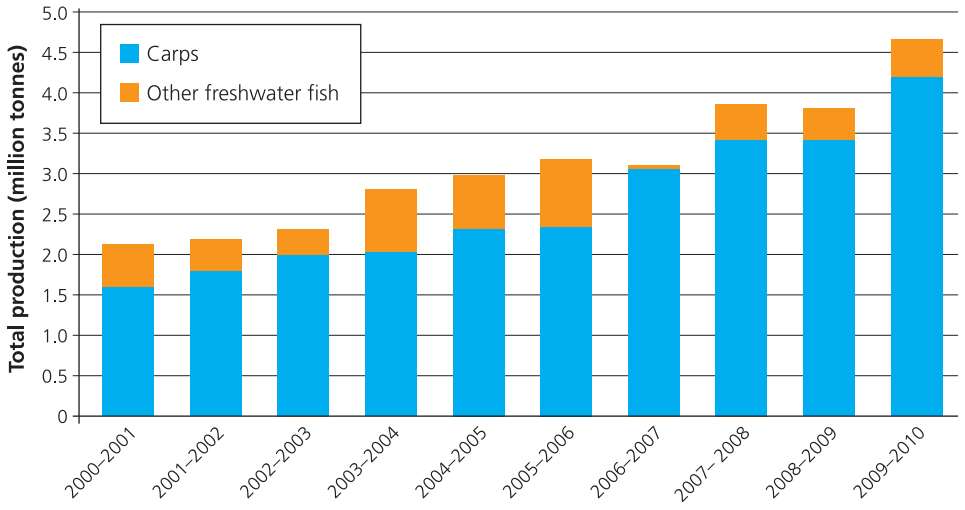
Source: Anon. (2006); FAO (2008).

reported to be only 4 kg. However, as about 65% of the population does not eat fish (due to religious and cultural reasons), it might be assumed that per capita fish availability is more than 11 kg; however the annual per capita fish consumption is only 9.8 kg, which is much lower than the World Health Organization (WHO) recommendation of 13 kg (MFS, 2011). It is projected that the national annual fish requirement will be around 10 and 13 million tonnes by 2012 and 2020, respectively (Eknath, Das and Jena, 2009). With the declining contribution from capture fisheries, much of the production will have to come from aquaculture to fill the deficit. To cope with the increasing demand, it has been projected (Eknath, Das and Jena, 2009) that Indian aquaculture will have to demonstrate an average annual growth rate of over 8 percent in the next five years. An increasing awareness of the health benefits of eating fish will also lead to greater demand.

2. CARP CULTURE IN INDIA

In India, carps are dominant in freshwater aquaculture, and they contribute most of the total cultured fish production (Figure 3). To date, polyculture of Indian major carps and Chinese carps is practiced in fertilized ponds. These fish are fed with a

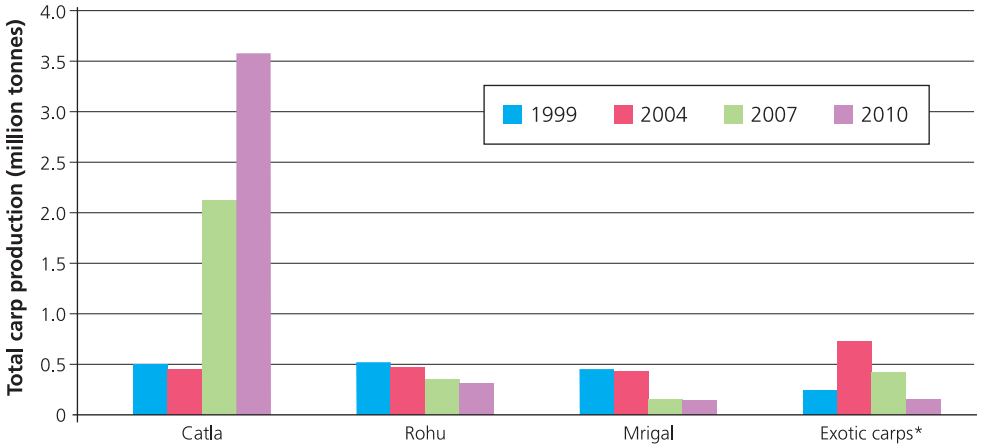
FIGURE 3
Carp production (million tonnes) in India from aquaculture, 2000–2001 to 2009–2010



Source: Anon. (2006); FAO (2012).

supplementary mash feed comprised largely of rice bran and oil cake. The three Indian major carps, namely, catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus cirrhosus*) contribute the majority of the national carp production (Figure 4).

FIGURE 4
Species contribution to total carp production in India (million tonnes)



Note: *Exotic carps include the Chinese major carps (common carp, grass carp and silver carp)
Source: Anon. (2006); FAO (2012); courtesy of Paul Pandian, Deputy Commissioner of Fisheries, Planning Commission, Government of India.

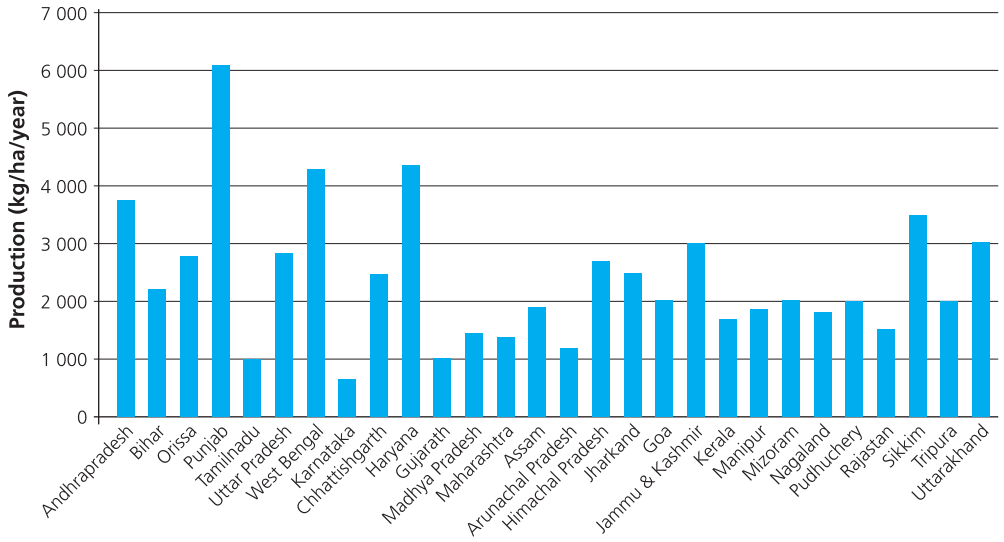
The Indian major carps, with their ability to filter feed by harvesting the natural plankton produced in the system through fertilization, provide the opportunity for low-cost aquaculture systems with reduced risk to farmers. Recognizing this potential, the Government of India has established fish farmers development agencies (FFDA) in almost all possible districts of every state, and provided special support to promote carp farming. Although carp culture now takes place in most states, it has particularly become a commercially significant venture in Andhra Pradesh, Punjab, West Bengal and Tamil Nadu. The species composition of the carps cultured and the farming methods used vary in different parts of the country. Carps are mainly cultured in earthen ponds; these are considered semi-intensive culture units. On the other hand they are also cultured in extensive systems, in large ponds and reservoirs; here the only intervention is to stock fish seed, the fish being allowed to harvest the natural food produced through inherent fertility. Chinese carp culture has also become successful in the colder parts of the country, particularly in northern and eastern India, which are close to mountainous regions.

A three-tiered carp culture system is practiced in India, namely, nursery, rearing and grow-out production systems. Depending on the management strategies that have been adopted, fish production of 1–10 tonnes/ha/year is obtained in different regions, with some progressive farmers recording up to 16 tonnes/ha/year. Small farmers, who constitute the bulk of the fish-farming population, are not able to follow all the package of practices, and their production remains <3 tonnes/ha/year. Many small farmers procure small-sized fish seed instead of fingerlings and stock them in poorly prepared ponds. Failure to follow recommended pre-stocking, stocking and post-stocking management procedures has been limiting production in many of the states. The data compiled by the Government of India (based on the input provided from each state) demonstrate that Punjab, Haryana, Andhra Pradesh and West Bengal have higher per hectare productivity than other states (Figure 5). In Tamil Nadu, although per hectare productivity for the state as a whole is low, higher production is noticed in some areas where feed is included as an integral part of the culture system. The productivity level

observed and the availability of feed ingredients reported in each state is linked; hence any intervention must aim at increasing the availability of feed to farmers in other states.

Survey results indicate that farmers use nine major ingredients and five feed types. The major ingredients are rice bran, groundnut oil cake, cottonseed meal, sunflower meal, soybean meal, mustard oil cake, wheat bran, common salt and mineral mixture. The feed types used are rice bran alone, rice bran and cottonseed meal, rice bran and groundnut oil cake, rice bran and sunflower meal, and rice bran and mustard oil cake. In addition, farmers in some areas also prepare feed mixtures using a variety of locally available resources, including fishmeal and/or locally available low-value and trash fish.

FIGURE 5
Productivity of freshwater fish farming in the states of India (kg/ha/year), 2008–2009



Note: Data presented pertain only to the productivity from the Fish Farmers Development Agency (FFDA) ponds.
Source: Data courtesy of Paul Pandian, Deputy Commissioner of Fisheries, Planning Commission, Government of India.

2.1 Species combinations

Carp farming in India is undergoing major changes that are related mainly to market focus. The traditionally recommended six-species composite carp culture system has not been successful from an economic point of view, even though a higher level of productivity is obtained. Several strategies for carp culture have thus evolved in the country to suit the market requirements and the availability of water resources, fertilizers, feeds, etc. and the investment capability of farmers.

Market demand for rohu is the highest, and this species is preferred in most parts of the country. Catla is also a preferred species in the carp farming community, owing to its fast-growing nature; hence in Andhra Pradesh it is stocked with rohu at about 10–20 percent and cultured in commercial systems. Along with these two species, 5–10 percent mrigal is also stocked as a scavenger to consume the food available at the pond bottom.

In other areas of the country, stocking densities for catla and mrigal are increased, with rohu being stocked at around 40–50 percent. Unlike Andhra Pradesh where the stocking percentages for rohu, catla and mrigal are strictly regulated, the availability of seed in other areas influences the species stocking composition and density. In addition to Indian carps, Chinese carps such as grass carp and common carp are added, with least preference given to silver carp. Also, polyculture of carps and giant river prawns (*Macrobrachium rosenbergii*) is practiced by some farmers in Andhra Pradesh, as well as in West Bengal. The culture of striped catfish (*Pangasianodon hypophthalmus*) with carps is gaining popularity in Andhra Pradesh and a few other parts of the country.

The stocking density adopted by farmers varies widely in different parts of the country, but progressive farmers generally restrict stocking density to less than 10 000/ha. Some farmers who use small fish seed employ higher stocking densities (up to 20 000/ha). In commercial systems the stocking density is highly regulated, and based on the final weight targeted. Also, the size of the seed stocked has a tremendous influence on growth and production; Table 1 presents an example from the study carried out in Tamil Nadu. Farmers stock small fish, whose survival depends on the care taken in pond preparation (i.e. removal of predators and other fish that compete with these species for food and space). As can be seen from Table 1, farmers stock six major carp species (however, the proportions stocked are not available). Generally the progressive farmers, who decide on stocking density based on market demand, tend to stock a larger percentage of rohu. Farmers using floating feed stock larger, stunted fingerlings/yearlings (see Section 2.4) with the objective of harvesting fish within about six months, when they will have attained a marketable weight of about 500 g.

The technology for stocking larger fish seed has yet to become a reality in most parts of the country. As the breeding of carps is still limited to the monsoon season, constraints in rearing space have compelled producers to sell smaller seed; the buyers, who are unaware of the benefits of stocking larger seed, have resorted to stocking with available seed - irrespective of the size. However, this trend is changing with the increasing spread of information on the benefits derived by the farmers in Andhra Pradesh. An important strategy that needs to be adopted to increase carp production is to stock larger seed at appropriate densities.

TABLE 1
Stocking practices adopted in carp culture systems in Thanjavur District, Tamil Nadu

	Conventional[1]	Floating Pellet	Mash + sinking pellet	Overall
No. stocked/ha	6 067±156	6 929±185	5 896±2 496	4 670±2 573
Species stocked		***Number of farmers***		
Catla	15	15	15	45
Rohu	15	15	15	45
Mrigal	15	15	15	45
Silver carp	9	4	1	14
Grass carp	9	3	7	19
Common carp	6	8	5	19
Size stocked (g)	**5**	**50–100**	**5–10**	**–**

Note: Generally 60 percent of the stock was rohu, with the rest being distributed mainly among the two other Indian carps and a very small percentage of Chinese carps.

Source: Field survey (2010).

2.2 Pond preparation and fertilization for live feed generation

Lime is commonly used by farmers and is applied at 200–300 kg/ha as an initial dose, irrespective of the pH level. This is followed by the application of cow dung (the most common animal manure used) by most farmers at an initial dosage of 2 000–3 000 kg/ha. In addition to cow dung, inorganic fertilizers such as urea and superphosphate are also commonly used. Organic compost (Figure 6) is used by some farmers to improve plankton productivity. Following the initial dose and after stocking the seed, farmers in most parts of the country resort to regular fertilization with organic manures and inorganic fertilizers. The amounts used are based on the fertility level of the water, which is estimated by visual observation coupled with the

experience of the farmer. The application of organic manures (Figure 7) can be up to 20 tonnes per ha, or more in the case of farmers in Andhra Pradesh; coupled with a higher level of application of inorganic fertilizers such as urea and superphosphate, the combined level of all the inorganic fertilizers used could be more than 1 000 kg/ha. Farmers in Andhra Pradesh have developed these application levels based on practical experience, and thus studies are needed to ascertain the impact of these fertilizers on fish growth (such studies can help to determine the optimal level of fertilization and reduce nutrient input costs).

A summary of the variety of levels of organic manures and inorganic fertilizers applied during the different stages of carp culture in various parts of the country is given in Table 2. The practices adopted vary widely and thus this information can only be used as indicative data to conduct trials in specific areas and develop technologies appropriate to the locations. The use of fertilizers in reducing risk to farmers and increasing productivity is an important factor to be considered, and emphasis should be placed on making farmers aware of the advantages of the use of formulated pelleted feeds. Feed companies also need to explore the ability of carps to harvest natural food that is rich in micronutrients essential for fish health and growth. Such an approach would reduce feed costs, help farmers derive greater benefits from the system and contribute to reducing nutrient discharge to the environment.

FIGURE 6
Compost pit

Courtesy of P. Antony Jesu Prabhu

FIGURE 7
Organic manure application

Courtesy of P. Antony Jesu Prabhu

TABLE 2

Fertilization schedule for different types of carp culture ponds

Type of pond & stocking density	Type of fertilizer	Rate of application	Frequency
Nursery pond 6.25 million /ha for 2 weeks	***Organic manure***		
	Cow dung	5 000 to 15 000 kg/ha	In one instalment at least 14–15 days before stocking
	Spaced manure application		
	Cow dung	10 000 kg/ha	15 days prior to stocking
		5 000 kg/ha	7 days after stocking
		5 500 kg/ha	Immediately after removal of the first crop, when more than one crop is raised
	Mustard oil cake + cow dung + poultry manure at 6:3:1	1 000 ppm for the culture of zooplankton for carp spawn	
	Inorganic fertilizer		
	N:P 4:1		
	N:P:K 8:4:2		Weekly
	N:P:K 18:8:4	500 kg/ha	After liming at 200 kg/ha
	Both		
	Mustard oil cake + 6:8:4 N:P:K	On equivalent nutrient basis at 12 kg N/ha	
Rearing pond 200 000 to 300 000/ha	***Organic manure***		
	Cow dung	3–7 tonnes/ha	In rearing ponds, 50% of the total requirement is applied 15–20 days prior to stocking of fry and the remainder in two equal monthly applications during the rearing period
	or	*or*	
	Biogas slurry	5.5–12 tonnes/ha	
	and	*and*	
	Cow dung	2.5–5 tonnes/ha	
	or	*or*	
	Biogas slurry	10–30 tonnes/ha	
	or	or	
	Poultry dropping	5–15 tonnes/ha	
Rearing pond	***Inorganic fertilizers***		
	Urea	108–152 kg/ha	Should be applied in equal monthly applications alternately with organic manure with a gap of about 2 weeks
	Calcium ammonium nitrate	200–280 kg/ha	
	Ammonium sulphate	250–380 kg/ha	
	Single superphosphate	156–312 kg/ha	Weekly; first instalment is given 7 days after initial organic manure application in equal monthly applications
	Murate of potash	16–32 kg/ha	
	or Sulphate of potash	20–40 kg/ha	
Stocking pond	***Inorganic fertilizers***		
	Urea	163–326 kg/ha	
	Calcium ammonium nitrate	300–600 kg/ha	
	Ammonium sulphate	375–750 kg/ha	
	Single superphosphate	250–468 kg/ha	
	Murate of potash	41–66 kg/ha	
	or		
	Sulphate of potash	52–83 g/ha/year	

Source: Reproduced from Ray (2013).

In the study area of Tamil Nadu, farmers have been using fertilizers at various levels depending on the quality of supplementary feed used (Table 3). In general, the use of lime, organic manures and inorganic fertilizers declines when farmers use pelleted feed. The amount of lime used by conventional farmers (463 kg/ha) and the sinking-pellet farmers (474 kg/ha) was almost equal, while the farmers using floating pellets used only a small amount (127 kg/ha). The use of organic manures and inorganic fertilizers was higher in the case of the conventional system as compared to the other two systems. Interestingly, farmers using floating or sinking pellets used other organic inputs such as Zymac (brand name of a commercially available biofertilizer applied to increase plankton production). Pond preparation is completed by July or August and thereafter, stocking with fingerlings or stunted fish seed is undertaken.

TABLE 3

Input usage (kg/ha) patterns observed in the different feed-based systems in Tamil Nadu

Parameter	Conventional	Floating pellet	Mash + sinking pellet	Overall
Cow dung	6 119±3 820	4 623±2 573	3 557±3 079	4 766±2 840
Urea	145±61	3.5±10.2	60.8±57.4	70±50
Super phosphate	147±70	4.3±45.9	50.5±67.2	67±53
Zymac	–	1.52±2.81	5±7	2.2±5.5
Feed	5 915±2 940	5 084±643	3 505±1 329.3	4 835±1 303
Feed conversion ratio (FCR)	1.96:1	1.11:1	1.26:1	1.44:1
Feed type	Rice bran/oil cake mix	Uno	Gold Mohur, CP	–
Lime	463±320	127±109	474±613	348±77

Source: Field survey (2010).

2.3 Feed conversion ratios (FCR)

The best FCR is obtained through the judicious use of feed and the production of natural food through fertilization. Among the three types of feed used in Tamil Nadu, the best FCR (1.1:1) was obtained by floating pellets (Table 3). Regulation of feed ration based on the actual feed consumption pattern helped farmers to minimize feed wastage. Furthermore, the higher stability of floating pellets ensured their nutritional quality without much loss due to leaching, even in cases where their consumption was delayed.

The lowest FCR (1.96:1) was observed when conventional feeding practices were used, reflecting the higher wastage of feed as well as the low nutrient availability of the feed used. Although carps are known to browse the feed through the holes in the feeding bags, there appears to be more feed wastage than in the case of conventional feeds.

In contrast, the feeding of pellets provided a slightly better FCR (1.26:1). As the ponds are also fertilized, these FCR values reflect the combined effect of feed and the natural food produced through fertilization.

2.4 Increasing natural food production through the use of substrates

Although pelleted feeds are gaining increasing acceptance, farmers hold a strong belief that the production and use of live food will help to improve the quality of fish and the profitability. Farmers have started to adopt techniques to develop the periphyton community in the ponds, such as fixing bamboo poles, installing coconut leaves, hanging sugarcane baggase in the pond, etc. (Figure 8). These organic substrates are known to increase the availability of periphyton and other food organisms. The results of such research have demonstrated the great potential of this technique in increasing the production of carps, particularly of species like rohu (Shankar, Mohan and Nandeesha, 1998; Mridhala *et al.*, 2005). Testing the commercial-scale application and viability of these techniques may have great benefits for farmers, as there is enormous demand for species like rohu.

FIGURE 8
Periphyton generation in ponds using various substrates and the measurement of productivity
Top left: coconut leaves; top right: bamboo poles; bottom left: sugarcane baggase; bottom right: plankton estimation

COURTESY OF P. ANTONY JESU PRABHU, M.C. NANDEESHA AND K.M. SHANKAR.

The addition of organic manures and inorganic fertilizers helps to improve natural food availability. The quality of the natural food produced will also influence feed conversion ratios (FCR), as is evident from the small number of samples studied in Tamil Nadu comprising three different systems.

2.5 Stocking size

In most of the country, the stocking of undersized fish seed continues to be a major hurdle to increasing fish production. Although a huge amount of carp seed is easily produced by employing the Chinese and/or 'jar' hatchery systems, the survival from spawn to fry stage is mostly still less than 20 percent. The fry are then reared to fingerling size if there is enough space, or else they are used for stocking once they reach 3–4 cm. However, the percentage surviving from this small size to adult fish is very low, particularly when the waterbodies are infested with predators and water quality is poor.

The concept of stunted yearling production and stocking in grow-out ponds was developed and propagated by the fish farmers of Andhra Pradesh and is gradually spreading to other parts of India. Farmers stunt fingerlings for a period of 6–12 months by maintaining them at high stocking densities and feeding at a rate of 2–3 percent body weight, a level sufficient for survival and some growth (Figure 9). The stocking density used in such ponds can vary from 50 000 to 100 000/ha. On average, the stunted yearlings reach a size of 100–150 g. When stocked in production ponds at normal density levels and given adequate food, these stunted yearlings rapidly gain additional weight, reaching a marketable size of 700–1 000 g in 6–8 months.

FIGURE 9
Stunted yearlings

COURTESY OF A. SUDHAGAR.

Once nutritional restriction (or under-nutrition) is removed, the favourable conditions in the grow-out ponds invoke a number of compensatory responses, including hyperphagia, rapid weight gain and better feed conversion efficiency as compared to that seen in continuously fed (normal) fish. Farmers thus take advantage of this compensatory or 'catch-up' growth phenomenon that occurs following a period of food deprivation. Although the production of stunted fingerlings involves a delay of one year, this loss of time is compensated by the production of a greater number of yearlings due to high stocking density, higher growth rate in the production ponds and a subsequent reduction in the culture period and feed costs. Survival rates are also high, as the stunting process eliminates the weaklings.

Farmers in Andhra Pradesh have further improved this stunting technology through stocking density management. They produce fish of larger weight (up to 500 g) by the stunting process; these are called 'zero class' fish. When thinned and stocked in grow-out ponds, these fish attain market size in 5–6 months. When there is an assured water supply, farmers using this process can easily raise two crops of fish per year.

2.6 Nutrition and feeding

Extension support to farmers and the entry of entrepreneurs into carp aquaculture have helped to realize the optimal production level in a significant number of farms. However, a much greater number of small farmers that are spread throughout the country have not yet been able to harness the technological progress, either due to difficulties in obtaining feed or to socio-economic reasons. Many of the carp farmers of Andhra Pradesh, Punjab, West Bengal and Tamil Nadu have realized the importance and benefits of the use of pelleted feeds in carp culture and have been able to obtain good production. The transition of the carp farmers from traditional mash feed to pelleted feeds is discussed later in this review.

3. FEEDING PRACTICES

3.1 Conventional feeding practices and their limitations

India is reported to produce nearly three million tonnes of carps annually (Anon, 2006). Most of this production is based on the use of a farm-made mash of raw ingredients. The farm-made mash feed is comprised of rice bran and oil cake (groundnut, mustard and cottonseed cakes are widely used), typically in the ratio of 50:50. However, nowadays 80 (or even 90) rice bran: 20 (10) oil cake is popularly used in the kolleru

regions of Andhra Pradesh. This conventional method of feeding costs US$ 0.1–0.2 per kilogram of fish produced (Suresh, 2007), which is much less than the US$ 0.4–0.6 per kilogram that it costs with commercial pelleted feeds. However, the use of this conventional feed mixture, or no feed at all, contributes to the poor growth of fish as compared to that achieved by pellet-based carp farming. Some of the main limitations encountered in the use of farm-mixed conventional supplemented feeds are:

- The procuring and storing of large quantities of raw ingredients requires good infrastructural facilities that are not available to small- and medium-scale carp farmers. In such cases, farmers are subjected to seasonal fluctuations in the availability and market price of the required ingredients. Even large farmers who can procure and stock these ingredients in bulk when the market price is low are confronted with storage-related quality issues.
- Most importantly, the nutrients in the mash feed mixture are sometimes placed in perforated bags that are suspended in the pond water column; these leach into the water very quickly. It appears that a portion of the ration is not eaten by the fish, instead serving to fertilize the pond.
- The nutrient load that is delivered into the pond soil and water through the use of these conventional feed mixtures can lead to production problems and also poses a potential danger to the natural ecosystem through eutrophication, a prime environmental concern.
- The poor FCR (3:1–4:1) of these conventional mash feeds, due to rapid nutrient leaching and poor water stability, cannot support the intensification, expansion and further development of carp culture in India.

3.2 Unconventional feeding strategies

Certain progressive fish farmers, mainly from the states of Andhra Pradesh, West Bengal, Punjab, Haryana and Tamil Nadu, have evolved and adopted some unique practices in seed production, nursery rearing, grow-out culture, feeding and - to some extent - marketing. The feeding strategies that have been adopted play an important role in maximizing nutrient availability and can determine the success of a culture operation. Specifically defined feeding strategies have been adopted to minimize feed wastage and nutrient loss by leaching and to maximize growth. Andhra Pradesh remains a pioneering state in Indian aquaculture because of the innovative thinking and experimental ability of its fish farmers, who have developed their own successful feeding strategies that have contributed to boosting aquaculture production in the country. The feeding strategies employed are outlined below.

3.2.1 "Stop feeding"

These farmers employ the simple feed management practice of not feeding the fish at regular intervals. Generally, the fish are not fed one day in every ten; this allows the farmers to eliminate the cost of feeding for that particular day and ultimately reduces the cost of production significantly. This practice of 'stop feeding' is well supported scientifically by the fact that starvation and subsequent feeding enhances feed intake and improves growth rate through compensatory growth mechanisms.

3.2.2 "Break feeding"

One of the basic principles in feed management is that an increase in the feeding frequency will lead to a uniform size of the population. When the total feed ration per meal is applied at a single time, the larger fish or 'shooters' dominate and consume most of the feed, and the relatively smaller fish get only the leftovers. This leads to unequal fish size at harvest, which affects market price. To solve this problem, farmers using pelleted feed have devised an approach known as 'break feeding', in which the ration for each meal is split into two portions and applied at an interval of 20–30 minutes.

The dominant fish are fed to satiation by the first portion of the ration and the smaller fish get to feed to satiation on the second portion. This has helped to minimize size variation at harvest. However, in this case farmers do not use bags for feeding but apply pellets to the water at fixed times every day.

3.2.3 "Bag feeding"

Fish fed to satiation through demand feeding show higher weight and protein gain. This principle is effectively exploited by these fish farmers, based on their experiences and observations. Mainly for carps, farmers practice a different type of feeding method termed 'bag feeding', in which perforated bags are filled with the mash of feed ingredients or the sinking pellets and suspended in the water column by tying them to bamboo poles (Figure 10). The fish feed to satiation by nibbling through the holes in the bag. The feed bags are removed and dried before re-use.

FIGURE 10
Feeding bags in pond

COURTESY OF B.S. KAMALAM.

3.2.4 Feeding enclosures

A feeding enclosure is a small area in the centre of the pond, which is enclosed on all sides by netting that extends one foot above and one foot below the surface of the water and is fixed in place by bamboo poles. Floating feed pellets are broadcast inside this netting enclosure. In this way, the feed is made easily accessible to the fish in a specific area where they can aggregate and feed, thus preventing wastage (Figure 11).

FIGURE 11
Feeding enclosure

COURTESY OF B.S. KAMALAM.

3.2.5 Gelatinization

Gelatinization is a process by which the bound starch granules in some plant-based feed ingredients are converted into an easily digestible and more bio-available form by means of cooking. Some of the fish farmers in Andhra Pradesh cook broken rice and feed it to their fish as a mash mixture, based on their experience that cooking improves digestibility and thereby enhances growth. However, this method of cooking is not generally practiced for carps, but is used mainly in the case of catfish production.

4. COMPOUNDED PELLETED FEEDS FOR CARPS

The conventional feeding practices used in India have gradually been transformed with the commercialization of carp culture and the entry of commercial feed manufacturers.

4.1 Sinking pellets

Sinking pellets possess better water stability, compared to mash feed, but that stability depends on the ingredient composition and the method of processing. This type of feeds are manufactured commercially for carps by a few feed mills with the incorporation of various plant-based feed ingredients (fishmeal is generally not included or is included only at a low percentage) and other nutritional supplements such as a vitamin and mineral premix. The size of the pellets used in the grow-out system varies widely, the diameter ranging from 2.3 to 3.2 mm and the length from 8 to 12 mm. The feed is heat processed by steam, which increases stability, reduces microbial load and improves nutrient digestibility and palatability.

However, the use of sinking pelleted feeds for carps also has some limitations. The pellets cannot be broadcast freely on the pond surface, as they sink to the pond bottom because of their high density, making the feed less available to fish. Hence sinking pellets are generally given using the bag feeding method; however, due to the use of this method the actual amount of feed eaten by the fish is difficult to assess (Sahu and Saravanan, 2009). The FCR (2:1) of the sinking pelleted feed for carps is much better than that of the conventional feed mixture, which is a mixture of either rice bran/de-oiled rice bran and oil cake (groundnut oil cake/mustard oil cake) in the ratio of 1:1 to 4:1 (the ratio varies with local availability of ingredients, price fluctuations and the preferences of individual farmers). In Punjab, sinking pellets have gained popularity because of the promotional efforts of the feed companies. Although the growth is not substantially different to that achieved with the conventional mixture, farmers have begun to adopt pellets because of their convenience (Debnath *et al.*, 2007). This not only helps to reduce feed costs, which account for 50–60 percent of the operating costs in any aquaculture venture, but also helps to reduce the environmental impacts by minimizing feed wastage.

4.2 Floating pellets

The processing of feed ingredients by extrusion not only helps in the production of hard sinking pellets but can also be used to produce pellets with very low density such that they can float on the water surface for a period of time (20–30 min). As with most advanced technologies, the cost of production per unit of floating pellets is higher than that of sinking pellets. However, floating pellets have a range of advantages over sinking pellets, including: better FCR (1.2:1–1.5:1); reduced feed wastage; easier feed management (including regulation of feed ration through direct observation); easier accessibility to fish; easier removal of unconsumed feed to prevent environmental degradation; and less labour requirements. In addition, the use of floating pellets increases production per unit area by improving the growth rate achieved through the use of mash feeds and sinking pellets. This is evident from the results of the study carried out in Tamil Nadu, where preliminary comparisons, based on actual practice were made (see Sections 9 and 10). Although more extensive studies are needed to draw definite conclusions, the results are indicative of the larger benefits that can be obtained by using floating pellets.

5. FEED DISPENSING METHODS

In addition to the nutritional composition of the diet, importance must be given to the methods used by farmers to present feed to the fish. A wide range of feed-dispensing practices are used by carp farmers in India. These vary from region to region, and even from farmer to farmer within the same region. Some of the feeding methods followed by the Indian carp farmers are:

- baskets tied to poles installed in the pond and kept immersed in the water column (Figure 12);
- perforated bags tied on a rope and immersed in ponds to a depth of 1 foot from the bottom (Figure 13);
- polythene bags tied horizontally in the corners between four poles and made like a tray; and
- a pen-like structure created with the help of poles and fishing net, with a bottom opening.

The success of Andhra Pradesh farmers in bag feeding has influenced many farmers from other regions to adopt this method. While the above types of feed-dispensing methods are adopted by progressive farmers, a large majority of farmers follows the method of spreading the feed in fixed spots of the pond. This feeding practice results in considerable wastage of feed, the feed mostly serving as manure.

FIGURE 12
Basket feeding

COURTESY OF J.K. JENA.

FIGURE 13
Bag feeding

COURTESY OF J.K. JENA.

6. PROMOTING PELLET-FED CARP CULTURE IN INDIA

Considering the fact that mariculture is still in its infancy in India, the best option is to focus on increasing production from the national freshwater sector. Alternative species, such as tilapia and striped catfish, are viable additional species that can be promoted together with carps; however, farmers are likely to continue to depend on Indian major carps and Chinese carps (particularly common carp and grass carp) in many localities. While the culture success of tilapia and catfish would largely depend on the availability of seed and pelleted feed, Indian major carps can continue to thrive on natural production enhanced by fertilizers coupled with the use of conventional feed mixtures.

Most of the Indian carp farmers who have been taught feed-based fish farming through demonstrations and seminars have accepted the new technology and have started using formulated fish feeds. Godrej Agrovet (P) Ltd., which has a special division for the production of livestock and fish feeds, has taken a major initiative to promote feed-based carp farming in Punjab and Andhra Pradesh. This company has been

successful in encouraging a majority of farmers in Punjab by providing competitively priced feed, a practice that helps farmers to buy compounded feed, rather than feed ingredients for on-farm use. However, the success of such companies in promoting pelleted feed for carp culture in India, where the bulk of the fish is produced through semi-intensive culture, is still limited by various constraints. For marketing, most of the fish produced in Andhra Pradesh have to be transported to various parts of the country, particularly to eastern India. Hence, the additional transportation costs and the relatively low farm-gate price offered by buyers in Andhra Pradesh have discouraged farmers from venturing into the use of pelleted feeds, and they continue to rely on rice bran mixed with oil cake in their production systems. In contrast, in Punjab and Tamil Nadu much of the harvested fish is marketed locally or at best transported to nearby markets in other states; thus farmers can make a profit by using quality pelleted feed.

The responses from the farmers (see Sections 9 and 10) on the benefits of using pelleted feed highlight increased productivity, reduced grow-out time, ease of operation, good fish health caused by better water quality, etc. A few of the progressive farmers from Tamil Nadu have been experimenting with the use of floating pellets in carp culture for the past four to five years with positive results. With the establishment of floating pelleted feed companies and the increased availability of pelleted feed, the number of farmers switching to floating pellets should increase. A progressive farmer has established a small floating feed manufacturing unit to cater to his needs. The promotion of such small-scale production units as a business model may help farmers locally. By ensuring an adequate supply of quality feed ingredients, such small-scale feed plants have the opportunity to succeed.

7. FEED INGREDIENT AVAILABILITY

Due to India having an agrarian economy, a variety of agricultural resources are available for use in animal feeds. The estimated production of primary agricultural commodities that provide a significant amount of by-products, which can be used in fish feed, is presented in Table 4, while the chemical composition of the commonly used feed ingredients is given in Table 5. There is heavy competition for several of the agricultural by-products from the poultry and other animal husbandry sectors, which have well-established markets for their produce. Although estimates indicate that the agricultural by-products available nationally are adequate to meet the expected demand for feed ingredients, there is an urgent need to make feeds and fertilizers available in individual states and to develop strategies to increase the availability and distribution channels for them to aquaculture feed industry establishments (Ayyappan and Ali, 2007; Suresh, 2007).

TABLE 4

Estimated production of primary agricultural commodities in India, 2007–2008

Commodity[1]	Quantity (million tonnes)
Pearl millet (bajra)	9.79
Sorghum (jowar)	7.78
Corn (maize)	19.30
Oilseeds	28.83
Rice	96.43
Wheat	78.40
Groundnut	9.36
Rapeseed & mustard	5.80
Sunflower	1.44
Soybean	9.99

Note: [1]Vernacular names commonly used in India are given in parentheses.

Source: Anon. (2009).

TABLE 5

List of commonly used feed ingredients used in carp culture[1]

Feed ingredients	Nutrient composition (% on dry matter basis)					
	Moisture	Crude protein	Crude lipid	Ash	Gross energy (kJ/g)	Price per tonne (US$)
Ingredients of animal origin						
Fishmeal	8–10	45–65	8–12	20–40	14.94	611.1
Shrimp waste	10–15	22–34	2–7	10–20	n.s.	n.s.
Squilla meal	10–14	40–46	1–3	12–18	12.62	n.s.
Squid meal	8–12	70–75	4–8	3–5	n.s.	n.s.
Clam meal	8–10	48–50	8–11	4–6	n.s.	n.s.
Silkworm pupae	8–10	40–45	15–25	12–15	28.88	n.s.
De-oiled silkworm pupae	8–10	60–70	2–5	6–7	n.s.	n.s.
Blood meal	10–15	85–90	1–2	2–4	83.72	n.s.
Meat meal	8–10	50–70	4–9	10–15	70.32	n.s.
Liver meal	7	65	3.4	2.4	n.s.	n.s.
Earthworms	5	51.7	3.4	12.5	n.s.	n.s.
Ingredients of plant origin						
Groundnut oil cake	7–10	40–43	4–8	8–10	19.53	175.9
Soybean meal	8–10	50–55	1–2	5–6	19.08	296.3
Broken rice	7–10	12–16	12–14	5–8	14.75	129.6
Rice polish	8–12	12–18	12–14	5–8	19.21	101.9
De-oiled rice bran	8–10	15–18	1–2	8–12	10.11	133.3
Rapeseed cake	11–12	32–38	5–7	6–7	n.s.	174.1
Salseed cake	8–10	7–8	3–4	10–12	n.s.	n.s.
Sesame oil cake	7–10	35–42	3–6	10–13	19.61	n.s.
Mustard oil cake	8–10	25–38	6–9	10–12	19.57	n.s.
Cotton seed cake	7–10	32–35	6–8	8–12	19.74	89.3
Sunflower oil cake	10–12	30–32	4–8	8–10	14.21	92.6
Maize flour	10–12	5–6	3–4	2–3	13.92	111.1
Barley grain	10–12	8–10	2–3	2–3	n.s.	n.s.
Wheat bran	9.3	12.6	7.5	4.2	18.82	92.6
Wheat flour	10–15	8–11	2–4	1–3	18.79	194.4
Tapioca flour	10–12	3–6	2–3	2–3	16.45	n.s.
Spirogyra powder	44.5	8.1	2.8	5.95	6.28	n.s.
Sorghum	10	9	2.8	0.1	n.s.	92.6
Spirulina powder	8.47	54.5	1.1	11.53	20.12	n.s.
Water hyacinth meal	3.3	19.5	2.3	9.3	16.87	n.s.
Pistia meal	4.9	19.5	1.3	25.6	n.s.	n.s.
Leucaena meal	11.8	33.1	4.7	7.2	n.s.	n.s.
Salvinia meal	2.6	16.2	1.1	22	n.s.	n.s.

Note: n.s. = not stated.

Source: Jafri *et al.* (1992); Erfanullah and Jafri (1998); Nandeesha *et al*. (2000); Anon. (2006); Suresh (2007).

7.1 Relationship between fish production and feed ingredient availability

Analysis of the trends in the state-wise production of primary agricultural commodities and in the state-wise aquaculture or carp-culture production shows that those states that are the major producers of agricultural commodities have also established themselves as major producers of aquaculture commodities (Table 6). This clearly shows that feed ingredient and feed availability play a pivotal role in the development of freshwater aquaculture, mainly the carp-farming sector of India.

TABLE 6

Top Indian states in the production of agricultural commodities of aquafeed importance, together with the top inland fish and Indian major carp producing states

Crop	Top 3 state producers	Production (million tonnes)	% share		
Food grains					
Rice	West Bengal	14.75	15.80	**Top ten states in inland fish production (thousand tonnes)**	
	Andhra Pradesh	11.87	12.72		
	Uttar Pradesh	11.12	11.91		
Wheat	Uttar Pradesh	25.03	33.02	West Bengal	1 020
	Punjab	14.60	19.26	Andhra Pradesh	673
	Haryana	10.06	13.27	Uttar Pradesh	290
Maize	Karnataka	2.72	18.01	Bihar	280
	Andhra Pradesh	2.46	16.29	Orissa	203
	Bihar	1.71	11.32	Assam	188
Total food grains	Uttar Pradesh	41.21	18.97	Tamil Nadu	155
	Punjab	25.31	11.65	Maharashtra	135
	Andhra Pradesh	16.23	7.47	Chhattisgarh	132
Oil seeds				Karnataka	121
Groundnut	Gujarat	1.44	29.63	**Top five states in Indian major carp production (thousand tonnes)**	
	Tamil Nadu	1.01	20.78		
	Andhra Pradesh	0.74	15.23		
Rapeseed & mustard	Rajasthan	3.81	51.21		
	Uttar Pradesh	0.87	11.69	West Bengal	790
	Haryana	0.80	10.75	Andhra Pradesh	377
Soybean	Madhya Pradesh	4.78	54.01	Uttar Pradesh	291
	Maharashtra	2.89	32.66	Bihar	111
	Rajasthan	0.77	8.70	Punjab	102
Sunflower	Karnataka	0.52	42.28		
	Andhra Pradesh	0.33	26.83		
	Maharashtra	0.20	16.26		
Total oil seeds	Madhya Pradesh	5.81	23.92		
	Rajasthan	5.17	21.28		
	Maharashtra	3.72	15.31		

Source: Anon. (2006, 2009).

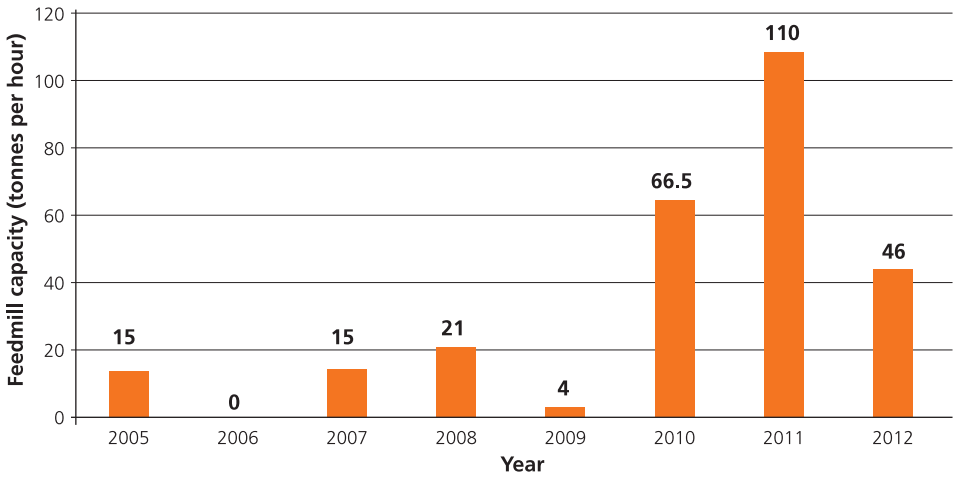
7.2 Impact of climate change on availability of carp feed ingredients

According to FAO estimates (Rana, Siriwardena and Hasan, 2009), India is projected to be one of the countries whose production of agricultural commodities is likely to be severely affected (28.8 percent reduction) due to climate change by 2080. Already several areas in the country that have produced abundant agricultural commodities are facing severe drought. Many areas that depend on groundwater to irrigate agricultural crops are facing water shortages, and bore wells in several areas have completely dried up. If the conventional feeding practices with high FCR (3.5:1) are employed, several challenges related to shortage of ingredients and water quality problems will have to be addressed. The adoption of pelleted feed-based carp culture production systems will help to increase profitability through the wise use of resources.

8. STATUS OF THE CARP FEED INDUSTRY IN INDIA

The commercial production of floating pellets for carps started in the year 2008 with a modest estimated production of 2 500 tonnes per month (30 000 tonnes per year), with soy meal incorporated at 35–56 percent. It has been estimated by the American Soybean Association – International Marketing (ASA-IM) that the sales of extruded soy-based floating fish feed will reach 500 000 tonnes annually by the year 2011 (Clark, 2009). Currently, India has an extrusion feed milling capacity of about 91 tonnes/hour and produces approximately 410 000 tonnes/year (estimate based on 75 percent mill efficiency, 20 hour operation per day and 25 working days a month). Rapid expansion in feed milling capacity is expected in 2011 and 2012 (Figure 14 and Table 7), when some major feed mills are expected to commence operation. It is predicted that this will boost annual fish feed manufacturing in India to about one million tonnes.

FIGURE 14
Development of extrusion feed mill capacity in India



Note: Estimated projection by the American Soybean Association – International Marketing/Soy in Aquaculture (ASA-IM/SIA); the figures represent the additional capacity installed/to be installed during each year.
Source: Vijay Anand, Cremer and Ramesh (2010).

TABLE 7
Development of extrusion feed mill capacity in India (tonnes/hour)

Company	2005	2006	2007	2008	2009	2010	2011	2012	Total
Indian Broiler	–	–	–	8	–	18+12	–	16	54.0
Uno	–	–	–	3 (X)	–	5+5+1.5	–	–	21.5
Kwality	1.5 (X)	–	1.5 (X)	–	4	4+1	10	–	19.0
Ananda	–	–	–	5	–	–	10	–	15.0
CP	–	–	–	5	–	–	20	–	25.0
Growel	–	–	–	–	–	10	10	–	20.0
Rudra	–	–	–	–	–	10	–	10	20.0
Nexus	–	–	–	–	–	–	15	–	15.0
Mulpuri	–	–	–	–	–	–	15	–	15.0
Cateroh	–	–	–	–	–	–	10	10	20.0
Indepesca	–	–	–	–	–	–	10	–	10.0
Sneha	–	–	–	–	–		10	–	10.0
Totals	**1.5**	**–**	**1.5**	**21**	**4**	**66.5**	**110**	**46**	**244.5**

Notes: This table presents in detail the new additional capacity installed and to be installed each year (if any) by various feed manufacturers. Figures marked 'X' are those feed mills which have given up small extruders and have expanded. Figures provided up to 2010 are on an actual basis; figures for 2011 and 2012 are forecasts and may change with varying plans of the investors, new investors and market developments.

Source: Vijay Anand, Cremer and Ramesh (2010).

In India, the manufacturing and marketing of floating pelleted feeds for finfish was initially taken up on a commercial scale in 2008 by three animal feed manufacturing enterprises, *viz*. the Indian Broiler Group, Uno Feeds and CP Feeds. Additionally, three more feed-manufacturing enterprises, *viz*. Ananda Feeds, Kwality Feeds and Growel Feeds also plan to enter into the production and marketing of floating soy-based fish feed on a commercial scale in India.

Feeding demonstrations have convinced the entrepreneurs of a good return on investment, and this has resulted in investments in fish feed manufacturing plants, despite a 35–40 percent duty on imported machinery. As many of these feed companies are focussing on striped catfish, it remains to be seen how much of these pelleted feeds will become available to the carp culture industry.

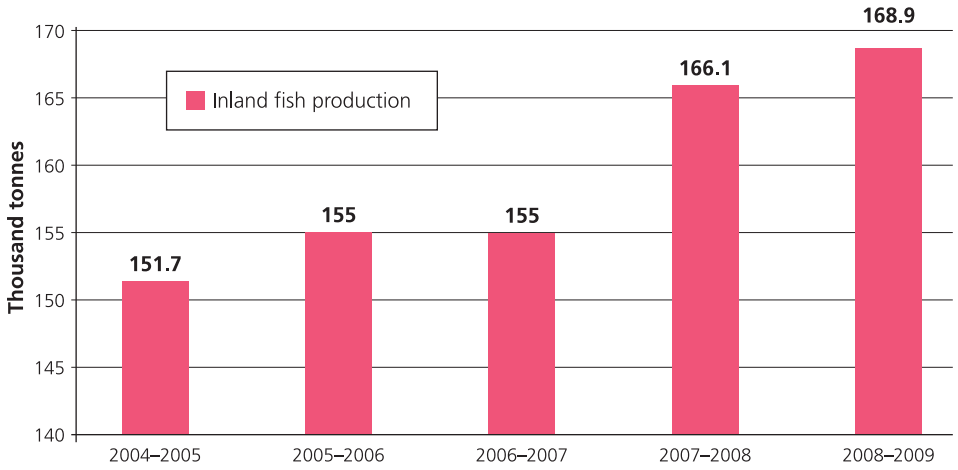
9. DEVELOPMENT OF A FEED-BASED CARP CULTURE SYSTEM IN TAMIL NADU

Tamil Nadu is one of the states that receive less rainfall, and thus people have evolved strategies to collect water during the monsoon by building reservoirs. The state has a long coastline and the marine capture fishery provides the major fish supply. The state has a number of river basins, with the Cauvery River basin being an important area for agricultural development. The reservoirs provide water for irrigation and other human necessities and have been contributing a substantial amount of fish to the capture fisheries sector (Figure 15). As the Cauvery basin has greater water availability than other regions, carp culture has been undertaken by farmers. As a result, carp production in Thanjavur district has improved substantially, largely because of the feeding practices adopted by farmers to increase fish growth rates and, consequently, overall production. The area being largely rice growing, rice bran is commonly available and is widely used as feed along with oil cake. In addition to these two principle ingredients, farmers also use maize powder, soybean flour and crude fishmeal[2] (made by grinding dry fish) in some places. These ingredients are mixed in various proportions, based on experience that is linked to natural food productivity in the ponds. In general, rice bran forms the major component (65 percent), and this is mixed with fishmeal at about 5 percent and the other ingredients (maize meal, soybean flour and oil cake) are added at about

[2] Generally referred to as fish powder.

10 percent each. Based on the natural food production and the growth of the fish, feeding is manipulated to minimize feed costs. Mash made of mixed feed ingredients is fed mainly by using feed bags. Although some farmers still broadcast the feed, a high percentage has adopted the bag feeding method.

FIGURE 15
Inland fish production (capture fisheries and aquaculture) of Tamil Nadu



Source: Anon. (2006); data for 2007 courtesy of Paul Pandian, Deputy Commissioner of Fisheries, Planning Commission, Government of India.

Table 8 shows that farmers in the Thanjavur District of Tamil Nadu have an average land area of 3.23 ha, with fish ponds covering an average of 2.17 ha. Most farmers have built ponds for fish culture, while some also reported the construction of ponds for water storage. Although direct integration of fish culture with other animals is not seen, most farmers have some animals on the farm, and the waste from these animals is used to increase pond productivity.

TABLE 8
Details of carp farming in the Thanjavur District of Tamil Nadu, India

Parameter	Conventional	Floating pellets	Mash + sinking pellets	Overall
Land area	2.8±2.3	3.42±3.1	3.53±4.2	3.23±3.6
Water area (ha)	1.84±2.0	2.75±2.5	1.9±1.3	2.17±2.0
Depth of pond (m)				
Maximum depth (m)	1.3±0.2	0.94±0.1	1.15±0.2	1.14±0.2
Minimum depth (m)	0.9±0.1	0.61±0.1	0.75±0.1	0.75±0.2
Age of the pond (year)	6.6±7.1	4.5±3.7	3.6±2.0	3.53±4.6
Purpose of construction				
Fish culture	13	8	6	27
Water storage	2	7	9	18
Integration[1]				
Rice	1		2	3
Cow	8	6	5	19
Pig	1	8		9
Poultry	8	7	3	18
Duck	4	5	2	11
Ownership of the pond		Single		
Type of operation		Polyculture		
Type of waterbody		Perennial (July–March)		

Notes: [1]Indirect, with the faeces (in the case of livestock, poultry and duck) of these components being used as fertilizers.
Source: Field survey (2010).

Although the use of pelleted feeds and commercially produced feed mixtures is gradually increasing, several farmers continue to prepare on-farm feed mixtures to reduce the cost of production. Some farmers join together to buy the necessary ingredients and grind and prepare the feed mix for use by farmers belonging to the group. This feed mixture is used in the early months of culture but once the fish attain a weight of 200–300 g the farmers switch over to pelleted feeds. The pelleted feeds, with their higher protein content and good stability, are used to promote the growth of carps. The yield of fish obtained by the farmers using floating pellets was consistently higher than that of the farmers using the other feeds (Table 9). Farmers using floating pellets can raise two crops per year through judicious stocking.

TABLE 9
Production details (kg/ha) observed for different feeding systems

Parameter	Conventional	Floating pellet	Mash + sinking pellet	Overall
Production (kg/ha/year)	3 010±643	4 596±501	4 432±2 579	4 012±1 687
Market price of fish (US$/kg)	1.38±0.13	1.56±0.09	1.43±0.15	1.46±0.14
Expenditures in harvesting (US$)	167.44±72.5	244.85±60.19	150.55±112.94	187.63±101.02
Size of harvested fish	>500 g			
Harvestings per year	Generally twice			

Source: Field survey (2010).

The use of floating pellets in carp culture has been promoted by organizations such as the American Soybean Association. As the feed companies demand cash payments, farmers with limited financial resources are not able to buy the feed. In shrimp farming, the supply of feed on a credit basis has become commonplace, but such a system has yet to be established in carp culture. Interestingly, yield, FCR and return on investment are better when floating pellets are used. Farmers using floating pellets for stock fish of a larger size (i.e. >50 g). These stunted large fish attain market size (400–600 g) in about six months and can then be harvested and sold. Depending on seed availability, and with proper planning, the farmers can raise almost two crops in a year.

Farmers using the conventional system resorted to significantly lower stocking densities, compared to the other two types of system. Interestingly, farmers used less inorganic fertilizers and less organic manure in both the floating and sinking pellet systems, and were thus able to maintain good water quality. These farmers also used less lime, compared to conventional-system farmers. Floating pellets are fed in net enclosures that prevent their dispersal and allow the fish to feed at one specified location. The amount of feed is also regulated based on the consumption pattern.

Farmers recognize the benefits of feeding with floating pellets, particularly with regard to economies in labour and ease of feeding, as summarized in Table 10. Furthermore, ponds fed with floating pellets have better water quality. While farmers appreciate these benefits, a lack of assured supplies of floating pellets is the major constraint at present. Floating feed plants that are located in Andhra Pradesh focus on the striped catfish farmers in that state, and only when there is a bulk order do they supply feed to the carp farmers of Tamil Nadu. In addition, the cost of transport contributes to the increased cost of feed.

TABLE 10
Type of formulated feed used for carp culture with advantages and disadvantages and the type of processing

Type	Advantages	Disadvantages	Moisture (% max)	Processing techniques
Farm-made				
Dry	Use of locally available ingredients; easy to prepare using simple household machines; as moisture content is less, more durable than moist feed and cheaper	Poor water stability; poor digestibility; poor FCR; and rapid water quality deterioration	10	Grinding, mixing and drying
Moist	Easy processing; cheaper.	Highly perishable	>30	Wet dough
Commercially manufactured pellets				
Sinking	Good water stability and digestibility; good for bottom feeders	Not suitable for fish occupying surface and midwater levels	10	Pelleted
Floating	Good for surface feeders and larval fish	Not useful for bottom feeders	10	Extruded

The price of the various commercial feeds in the area is presented in Table 11. Feeds are supplied by the producers on a cash and carry basis. Since the transportation of small quantities is not considered economically viable by these companies, the dealers are not able to provide the supply when the collective order of the farmers is less than 10 tonnes per batch. This is a major hurdle to the rapid spread of floating feed usage. Although floating pellets are expensive, compared to sinking pellets and mash feeds, the farmers are happy with the results of their use. Hence, if there were an assured supply, farmers would be likely to switch to using floating pellets on a large scale.

TABLE 11
Price of various feeds used by the carp farmers

Manufacturer's price of feed (US$/kg)				
Type of feed	**Gold Mohur**	**CP**	**Uno**	**Farm-made**
Mash	–	–	–	0.27
Sinking pellet	0.33	0.39	–	–
Floating pellet	0.5	–	0.44	–
Market price per kg of raw ingredients used by farmers (US$)				
	De-oiled rice bran	Soy flour	Maize flour	Crude fishmeal
Price	0.24	0.55	0.28	0.65

Source: Field survey (2010).

The nutrient composition of the different types of feed used indicates that the protein level of all three types is almost the same but floating pellets have a higher percentage of fat and a lower fibre content (Table 12). However, the processing method has a major influence on nutrient availability and, as a result, floating pellets have been inducing good growth when compared to other feed types.

TABLE 12
Various feeds and their proximate composition (% dry matter)

Size (mm)	Crude protein (min)	Crude lipid (min)	Crude fibre (max)	Moisture (max)	Net weight per bag (kg)
Mash feed					
0.89	32	3.5	8	12	20
1.41	32	3.5	8	12	20
Sinking pellet					
2.3 x 3–5	31	3.5	8	12	20
2.3 x 6–12	30	3.5	8	12	20
Floating pellet					
1.5	32	6	4	10	20
3	32	6	4	10	20
4.5	31	6	4	10	20
6	30	6	4	10	20

Source: Field survey (2010).

10. ECONOMICS OF CARP CULTURE IN TAMIL NADU WITH DIFFERENT FEED-BASED SYSTEMS

As in all other areas of the country, carp farming in Tamil Nadu has proved to be more profitable then paddy cultivation. As a result, the aquaculture industry is growing rapidly in the state and this is contributing to the increased availability of fish to local populations. Most of the fish produced is sold locally, and farmers are able to get a good farm-gate price. Although the existing demand for fresh fish far exceeds local production, due to inefficient marketing mechanisms farmers are not able to obtain the best price for their produce on a sustained basis. In the present study (Table 13), the best benefit-cost ratio was observed when farmers used floating pellets (1.6), while those using the conventional feed mixture (1.4) and sinking pellets (1.5) obtained lower levels of return. The higher cost of sinking pellets, coupled with the low production level, contributed to reduced economic returns. The total and net returns were higher for floating pellets, compared to other types of feeding practices, but were lowest for the conventional system. Similarly, the benefit-cost ratio remained higher for floating pellets (Table 13 and Figures 16–19). It is evident from the study that by adopting quality feed, return on investment can be improved. These benefits are well recognized by the farmers and their concern relates to the need to make floating pelleted feeds available without interruption. If the supply chain could be well established, it is likely that the farmers would accept the new technology.

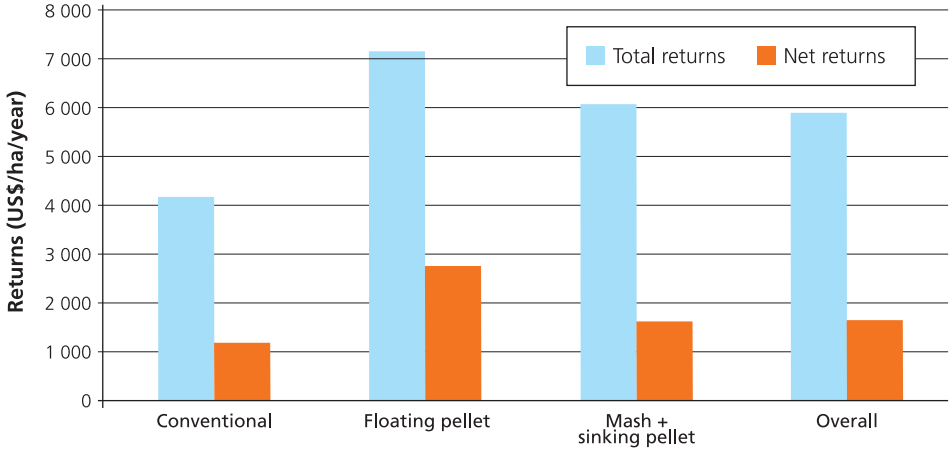
There are various opportunities by which the profitability of the system can be further improved by adopting improved management strategies. The use of larger seed and stunted seed would be beneficial, particularly in the case of Indian major carps (e.g. rohu and mrigal). Furthermore, by improving marketing support, there is good opportunity to increase profitability.

TABLE 13
Economics of production observed in different diet-fed systems (US$/ha/year)

Parameter	Conventional	Floating pellet	Mash + sinking pellet	Overall
Variable costs				
Seed	97.0	826.9	148.7	234.2
Fertilizers	40.6	16.6	20.6	18.9
Manure	113.3	85.6	65.9	88.3
Feed	1 643.0	2 541.9	3 294.5	2 864.6
Lime	138.0	11.8	43.9	100.7
Labour	118.3	114.7	121.2	127.1
Pumping	196.4	188.1	183.2	197.7
Harvesting expenses	167.4	244.9	150.6	187.6
Subtotal	2 513.9	4 030.3	4 028.4	3 819.1
Fixed costs				
Lease amount	271.6	200.6	256.2	242.8
Depreciation	27.8	27.8	27.8	27.8
Interest	166.7	138.9	148.2	151.9
Subtotal	466.1	367.3	432.1	422.4
Total cost	**2 968.9**	**4 397.6**	**4 460.5**	**4 241.5**
Total returns	4 141.1	7 148.2	6 073.5	5 869.4
Net returns	1 172.2	2 750.6	1 613.0	1 627.9
Benefit-cost ratio on TVC1	0.03	0.03	0.02	0.03
Benefit-cost ratio on TC1	0.03	0.03	0.03	0.03
Break-even price	0.98	0.94	1.00	1.06
Actual price	1.37	1.56	1.43	1.46

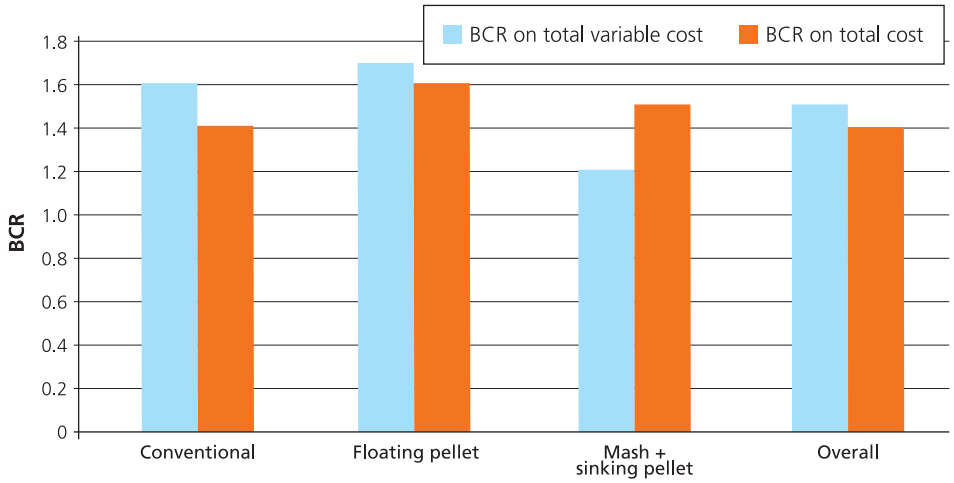
Notes: [1]TVC = total variable cost; TC = total cost.
Source: Field survey (2010).

FIGURE 16
Total and net returns (US$/ha/year) of different diet-fed carp culture systems



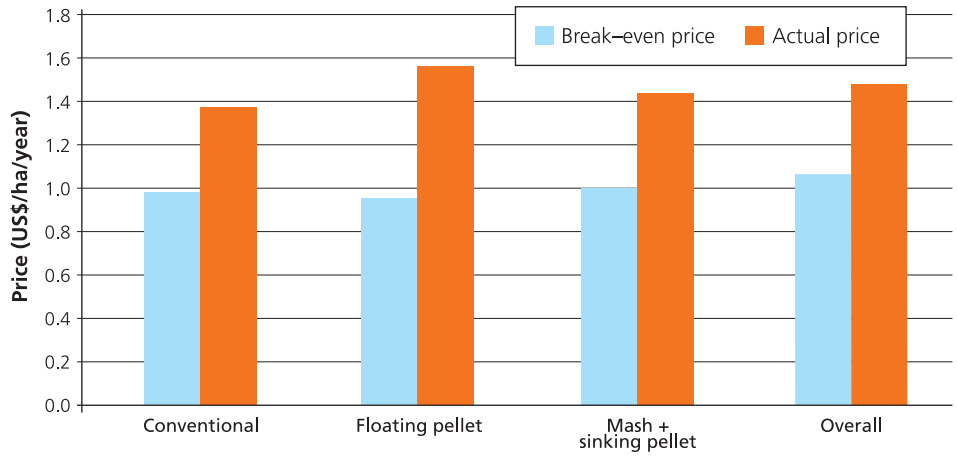
Source: Field survey (2010).

FIGURE 17
Benefit-cost ratio (BCR) of different diet-fed carp culture systems



Source: Field survey (2010).

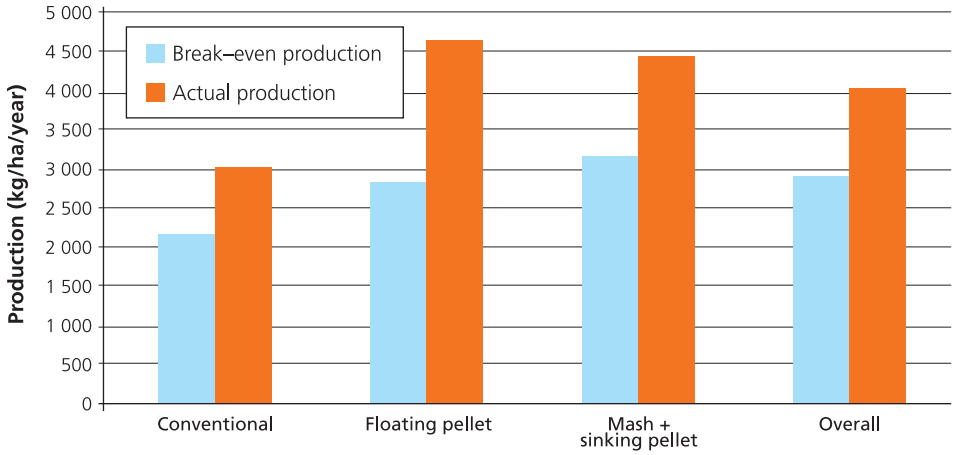
FIGURE 18
Break-even and actual price (US$/ha/year) in various diet-fed carp culture systems



Source: Field survey (2010).

In general, from paddy cultivation farmers are able to obtain a profit of US$ 363–556/ha/year. In contrast, aquaculture farmers have been able to obtain almost double this amount. Hence, planned intervention to convert unproductive and unused paddy cultivation areas to fish culture would help in generating additional income and improving food quality.

FIGURE 19
Break-even and actual production (kg/ha/year) in diet-fed carp culture systems

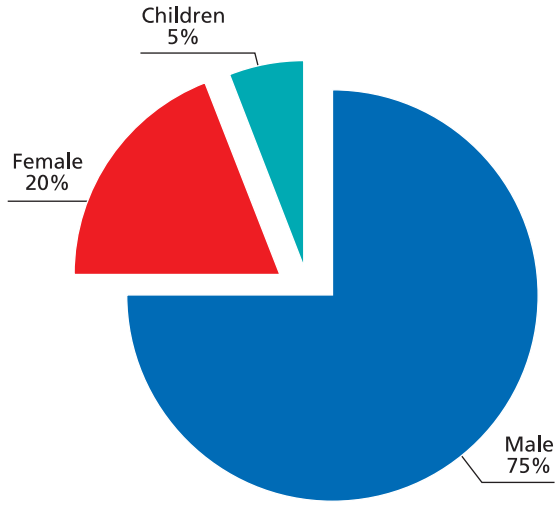


Source: Field survey (2010).

11. GENDER ROLE IN AQUACULTURE PRODUCTION OF TAMIL NADU

In Tamil Nadu, the participation of women in aquaculture is very limited, both in culture-related activities and in the marketing of freshwater fish. However, in some families women are involved in feeding and other aquaculture management activities (Table 14 and Figure 20). As the rural society in India still follows a patrilineal system, planned intervention strategies are needed to increase the role of women in aquaculture and gradually to build their knowledge. When queried about the poor participation of women in aquaculture, most men felt that it was not the tradition, while most women felt that the involvement of their husband was enough to manage the activity. As many aquaculture activities (e.g. feeding, fertilization, pond care) are better managed by women, their involvement would help to increase production, while men could attend to other farm activities.

FIGURE 20
Participation of family members in aquaculture activities



Source: Field survey (2010).

TABLE 14
Involvement of family members in aquaculture activities

Family members	Average overall activity (%)	Activities
Males	75	Water exchange, pond maintenance, etc.
Females	20	Feeding and marketing
Children	5	Feeding

Source: Field survey (2010).

12. PROBLEMS ENCOUNTERED BY FARMERS

Carp farmers face various hurdles in their farming practices. The major problem relates to the non-availability of pond inputs, particularly pelleted feeds. Although the farmers realize the benefits of using compounded pellets for carps, they are confronted with high prices and their lack of availability in many areas. The carp feed and animal feed mills that engaged in the manufacture of pelleted feed for carps on a commercial scale are located only in certain regions of the country. As a result, farmers of those particular regions and, to a certain extent of neighbouring regions, enjoy good availability of adequate quantities. However, a major constraint is that the feed manufacturing enterprises have not yet established efficient marketing networks and strategies so that their products are available at a reasonable cost to farmers distant to their production sites.

The feeds produced locally by farmers through small feed units do not have a long shelf life and hence cannot be prepared in bulk and stored. This problem could be addressed by the initiation of social bodies such as farmer cooperatives. By doing this, the small farmers would be able to obtain the required quantities of feed at a reasonable price, which would provide net benefits and the eventual intensification of carp farming.

The marketing of farmed fish and the ability of obtaining a good farm-gate price for them is another challenge faced by the farmers. This can be achieved by adopting pellet-fed farming and better management practices (BMP), thus ensuring that the harvested fish are of high quality and fetch a good market price. Live fish marketing is becoming popular, especially in the northern regions of the country and also in some southern parts of India. In addition the Indian Government is taking measures through the central sector scheme to strengthen the infrastructure for inland fish marketing; specifically to improve marketing channels through the establishment of fish marketing outlets/kiosks.

The availability of credit at the right time and at low interest rates is another constraint that has particularly affected small farmers. This is now being addressed by the agricultural credit policies of the Indian Government. A recent study conducted on the credit availability and utilization patterns of carp farmers in the Thanjavur district of Tamil Nadu (Ramkumar, 2010) revealed that the amount of credit provided per unit area by government financial institutions is more for small farmers than for large- and medium-scale farmers.

A lack of technical support from the institutions involved in aquaculture activities is recognized as an additional problem that could be solved by the provision of effective extension services by the research institutes, Krishi Vigyan Kendra (KVK; farm science center) and non-governmental organizations (NGO) involved in fisheries and aquaculture.

Electricity supply was identified as a common problem by almost all the farmers. Currently, electricity used for aquaculture activities is charged at industrial rates, which is burdensome to the farmers. As agricultural activities have been provided with free electricity, fish farmers have naturally been demanding that electricity should be provided for them at reduced or subsidized tariffs.

13. CONCLUSIONS

Although India is the second largest aquaculture producer globally, the gap between the production levels achieved by research and that accomplished by farmers is still very high. Although a high percentage of resource-rich farmers in Punjab and Andhra Pradesh have been able to bridge this gap through their own innovations and the efficient use of feed resources, many farmers continue to obtain yields of less than 2 500 kg/ha/year. Bridging this gap between actual and potential production through the creation of additional support services, such as access to feed supply systems,

increased availability of credit, improved availability of quality seed, etc. will help to augment production.

Furthermore, the additional aquatic resources and new areas that are becoming available (e.g. saline-affected soils) will help to increase aquatic production, if efficient marketing systems are provided that enable farmers to obtain the best price for their produce. The development of local marketing systems will help both consumers and producers in the long run. Although a high demand for carp still exists in the eastern part of the country, value addition through processing and the creation of products directed at non-traditional consumers is recognized as key to the success of carp culture development in India.

Aquaculture is dependent on agricultural and fishery resources for fertilizers and feed inputs. Effective utilization of the feed ingredients is an essential requirement for sustained development of the aquaculture sector in India. There will be increased competition for these agricultural by-products from the livestock and poultry sectors, and hence continued research to keep production costs low and market prices affordable to consumers is essential. Increased competition between users may lead to a rise in the cost of feed ingredients and farm inputs; hence there is a need to identify new resources that can be cost effective in aquaculture.

Climate change is expected to threaten the sustained production of agricultural commodities that are the sources of the major inputs to aquaculture. Hence, there is a need for the judicious allocation and use of available feed resources by adopting efficient feed management practices such as:

- using high conversion-efficient diets (thereby minimizing the amount of feed used per unit of fish produced);
- minimizing feed wastage;
- using alternate/mixed feeding schedules; and
- improving feed ingredient processing for better digestibility and conversion efficiency.

These improvements can only be achieved by switching from conventional feed mixtures to compounded feed pellets. The Indian carp culture industry has not moved to pelleted feeds because of the non-availability of feeds that can be used economically. This situation is changing rapidly with the establishment of a large number of feed factories, with demonstrations being given to prove the economic viability of the fed aquaculture systems.

The coming decade is expected to bring all these positive changes and an increase in carp production. With the approval of striped catfish and tilapia as aquaculture species, the aquaculture situation in India may change; however, carps will continue to dominate for at least another decade.

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