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Feeding and feed management of Indian major carps in Andhra Pradesh, India

Cover photographs:
Left top to bottom: Industrially manufactured floating pelleted feeds are made ready for broadcast feeding. A farmer tying the feed bags filled with mash feed to a rope, a method of feeding known as "rope-bag feeding" commonly practiced in Andhra Pradesh.
Right top to bottom: Harvested fish are stacked near the pond side to be packed in plastic containers for distribution throughout the state and the country. Harvest of Indian major carps, Andhra Pradesh, India. All photographs are through the courtesy of FAO/R. Ramakrishna.

Cover design:
Mohammad R. Hasan and Jose Luis Castilla Civit.

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This technical paper was edited by Mr Michael B. New for linguistic quality and technical content. For consistency and conformity, scientific and English common names of fish species were used from FishBase (www.fishbase.org/search.php). Most of the photographs in this technical paper were provided by the first author Dr R. Ramakrishna. Where this is not the case, due acknowledgements are made to the contributors.

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Abstract

This study reviews the aquaculture of Indian major carps, rohu (*Labeo rohita*), catla (*Catla catla*) and mrigal (*Cirrhinus cirrhosus*) with special reference to current feeding and feed management practices in Andhra Pradesh, India. The study is based on a survey of 106 farmers from four regions in Andhra Pradesh (Kolleru, Krishna, West Godavari, and Nellore). Kolleru and the surrounding districts of Krishna and West Godavari are the primary culture areas. In Nellore district, Indian major carp culture is practiced at a lower intensity to that practiced in Kolleru. In East Godavari district, Indian major carps are primarily cultured in polyculture systems with either black tiger shrimp (*Penaeus monodon*) or giant river prawns (*Macrobrachium rosenbergii*). While the study primarily focused on the feed management practices associated with Indian major carp production, management practices that are used under polyculture conditions with other species-groups were also assessed.

The study revealed that mash feed was the most popular and widely used feed type. De-oiled rice bran was used as the principal feed ingredient, followed by groundnut cake and cottonseed cake. All the farmers reported using de-oiled rice bran, while 56 percent used groundnut cake, 40 percent used cottonseed cake, and 30 percent used raw rice bran and other mash feed ingredients. The poor quality of the mash feed ingredients, especially the de-oiled rice bran, groundnut cake, and cottonseed cake was an important issue of concern to the farmers. Commercially manufactured pelleted feeds were used by 33 percent of the farmers to complement their mash feeds, with the majority choosing to use sinking pellets. Since 2007, there has been a marked increase in the use of commercially manufactured aquafeeds, most notably for the large-scale production of the striped catfish (*Pangasianodon hypophthalmus*).

Grow-out farmers feeding mash feeds used variants of a bag feeding method known as rope and pole feeding. In Nellore district some farmers practiced hapa feeding, while in East Godavari district, farmers fed their fish using both methods of feeding (bag and hapa). Black tiger shrimp or giant river prawns were fed in these ponds using broadcast feeding method.

In the nursery and rearing ponds, the commonly used feed ingredients included groundnut cake, de-oiled rice bran and raw rice bran. The most common feeding practice was broadcast feeding. Rohu broodstock that were collected during the breeding season were fed in a similar manner to the fish in the grow-out production systems. Catla broodstock were segregated from the other culture species, and fed a diet comprising soybean cake, dried fish, and a mineral mixture.

Constraints to Indian major carp production were identified, and research and development needs characterized.

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Contents

Abbreviations and acronyms

AI	active ingredient
B.F.Sc.	Bachelor of Fisheries Science
CCRF	Code of Conduct for Responsible Fisheries
CFU	colony forming units
cm	centimetre
COFI	Committee on Fisheries
Complex fertilizers	inorganic fertilizers containing two or three primary macronutrients (nitrogen, phosphorus and potassium)
CP	crude protein
CP (India)	Charoen Pokphand (India)
DAP	diammonium phosphate
DoA	Department of Agriculture
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FCR	feed conversion ratio
g	gram
GO	government order
ha	hectare
HCl	hydrochloric acid
ICAR	Indian Council of Agricultural Research
IMC	Indian major carps
INR	Indian rupee
IU	international units
Jaggary	a type of traditional unrefined uncentrifuged whole cane sugar
kg	kilogram
m	metre
mg	milligram
MPEDA	Marine Products Export Development Authority
NACA	Network of Aquaculture Centers in Asia-Pacific
NFDB	National Fisheries Development Board
NFE	nitogen free extract
No.	number
ppm	parts per million
ppt	parts per thousand
SD	standard deviation
SSP	single superphosphate
USFDA	United States Food and Drug Administration
US$	United States dollar
VAT	value added tax

A view of a grow-out earthen pond for carp culture in Andhra Pradesh, India. Pond sizes vary between 0.5 to 4 ha.
COURTESY OF FAO/R. RAMAKRISHNA

1. Introduction

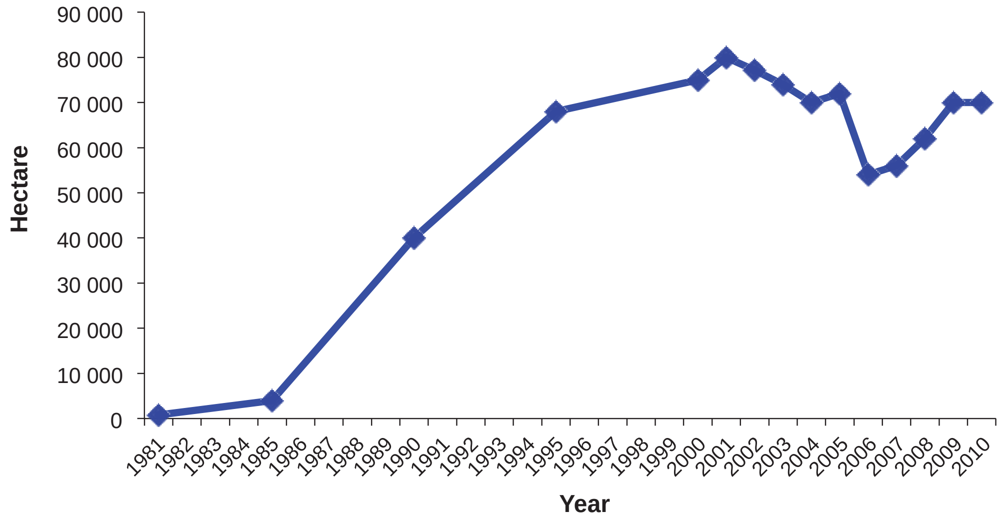
In recent years, there has been a significant expansion in commercial pond carp culture in India. While much of this development has focused on Andhra Pradesh, Punjab, and Haryana, there are several other states such as Orissa, Karnataka and Tamil Nadu where commercial carp culture is gaining momentum. Reservoirs and other freshwater bodies are becoming increasingly important production areas. By 2010, annual Indian freshwater fish production had reached 3 614 941 tonnes. Carps (Indian major, Chinese and common) comprised over 94 percent (3 417 493 tonnes) of production. Annual Asian production of the three Indian major carps, namely rohu (*Labeo rohita*), catla (*Catla catla*) and mrigal (*Catla catla*), was 4 412 078 tonnes, of which rohu comprised 1 133 233 tonnes; catla 2 976 820 tonnes and mrigal 302 025 tonnes (FAO, 2013). About 70 percent (3 071 874 tonnes) of the production of the three Indian major carps is associated with India. Both monoculture and polyculture systems are described in this report. The scientific and common names of the fish species used in these systems are provided in Annex 1.

Indian major carps are widely cultured across Bangladesh, Myanmar, Nepal and Pakistan. Both rohu and catla have been introduced as exotic species into nine non-native countries and mrigal into seven (Welcomme, 1988). Until the nineteenth century, carp culture was confined to backyard ponds in the eastern Indian states of West Bengal, Orissa and Bihar. At the time, the seed was harvested from the local rivers. In 1957, hatchery and hypophysation breeding technologies were developed, and this provided the impetus for a new era of carp culture in the country. Between 1963 and 1984, the successful demonstration of polyculture systems based on Indian and Chinese carps by the Central Inland Fisheries Research Institute in West Bengal (Jhingran, 1991), and a successful demonstration programme by the Fish Farmer Development Agencies resulted in the commercialization of the technologies.

In Andhra Pradesh, pond culture was initiated in the Kolleru lake region in 1976. Initially, 133 fish ponds covering an area of 2 040 ha were constructed by the State Government. The initial successes that were achieved by a few private farmers encouraged large numbers of people in Krishna and West Godavari districts to take up commercial fish farming in and around Kolleru lake. Other factors that contributed to the rapid development of the sector included the frequent flooding of the agricultural land, increased labour costs, and a concomitant low return from traditional paddy crops. By 1981, several fish farms ranging from 2 to 100 ha were operating in the region (Gopal Rao, 1987). Since 1981, the area under aquaculture has continued to expand. This has resulted in the conversion of about 5 000 ha of flood-prone fallow land to pond farming, and in some areas, agricultural fields have also been converted for this purpose. Most of the carp culture in Andhra Pradesh is located in and around Kolleru Lake (Nandeesha and Gopal Rao, 1989). By 1985, fish culture had expanded to other irrigated areas in Krishna and Godavari districts, and on a smaller scale to Nellore, Guntur, Prakasam and East Godavari districts. The recent growth of the sector around Kolleru Lake and the surrounding districts of West Godavari and Krishna is presented in Figure 1.

In 2001, the area under Indian major carp production peaked at 80 000 ha. While the production area was reduced in subsequent years, new production areas were developed, and by 2010, the area under production once more reached 80 000 ha. With the gradual expansion of striped catfish culture, 10 000 ha that had originally been used for Indian major carp production was converted to monoculture or to mixed striped

FIGURE 1
Estimated culture area of Indian major carps in Andhra Pradesh between 1981 and 2010

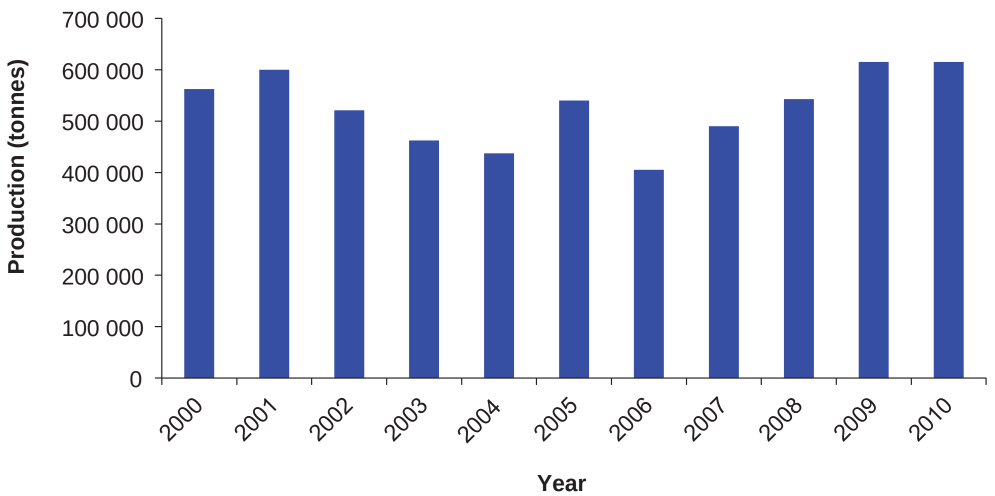


Source: Field survey (2010).

catfish production. In 1994–1995, the striped catfish was introduced into Andhra Pradesh from Bangladesh *via* West Bengal, India. At present, the total area under striped catfish production in the state is estimated to be 32 000 ha (Gopal Rao, 2010). Observations made during the current study indicate that the culture of both Indian major carps and striped catfish is expanding across West Godavari, Krishna, East Godavari and Nellore districts.

Kolleru Lake and the surrounding areas of West Godavari and Krishna districts are currently the centre of Indian major carp and striped catfish production. In East Godavari and Nellore districts, an estimated 4 000 ha are under Indian major carp production, with a further 4 000 ha under striped catfish production. The historical production of Indian major carps from Andhra Pradesh is presented Figure 2. Approximately 700 000 tonnes of Indian major carps are currently produced in the state. Much of the production is traded, mainly by road transport to 19 Indian

FIGURE 2
Estimated production of Indian major carps in Andhra Pradesh between 2000 and 2010



Source: Field survey (2010).

TABLE 1
Trading of Indian major carps from Andhra Pradesh to other Indian states

Name of the state	Quantity (tonnes)
West Bengal	259 200
Assam	81 000
Jarkhand	48 600
Bihar	48 600
Maharashtra	48 600
Orissa	25 920
Gujarat	19 440
Uttar Pradesh	16 200
Chhattisgarh	12 960
Madhya Pradesh	9 720
Delhi	9 720
Tripura	9 720
Nagaland	6 480
Rajasthan	6 480
Manipur	3 240
Arunachal Pradesh	3 240
Uttaranchal	3 240
Kerala	1 620
Tamilnadu	1 620

Source: Field survey (2010)

TABLE 2
Important fish processing and packing centres in the Kolleru lake region

Name of the centre	Quantity processed (tonnes)
Nidamarru	49 730
Ganapavarm	38 820
Akividu	99 450
Bhimavaram	198 930
Eluru	49 730
Gudivada	23 050
Kaikaluru	76 420

Source: Field survey (2010).

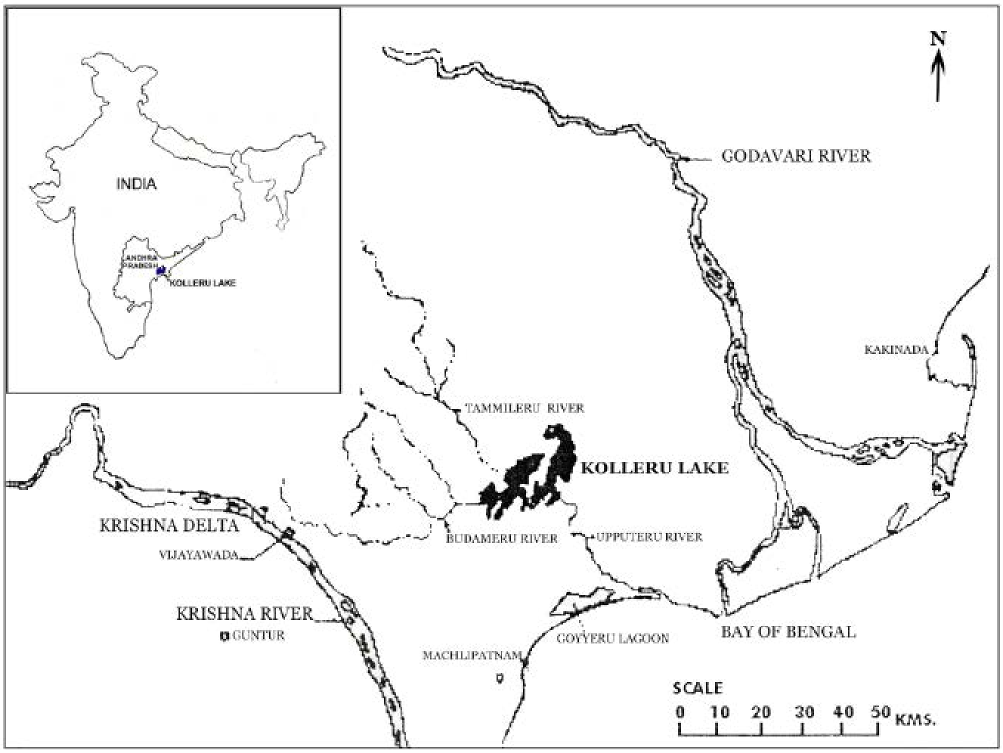
states, encompassing almost all of the country (Table 1). There are seven important fish processing and packaging centres in the Kolleru lake region, where the fish is segregated size- and species wise, preserved in ice, packed and, made ready to be sent to other Indian states (Table 2).

1.1 THE KOLLERU LAKE

The Kolleru Lake, a Ramsar lake, is a wetland eco-system of international repute. This is the largest freshwater lake in India (Plate 1). The lake, with an area of 954 square km at plus ten contour, is situated between West Godavari and Krishna districts of Andhra Pradesh. The lake includes parts of Eluru, Bhimadolu, Akiveedu, Denduluru, Unguturu, Pedapadu, Nidamarru revenue regions (locally called *mandals*) of West Godavari and parts of Kaikaluru and Mandavalli revenue regions of Krishna district (Mittal, 1993).

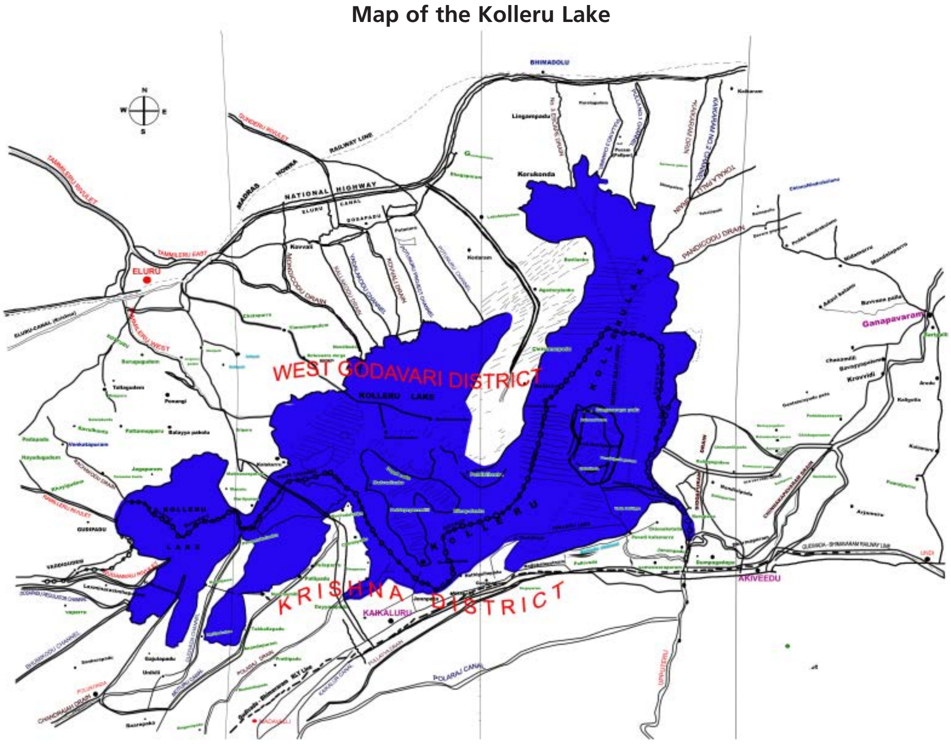
Water depth in the lake varies between 1 to 1.6 m in most periods of the year, but reaches 3 to 4 m during high floods. The lake receives water from the catchment area comprising 3 405 km^2 upland and 1 360 km^2, delta. Freshwater enters the lake through four rivulets - Budameru, Thammileru, Ramuleru and Gunderu. Besides, 30 major irrigation channels and agricultural drains flow into the Kolleru Lake. The lake empties into the Bay of Bengal through a 63 km long creek, Upputeru (Plate 2).

PLATE 1
Location of the Kolleru lake area in Andhra Pradesh



Source: Durga Prasad and Padmavathi (2003).

PLATE 2
Map of the Kolleru Lake



Source: Ramakrishna (2007).

Traditionally, Kolleru Lake has been a rich wild fisheries resource. Capture fisheries production was 7 000 tonnes in 1974. During the years of normal environmental conditions the production contributed by fish other than carps was about 50 percent, and freshwater prawns and carps was 30 percent and 10 percent respectively (Venkateswara Rao *et al.*, 2003).

1.2 WATER SOURCES

In West Godavari, Krishna and East Godavari districts, fish farmers are only permitted to draw water from the agricultural drains. These comprise a network of earthen canals through which the discarded water from agricultural fields is channelled. Farmers pay an annual charge of INR500 (US$10.63[1]) to use this water. The ponds or farms are registered by the state government, with registration being provided on the written assurance that the farmer uses only drainwaters released from agricultural fields, and is not drawing water from the irrigation canals that supply water directly to the agricultural fields. In Nellore district, water for fish culture is either drawn from irrigation canals and drains, or from boreholes; boreholes represent a major water source here.

1.3 ORGANIC MANURES AND INORGANIC FERTILIZERS

Manures and fertilizers play a key role in Indian major carp production. The two most common organic manures are poultry manure (dried poultry litter), followed by dried cattle manure. These manures are abundant in the state and are available throughout the fish culture areas - Andhra Pradesh is an agrarian state, with a large cattle population, and it is the largest poultry producer in the country. Poultry manure is supplied to the farmers through dealers, who maintain contacts with the commercial poultry farms located across the state. The price paid by the farmer for poultry manure is INR1 250/tonne (US$26.4/tonne), plus transport and labour charges for unloading the manure at the farm site of INR250 to 300/tonne (US$5.3–6.4/tonne) and INR150/tonne (US$3.2/tonne), respectively. The dealer retains a commission of INR200–300 (US$4.3–6.4) per 10 tonnes of poultry manure delivered. Cattle dung is usually procured from local farmers in the vicinity of the carp farms. Dealers are not used in the distribution chain, but rather local tractor owners. The tractor owners collect the manure from the farms, and transport it distances of 5 to 20 km. Two to three tonnes of cattle dung can be transported by a tractor at any one time. The farmers buy the cattle manure for INR360/tonne (US$7.7/tonne). In addition to the transport charges, the tractor owners retain a commission of INR75–100/tonne (US$1.6–2.1/tonne). The commission is paid by the seller.

Among the chemical fertilizers that are available, single superphosphate (SPP), diammonium phosphate (DAP) and urea are the most widely used fertlizers. However, potash (potassium) and complex fertilizers[2] are also used. These fertilizers are commonly used in rice production and for other crops. Both groups of farmers (arable and fish farmers) purchase chemical fertilizers from local dealers (state authorized), or local agricultural cooperative stores. These are under the control and regulation of the district agricultural officers. During periods of shortage, the agricultural officers ensure that the chemical fertilizers are sold exclusively to the arable farmers, and thus the fish farmers have to wait until there are sufficient stocks or, alternatively, purchase them at higher prices from the rice farmers.

1.4 ELECTRICITY

Fish farmers use electricity to aerate their ponds. Electricity is usually supplied for seven hours a day; however, as a result of shortages, supplies are often intermittent. The farmers indicated a need for a continuous supply of electricity or, at the very least, an uninterrupted supply between 2100 to 0800 hours; during this period, and under

[1] US$1 = Indian Rupee (INR) 47.03 as of July 2010.

[2] Inorganic fertilizers containing two or three primary macronutrients (nitrogen, phosphorus and potassium) are known as complex fertilizers.

high stocking levels and in the presence of algal blooms, the dissolved oxygen levels in the pond waters often fall to critical levels. At these times electricity is required to operate the mechanical aeration systems. A failure to supply electricity at these times can result in crop losses.

1.5 SOURCES OF FINANCE

The main sources of finance in Andhra Pradesh are the nationalized banks, the district co-operative central banks, and the private sector.

1.5.1 Nationalized banks

The nationalized banks have an almost uniform policy of granting loans to fish farmers in the state. The banks sanction an amount of INR100 000/ha (US$2 126/ha) for farm construction, and INR400 000/ha/crop (US$8 504/ha/crop) as a loan. Annualized interest rates of 18 percent are charged against the mortgage of the farmers' land. The loan sanctioned for pond construction is known as a 'term loan', which may be repaid within three to seven years, as opted by the farmer. The 'crop loan' is repaid after the crop is harvested. Farmers are eligible for new 'crop loans' once they have repaid any outstanding loan. In the event that a lessee has a valid agreement signed by a pond or farm owner for a period of five consecutive years, the lessee is also eligible to obtain 'crop loans' from the nationalized and local co-operative banks.

1.5.2 Co-operative banks

At present, the co-operative banks grant working capital to meet production costs for a maximum period of one year. They do not finance development costs such as those associated with pond construction. The level of finance is calculated according to the pond size, and currently stands at INR275 000 to 300 000/ha (US$5 847–6 379/ha) for Indian major carp production, and INR550 000/ha (US$11 695/ha) for striped catfish production.

1.5.3 Private financiers

In the Kolleru lake area, the villages have formed co-operative societies. These have not been formally registered but have been developed by mutual understanding between the participants. Each of the co-operative bodies, locally known as 'Bantas', comprise 40 to 50 members and collectively culture ponds of 15 to 20 ha. In the past, the executive committee of the 'Banta' obtained the loans required to cover one year's production costs from private financers. Typically, annual interest rates were 36 percent. Private financiers do not usually require collateral, and the loans are primarily provided on the ability to repay the loan and the personal creditability of the farmers. The net profit is shared equally by all the members of the 'Banta'. In recent years, a variation of the 'Banta' management system has developed in which members lease out their ponds to a group of four to five villagers who raise the capital required to culture a crop. The revenue that accumulates to the lease is subsequently shared by the members of the 'Banta'. Of all Indian major carp culture areas in Andhra Pradesh the rents are the highest in the 'Banta' villages. The farmers in the Kolleru area represent a relatively rich class, and currently the 'Banta' farmers borrow money from these farmers at an annual interest rate of 18 percent - these are significantly lower rates than are currently available from the private financiers.

1.5.4 National Fisheries Development Board

In July 2006, the National Fisheries Development Board (NFDB) was established in Hyderabad, Andhra Pradesh. The NFDB is an autonomous organization working under the administrative control of the Department of Animal Husbandry, Dairying and Fisheries, the Government of India. The overall objective of the board is to empower all states and union territories to develop their fisheries and aquaculture sectors, and to provide financial support to stakeholders, primarily through the use of subsidies.

The NFDB is mandated to provide financial assistance to establish large (5 tonnes/ha), medium (2 tonnes/ha), and small (1.2 tonnes/ha) scale aquafeed production units. Loans of up to 40 percent for machinery and building costs are available for the large- and medium-scale units. An annual interest rate of five percent is levied on the loans. For the small-scale units, a subsidy of 20 percent of the total unit cost (approximately INR750 000; US$15 950), with a limit of INR150 000/unit (US$3 480/unit), is provided.

The estimated unit cost for the construction of a new pond for aquaculture is INR300 000/ha (US$6 382/ha). NFDB provides a general subsidy of 20 percent of this cost but with a ceiling of INR60 000/ha (US$1 367/ha). However, for the farmers who belong to scheduled castes and scheduled tribes the ceiling for subsidy is INR 75 000/ha (US$1 595/ha). These special support measures are designed to improve the socio-economic status of the socially and economically marginalized sections of society. In terms of subsidizing input costs for carp culture, the NFDB sanctions INR50 000/ha (US$1 604/ha), or a 20 percent subsidy, over a single production cycle. In contrast, the input subsidies for striped catfish culture are INR500 000/ha (US$10 638/ha), or a 40 percent subsidy, for an initial two years of production; thereafter subsidies are reduced to 20 percent for standard farmers, and 25 percent for the special category farmers. The NFDB also provides financial assistance to renovate old or redundant ponds, and for fish seed farms, as well as providing assistance to establish fish, giant river prawn and black tiger shrimp hatcheries. In addition, the NFDB provides grants to the government fishery institutes and other eligible agencies for conducting training and demonstration programmes.

1.6 INSURANCE SERVICES

There are four insurance companies in the state that provide crop insurance services to the aquaculture sector. Crops valued between INR75 000 to INR250 000/ha (US$1 595–5 320/ha) can be insured. The insurance is valid for a maximum period of 12 months, and is restricted to the period in which the crop is under production, irrespective of the duration of the production cycle. Premiums are set at 0.75 percent of the sum insured. While the insurance is usually offered as a component of a bank loan that is issued to the farmer, it is optional on the part of the farmer whether to accept the insurance or not. Independent crop insurance is also available to farmers that do not require bank loans. Four National Insurance companies, all of which are public institutions, offer this type of insurance service.

Very few farmers insure their crops on a regular basis. The primary reason for this lack of interest is that the insurance companies only pay out for stock losses when 80 percent or more of the crop is lost, and losses can only be claimed for causes specified in the insurance agreements. Farmers strongly believe that the insurance coverage would be more beneficial and attractive to them if partial losses were also covered. The insurance companies are not disposed to paying partial losses as they claim that they are difficult to estimate. A processed claim is usually settled within one month of submission of the claim, and the insurance companies calculate the claim according to the market price of the fish (size) at the time of mortality. Transport insurance is also available. The insurance premium for transporting fish is currently 0.5 percent of the retail price of the fish.

1.7 REGULATIONS

The existing and proposed regulations national and the Andhra Pradesh state governments related to Indian major carp production are presented in Table 3.

TABLE 3
The regulations or interventions applicable to Indian major carp production in Andhra Pradesh State

Regulation, regulatory authority or interventions	Issues and actions to addressed in the regulations and interventions	Reference / source
Freshwater aquaculture regulation (The Andhra Pradesh state government)	• Register (compulsory) freshwater culture ponds and farms • Appoint district and state level committees to assess and register farms • Resolve water supply issues from irrigation canals, boreholes and other natural resources • Regulate the conversion of agricultural lands to aquaculture • Regulate the construction of fish ponds and farms, and the use of freshwater • Restrict stocking densities to 7 500 fish/ha. • Regulate fish and prawn species permitted under the Seed Control Act, 2004 (enacted by the Andhra Pradesh State Government) • Prohibit the use of twenty antibiotics and pharmacologically active substances that are banned by the Government of India • Promote environmentally-friendly and sustainable freshwater aquaculture • Maintain records of all the inputs used during each culture cycle, and the addresses of persons to whom the product is sold	Government Order (GO) Ms Number (No.) 83, dated 12 September 2007; GO Ms. No. 18, dated 26 March 2007; GO Ms. No. 58, dated 26 April 2008; and GO Ms. No. 108, dated 3 November 2008.
Seed quality control regulations (The Andhra Pradesh State Government)	• Regulate the appointment of seed committees at district and state levels • Permit all culture species in the state • Regulate the establishment of seed testing laboratories at the regional and state levels • Notify farmers of the different culture species that are suitable to different geographical regions of the state, and advise the farmers accordingly • Ban and prohibit the collection of wild seed from natural water bodies • Specify standards for size, quality, health status, and the labelling of seed for all culture species • Regulate seed sales and marketing • Delegate powers and functions to seed committees to recommend and certify hatcheries, nurseries, and other seed rearing facilities	Aquaculture Seed (quality control) Act, 2006 (Act 24 of 2006), enacted by the Andhra Pradesh State Government.
Declaration of a wildlife sanctuary (The Andhra Pradesh State Government)	• Declare the area between the zero and the five metre contour (above the mean sea level) around Kolleru Lake as a wildlife sanctuary • Remove of all obstructions/developments* located in Wild Life Sanctuaries; this includes fish ponds and associated facilities, e.g. feed storage and residential facilities, boat landing structures etc. • Demolish 2 916 fish ponds covering an area of 29 470 ha in the wild life sanctuary (Ramakrishna, 2007)	Government Order (GO) Ms. No. 120.
Wetland regulations (The Government of India)	• Draft regulatory framework formulated for the conservation of wetlands in India, including Kolleru Lake • Form wetland regulatory committees at the district, state and central government levels • Regulate the prohibition of activities that convert wetlands to non-wetland use; the reclamation of wetlands; the storage or disposal of notified hazardous substances; the discharge of effluents from industries, agricultural fields and human settlements; the construction of permanent structures; the withdrawal, impoundment, diversion and interruption of water sources; and the harvesting of living and non-living resources	Draft regulatory framework for wetland conservation (Wetlands (conservation and management) rules 2009.
The prevention and control of water pollution (The Government of India)	• Prohibit the establishment of any industry, operation or process, or any treatment or disposal system, including the effluents derived from fish ponds without the consent of a control board established at a state level	Water (prevention and control of pollution) Act, 1974.
Pre-shipment inspection of Indian fish and fishery export products (The Government of India)	• Defines pre-shipment inspection and certification of fish and fishery products, including the freshwater fish exported to other countries, by the Export Inspection Council and Export Inspection Agencies	Export (Quality control and Inspection) Act, 1963.

TABLE 3 (CONTINUED)

Regulation, regulatory authority or interventions	Issues and actions to addressed in the regulations and interventions	Reference / source
Banning of certain antibiotics and other pharmacologically active substances (The Government of India)	• Bans the use of 20 different antibiotics and pharmacologically active substances in culture or hatchery feeds, processing of prawns, shrimp or any other variety of fish and fishery products (Annex 2)	Notification of the Ministry of Commerce, the Government of India, dated 10 July 2002.
Preparation of a panel of pathologists to prescribe medicines to treat fish diseases and the related issues. (Coastal Aquaculture Authority of India)	• Restructure the Bachelor of Fisheries Science (B.F.Sc.) degree syllabus to include a course on aquaculture veterinary medicine to enable fish pathologists to prescribe aquaculture therapeutants • Provide pharmacology and clinical training to existing fishery science graduates • Promote the production of aquaculture medicines according to specified pharmacological norms • Conduct clinical trials of aquaculture medicines permitted in other countries/FAO/USFDA/EU, at the National Fishery Institutes in India • Promote the labelling of aquaculture medicines, clearly indicating their composition, active ingredients, treatment modalities, side effects, and withdrawal periods • Approve the production of aquaculture medicines	Conference recommendations by the Coastal Aquaculture Authority of India, to the Government of India, 29th April 2010.
Ban on unauthorized introduction of exotic fish species into India. (The Government of India)	• Bans the import of the North African catfish, *Clarias gariepinus*	Notification of the Ministry of Agriculture, the Government of India, dated 19 December 1997.

Source: Field survey (2010).

* Any constructions and structures of a permanent nature built by fish farmers or others.

The Marine Product Expert Development Authority (MPEDA) is mandated to prescribe nutrient standards in aquafeeds, including the maximum allowable levels of pesticides and anti-nutritional factors (e.g. aflatoxins) in starter, grower and finisher shrimp feeds. Under Schedule 1 (Section 7) of the import regulation of the commercial tax department of the Andhra Pradesh state government, compound aquafeeds and poultry and cattle feeds are exempted from value added tax (VAT). The regulations and rules of the Department of Weights and Measurements of the Andhra Pradesh state government are applicable to aquafeeds and the feed ingredients sold to farmers.

1.8 FEED AND NUTRITION RESEARCH CAPACITY

Indian Council of Agricultural Research (ICAR) operates a number of national fisheries institutes across the country, including those in Andhra Pradesh state. In addition, nutrition, feed development and feed management research is undertaken at fisheries research stations, fisheries colleges of the state Agricultural and Veterinary Universities, and at zoology and aquaculture University departments. Current research areas include the improvement of dietary and low-cost feed formulations, digestive physiology, the development of mixed feed schedules for carps, and an evaluation of the nutritional role of selected aquatic weeds in carp diets. While the results of this research have been important and useful, available technical expertise to develop semi-intensive commercial pond culture technologies remains inadequate and, notably, the technical capacity required to develop feeds and improve feed management practices is lacking.

1.9 THE CARP CULTURE SYSTEMS USED IN ANDHRA PRADESH

The semi-intensive carp culture system, popularly known as ‘Kolleru carp culture’, operates at production levels of between 7 000 to 10 000 kg/ha/annum. In the Kolleru region, an estimated 700 000 tonnes of carp is produced per annum. The pond systems are based on two culture species, *viz.* rohu and catla. These species are stocked at ratios of 80 to 90 : 10 to 20 (rohu : catla) with the occasional addition of mrigal. Typically the systems are stillwater systems that require relatively high levels of feed and fertilizer inputs. These culture systems have been adopted by thousands of farmers, and employ many more in associated supply and service industries (Plate 3).

PLATE 3

Important components and activities in Indian major carp culture in Andhra Pradesh Clockwise: fish farmers, pond management, supplementary feeds, chemical fertilizers, organic manures, seed production, harvest, ice manufacture, packing materials, short and long distance transport, and harvested fish (centre)]

The Kolleru carp culture system has become the dominant production model for Indian major carp culture. The production system has been replicated in many states, initially in Punjab and Haryana, and subsequently in Orissa, Tamil Nadu, and Karnataka. The technology has also been adopted in Myanmar where large scale production systems have been developed.

A description of the types of culture systems that have been used, or are under development, demonstrates the diversity and complexity of the culture systems that can be applied to the species group. It should be noted that some of the culture systems described in this section are no longer in use. However, these systems are included in the analysis as they provide insight into the historical development of on-farm feed and feed management practices. The descriptions of the culture systems are not exhaustive, and many variants have been developed. For example, in recent years, an increasing number of farmers have decided to re-introduce mrigal, common carp (*Cyprinus carpio*) and the grass carp (*Ctenopharyngodon idella*) to their production systems. These species are stocked at densities of 125 to 250/ha. The silver carp (*Hypophthalmichthys molitrix*) generally remains absent from the culture mix. The species used are illustrated in Plate 4.

The scientific and common names of fish species used in aquaculture in Andhra Pradesh are presented in Annex 1. The local and standard names of the aquaculture production systems and the feed types that are used in these systems are listed in Table 4 and full descriptions of each type of production system are provided in sections 1.9 to 1.14.

PLATE 4
Fish species used in Andrha Pradesh carp culture systems
Top row left to right: *Labeo rohita* (rohu), *Catla catla* (catla), *Cirrhinus cirrhosus* (mrigal)
Middle row left to right: *Ctenopharyngodon idella* (grass carp), *Cyprinus carpio* (common carp), *Hypophthalmichthys molitrix* (silver carp)
Bottom row left to right: *Pangasianodon hypophthalmus* (striped catfish) and *Piaractus brachypomus* (pirapatinga)

TABLE 4
Local and standard names of the aquaculture production systems and the type of feed used in them*

Local name**	Standard name	Feed used***
Initial culture	***Semi-extensive polyculture***	Mash
	On-growing semi-extensive polyculture – IMC - exotic (Chinese and common) carps	
Typical culture	***On-growing semi-intensive polyculture***	
Typical culture - IMC	On-growing semi-intensive polyculture - IMC	Mash
Typical culture - IMC: Nellore	On-growing semi-intensive polyculture - IMC: Nellore	Mash
Typical culture - IMC	On-growing semi-intensive polyculture - IMC	Mash - pellet
Typical culture - IMC: Nellore	On-growing semi-intensive polyculture - IMC: Nellore	Mash - pellet
Typical culture - IMC	On-growing semi-intensive polyculture - IMC	Pellet
Typical culture - IMC - striped catfish	On-growing semi-intensive polyculture - IMC - striped catfish	Mash
Typical culture - IMC - striped catfish	On-growing semi-intensive polyculture - IMC - striped catfish	Mash - pellet
Zero point culture	***Semi-intensive polyculture fattening***	
Zero point culture - IMC	Semi-intensive polyculture fattening - IMC	Mash
Zero point culture - IMC	Semi-intensive polyculture fattening - IMC	Mash - pellet
Zero point culture - IMC - striped catfish	Semi-intensive polyculture fattening - IMC - striped catfish	Mash
Zero point stock culture	***Semi-intensive juvenile polyculture***	
Zero point stock culture - IMC	Semi-intensive juvenile polyculture - IMC	Mash
Polyculture systems	***Polyculture grow-out systems***	
Polyculture - IMC - exotic carps	Semi-intensive polyculture - IMC - exotic (Chinese and common) carps	Mash
Polyculture - IMC - giant river prawn	Mixed culture - IMC - giant river prawn	Mash - pellet

TABLE 4 (CONTINUED)

Local name**	Standard name	Feed used***
Polyculture - IMC - black tiger shrimp	Mixed culture - IMC - black tiger shrimp	Mash - pellet
Polyculture - IMC - pirapatinga - exotic carps	Polyculture - IMC - pirapatinga - exotic (Chinese and common) carps	Mash – pellet
Polyculture - IMC - pirapatinga - striped catfish	Polyculture - IMC - pirapatinga - striped catfish	Mash - pellet
Nursery, juvenile and broodstock systems	***Nursery, juvenile and broodstock systems***	
Nursery - IMC	Nursery culture - IMC	Mash
Rearing - IMC	Juvenile culture - IMC	Mash
Broodstock - IMC	Broodstock and brood fish culture - IMC	Mash

Source: Field survey (2010).

* The acronym IMC, used in this table and throughout the remainder of the paper refers to Indian major carps.

** The term Kolleru carp culture is also used and refers to the totality of all Indian major carp culture systems from secondary nursery culture to semi-intensive polyculture currently practiced in the Kolleru lake and surrounding areas of West Godavari and Krishna districts.

*** The term 'mash', which includes rice bran and other ingredients, is fully defined later in this document (see section 3.3.1).

1.10 SEMI-EXTENSIVE POLYCULTURE OF INDIAN MAJOR AND EXOTIC CARPS (INITIAL CULTURE)

In semi-extensive polyculture systems, six (Indian major, Chinese and common) carp species are cultured (Veerina, Nandeesha and Gopal Rao, 1993). These species comprise rohu (25 to 30 percent), catla (10 to 15 percent), mrigal (15 to 20 percent), silver carp (20 to 30 percent), grass carp (5 to 10 percent) and common carp (10 to 20 percent).

Semi-extensive polyculture was introduced to the region in 1984; this followed a period in which farmers stopped producing the Chinese carps. The system is characterized by low stocking densities, good water quality, low feed inputs, and a concomitant low level of production. Typical stocking densities for rohu and catla are 2 000 to 3 000 fish/ha and 250 to 300 fish/ha respectively. Both species are stocked at 5–10 g. Harvest sizes range from 1 to 1.25 kg for rohu, and 2 to 2.5 kg for catla. Production volumes range between 2 000 to 3 000 kg/ha/year and 500 to 600 kg/ha/year for rohu and catla respectively. Total annual production from these systems is 2 500 to 3 600 kg/ha/year, and the average quantity of poultry manure and cattle dung that is required is 18 750 kg/ha/year and 2 000 kg/ha/year respectively. The chemical fertilizers required per hectare per annum are as follows: SSP (760 kg/ha/year); urea (440 kg/ha/year); DAP (380 kg/ha/year); complex fertilizers (200 kg/ha/year); and potash (220 kg/ha/year). The mean quantity of supplementary feed required to produce 2 500 to 3 600kg/ha/year of product is 4 800 to 7 200 kg/ha/year. Food conversion ratios were typically recorded at 1.8 to 2.0:1.

1.11 ON-GROWING SEMI-INTENSIVE POLYCULTURE (TYPICAL CULTURE)

On-growing semi-intensive polyculture systems generally stock larger stunted yearlings of 50 to 125 g. As these are yearlings, the production system is also known as yearling-based culture.

Stocking densities of rohu and catla range between 5 000 to 6 750 fish/ha and 550–800 fish/ha respectively. The fish are harvested at 1 to 2 kg (rohu) and 2 to 3 kg (catla). Production volumes range between 6 600 to 8 400 kg/ha/year. The quantity of feed required to achieve this level of production is 17 160 to 26 880 kg/ha/year, equating to feed conversion ratios (FCR) of 2.6 to 3.2:1.

1.12 SEMI-INTENSIVE POLYCULTURE FATTENING (ZERO POINT CULTURE)

Rohu and catla are generally harvested at 1 kg and 2 kg respectively. On occasion, farmers are forced to undertake emergency harvests of fish that are smaller than 1 kg. Emergency harvests are undertaken as a result of poor water quality (oxygen depletion), uncontrollable disease outbreaks, or as a result of poor growth associated with the chronic presence of toxic phytoplankton in the ponds. In the fish trade, farmers and buyers refer to these prematurely harvested fish as 'zero point size'. In general, zero point sizes for rohu and catla are categorized as 200–500 g and 250–1 000 g fish respectively. In the past, zero point size fish fetched lower prices than fish that had been grown to standard market sizes. For example, farmers used to be paid INR13 to 15 kg (US$0.27–0.32 kg) for zero point size and INR30 to 35 kg (US$0.63–0.74 kg) for standard market sized fish.

Around 1995, a number of innovative farmers started buying healthy zero point rohu and catla. These farmers made these purchases from farmers that were harvesting their fish prematurely. The innovative farmers developed a production system in which they cultured the fish for a further six to seven months. The zero point production paradigm is most advantageous to those farmers that have production facilities that are designed to produce stock material for zero point culture. If these systems are not in place, the farmer has to purchase their stock (INR40 to 50/kg; US$0.85–1.06/kg). In addition to the relatively short culture period, the main advantage of zero point culture is that the returns on investment are faster, and the production scenario enables the farmers to grow larger fish that are preferred by consumers. The usual stocking density applied to zero point culture is around 5 000 to 6 000 fish/ha (both species), and is thus lower than that used in typical semi-intensive grow-out systems. Typically, production ranges between 8 000 and 10 000 kg/ha/year. The FCR range between 2.5 to 3.2:1. Farm management practices, and most notably the use of feeds and feed management practices, are similar to those applied to the typical culture paradigm.

1.13 SEMI-INTENSIVE JUVENILE POLYCULTURE (ZERO POINT STOCK CULTURE)

The development of zero point culture has resulted in the emergence of a new class of farmer that produces zero point rohu and catla stock to sell onto zero point grow-out farmers. In general, it was the farmers that had two to four hectares of ponds that adopted zero point stock culture. The other farmers that practised this form of culture were the black tiger shrimp farmers who leased their ponds from village administrations. These farmers had access to one to two hectares of ponds (depth 1 to 1.5 m) and a source of freshwater. The village ponds are multipurpose ponds in which feeding and fertilization is not allowed. The fish in these ponds are therefore grown at relatively low stocking densities, and the natural productivity of the ponds provides the feed.

Fish are stocked at 5–10 g, and are cultured for approximately 120 days. Rohu are stocked at a density of 20 000 to 25 000 fish/ha, and catla at 1 500 to 2 000 fish/ha. Typical production levels of 8 000 to 12 000 kg/ha/year are achieved over a three to four crop cycle. In order to minimize feed costs, the farmers usually restrict their feeding to rice bran. Oil cakes may be used during last phase of the production cycle. The ponds are fertilized to promote primary productivity and natural feeds.

1.14 POLYCULTURE GROW-OUT SYSTEMS (SEMI-INTENSIVE POLYCULTURE AND MIXED)

1.14.1 Polyculture - Indian major carps, tiger shrimp and river prawns

Since 1990, Indian major carps as a principal or secondary crop have been cultured with black tiger shrimp in East Godavari district. Likewise, since 2000, polyculture systems based on a combination of Indian major carps and giant river prawns have been used in Nellore and East Godavari districts. While the black tiger shrimp is a marine-brackish water species, Indian major carps are freshwater species. The postlarvae, juveniles and adults of giant river prawns are also cultured in freshwater. As a consequence of their salinity tolerances, it is possible to culture combinations of these species groups at salinities of up to 10 ppt. For example, Boyd and Thunjai (2003) reported that tiger shrimp could be cultured in inland ponds at salinities of 2 to 5 ppt. Boyd (2002) defined low-salinity culture as the cultivation of tiger shrimp in waters of 10 ppt salinity or less, and Allan and Fielder (2009), reported the potential for giant river prawn culture in saline groundwater of 4 ppt. In contrast, common carp performs well in salinities as high as 7 ppt (Garg, 2004), and in West Godavari district the species is cultured in salinities ranging between 1 and 10 ppt. These ponds are supplied with both brackishwater and freshwater sources, and while they had originally been designed for tiger shrimp culture, they were subsequently converted to Indian major carp production. Some farmers also use these ponds for striped catfish culture.

1.14.2 Semi-intensive polyculture: Indian major carps and exotic fish

In 1995, the striped catfish (*Pangasianodon hypophthalmus*) (commonly known as pangus in Andhra Pradesh) was introduced by seed sellers from Bangladesh, *via* West Bengal, India. Due to their comparatively high growth rates and levels of productivity, farmers started to incorporate the species into their Indian major carp polyculture systems. Over time, they started to be grown in isolation, and by now striped catfish monoculture has developed as the second most important culture system in the state. Production is currently estimated at 400 000 tonnes per annum, and is increasing.

In 2008, pirapatinga (*Piaractus brachypomus*), commonly known as 'roopchand', was introduced into the carp culture systems. The species was initially introduced into West Godavari district, and more recently to Krishna and East Godavari. Currently, Indian major and Chinese carps and striped catfish polyculture using pirapatinga as the primary culture species, is practiced in about 400 ha of ponds in West Godavari district.

1.15 NURSERY, JUVENILE AND BROODSTOCK SYSTEMS

1.15.1 Nursery systems

During the establishment of Indian major carp sector, the majority of farmers adopted a three tier culture system comprising nursery, rearing and grow-out production units. Typically, the nurseries were 0.05 to 0.25 ha. Currently, the nurseries have grown into larger operations and can now be as large as 4 ha. Pond depths range between 1 to 1.25 m. Three day old (yolk-sack absorbed) larvae or spawn is purchased from the hatcheries, stocked into the nursery ponds, and grown to 25 mm fry over a 20 to 30 day period.

The larvae of each species are stocked separately. Stocking individual species facilitates their harvest and sale, as buyers choose to purchase their species separately. The mean stocking densities for rohu and catla are 3 302 866 larvae/ha (range 494 200 to 7 413 000 larvae/ha) and 3 314 775 larvae/ha (range 1 976 800 to 6 177 500 larvae/ha) respectively. While mrigal is stocked by a limited number of farmers, the mean stocking density applied is 432 450 larvae/ha. Usually farmers base nursery stocking density not only on the pond area but also on the size of fry to harvest. For example, they prefer a lower stocking density if they aim to produce bigger size fry at the end of a given culture period; but they prefer a higher stocking density if they aim to produce relatively smaller size fry at the end of the same culture period. In nursery production systems also the types of manures and fertilizers, and types of supplementary feeds used are similar as used in grow-out systems.

1.15.2 Juvenile culture

Two stages of juvenile culture are described in this section. The first describes growing 0.5 to 1 g fry to fingerlings (20–25 g) over a two to four month period. The second describes growing the fingerlings to stunted yearlings over a further 10 to 12 months.

The ponds used to culture juvenile fish range from 0.4 to 4 ha (mean 1.5 ha). Water depths range between 1.25 to 1.5 m. During the first culture stage, the mean stocking densities of rohu and catla fry are 293 460 fry/ha (range 170 050 to 993 400 fry/ha). The pond preparation and fertilization practices that are used to promote natural food production are similar to those used during the nursery production phase. The exception is the increased use of organic and inorganic fertilizers. In terms of organic manures, up to 4 000 kg/ha of poultry manure and, where cattle dung is used, up to 3 000 kg/ha may be applied. Some farmers report applying cattle dung at monthly doses of 2 700 kg/ha. Between 50 to 125 kg/ha of DAP, 25 to 125 kg/ha of urea, and possibly potash at 25 to 30 kg/ha may be applied. During the growing period, cattle dung is applied at rates of 1 000 to 2 000 kg/ha and, where monthly doses are given, about 270 kg/ha/month is applied. Those farmers applying DAP during the growing period, use a dose of 15 to 40 kg/ha/month.

During the second stage of juvenile culture, when the fingerlings are grown to stunted yearlings, rohu and catla are stocked at densities of 50 000 to 75 000/ha and 7 500 to 10 000/ha, respectively. The purpose of this culture stage is to grow stunted yearlings to 50 to 125 g. Compensatory growth is encouraged, thereby reducing the culture period by one to two months. Compensatory growth relates to a period of increased growth that follows a period of growth restriction that is caused by poor nutrition (Goddard, 1996). The juveniles are fed de-oiled rice bran (crude protein: 12 to 15 percent), with the occasional addition of raw rice bran and groundnut oil cake. The ponds are not as rich in plankton and natural feeds as those used in the grow-out systems - they are manured and fertilized at relatively irregular and infrequent intervals, and the fish become stunted as a result of the combined effects of poor nutrition and high stocking density.

While it is assumed that the combination of high stocking density and poor nutrition over the entire culture period results in stunting, it is not evident whether the fish truly exhibit the characteristics of stunted fish, or that compensatory growth is achieved during the nursery production period. The principal aim of the rearing practice is not to obtain large fish, but rather to obtain the maximum possible numbers of yearlings of the desired size (Plate 5).

1.15.3 Broodstock culture

Between 1978 and 1984 only a very limited number of private farmers and a handful of regionally operated state hatcheries produced Indian major carp seed through hypophysation. During this period, seed production was primarily undertaken in hapas. The seed produced was of very limited quantity, and was insufficient to meet the demands of the expanding sector. Prior to 1985, farmers had to import natural or hatchery produced seed from West Bengal state. In 1985, the first Chinese production models using round concrete spawning tanks, and egg/larval tank systems were built in the state. Currently there are an estimated 65 hatcheries based on the Chinese production model in operation in the state. To date, the state has attained self-sufficiency in terms of seed production of the primary culture species, *viz.* Indian major and Chinese carps. In addition, Andhra Pradesh is exporting spawn, fry and fingerlings to seven or eight other Indian states.

During the initial years of seed production, hatchery and nursery farmers maintained separate rohu and catla broodstock ponds. Rohu and catla broodstock were spawned for two and three years respectively and subsequently discarded. However, once the yearling culture systems became operational and optimized, the hatchery owners gradually stopped separating their broodstock species - they were now able to obtain two year old rohu broodstock from their grow-out ponds. In contrast, three year old catla broodstock could not be collected from the grow-out ponds, so separate catla broodstock had to be reared. Currently, the hatchery farmers collect rohu broodstock from selective grow-out ponds, and market the spent fish once they have been spawned. Spent catla broodstock are retained and reared for a further three to five seasons, after which they are sold (Plate 6).

PLATE 5
Different sizes of rohu and catla used for stocking
Top row: spawn and fry
Middle row: fingerlings and yearlings
Bottom row: zero point fish

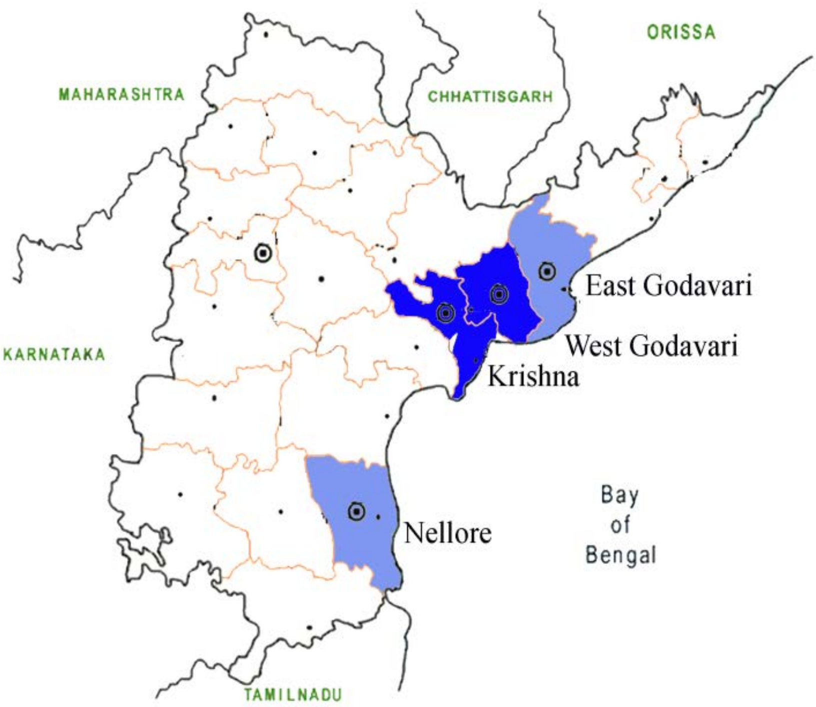
PLATE 6
Broodstock
Left: catla; right: rohu

2. Methods

2.1 REGIONAL DISTRIBUTION OF THE FARMER SURVEY

A questionnaire survey of 106 randomly selected farmers was undertaken to establish the on-farm feed and feed management practices that are applied to the production systems described in Section 1. The survey was conducted between December 2009 and May 2010. Three areas were selected for the survey, *viz.* West Godavari and Krishna districts, where Kolleru carp culture is practiced; Nellore district, where farmers use low density culture; and East Godavari district, where polyculture systems are used to culture Indian major carps, black tiger shrimp and giant river prawns (Plate 7).

PLATE 7
The important districts in Andhra Pradesh for Indian major carp culture



Source: Compiled by authors (2010).

Case studies were conducted in 11 areas, *viz.* West Godavari district - Eluru, Akiveedu, Ganapavaram, Undi, Narsapur; Krishna district - Gudivada, Mandavilli, Kaikaluru; East Godavari - Tallarevu and Kajuluru; and Nellore - Indukuripet. The case studies focused on typical culture, zero point culture, and zero point stock culture systems. Important variations between these culture systems were reported, and the information used to reflect the emerging diversity in culture systems and practices. The local names that are applied to the different aquaculture production systems, their corresponding standardized names, and their feed use are presented in Table 4. The geographic spread of the culture systems and the number of farmer questionnaires undertaken in each region and for each culture system is presented in Tables 5 and 6 respectively.

TABLE 5
ndian major carp culture production districts, the area under production, and the sampling schedule

District	Area (ha)	Farmer surveyed (Number)
West Godavari, Krishna	60 000–70 000	88
Nellore	3 000	10
East Godavari	2 000	8
Total		106

TABLE 6
Number of questionnaires allotted to each aquaculture production system

Local name	Standard name	Feed used	Cases
Typical culture	***On-growing semi-intensive polyculture***		
Typical culture - IMC	On-growing semi-intensive polyculture - IMC	Mash	15
Typical culture - IMC: Nellore	On-growing semi-intensive polyculture - IMC - Nellore	Mash	8
Typical culture - IMC	On-growing semi-intensive polyculture - IMC	Mash - pellet	4
Typical culture - IMC: Nellore	On-growing semi-intensive polyculture - IMC - Nellore	Mash - pellet	2
Typical culture - IMC	On-growing semi-intensive polyculture - IMC	Pellet	1
Typical culture - IMC - striped catfish	On-growing semi-intensive polyculture - IMC - striped catfish	Mash	2
Typical culture - IMC - striped catfish	On-growing semi-intensive polyculture - IMC - striped catfish	Mash - pellet	2
Zero point culture	***Semi-intensive polyculture fattening***		
Zero point culture - IMC	Semi-intensive polyculture fattening - IMC	Mash	10
Zero point culture - IMC	Semi-intensive polyculture fattening - IMC	Mash - pellet	7
Zero point culture - IMC - striped catfish	Semi-intensive polyculture fattening - IMC - striped catfish	Mash	8
Zero point stock culture	***Semi-intensive juvenile polyculture***		
Zero point stock culture - IMC	Semi-intensive juventine polyculture - IMC	Mash	5
Polyculture systems	***Polyculture grow-out systems***		
Polyculture - IMC - exotic carps	Semi-intensive polyculture - IMC - exotic (Chinese and common) carps	Mash - pellet	3
Polyculture - IMC - giant river prawn	Mixed culture - IMC - giant river prawn	Mash - pellet	4
Polyculture - IMC - black tiger shrimp	Mixed culture - IMC - black tiger shrimp	Mash - pellet	4
Polyculture - IMC - pirapatinga - exotic carps	Polyculture - IMC - pirapatinga - exotic (Chinese and common) carps	Mash - pellet	2
Polyculture - IMC - pirapatinga - striped catfish	Polyculture - IMC - pirapatinga - striped catfish	Mash - pellet	1
Nursery, juvenile and broodstock systems	***Nursery, juvenile and broodstock systems***		
Nursery - IMC	Nursery culture - IMC	Mash	10
Rearing - IMC	Juvenile culture - IMC	Mash	9
Broodstock - IMC	Broodstock and brood fish culture - IMC	Mash	9
Total cases			**106**

Source: Field survey (2010).

Seventy eight grow-out systems, ten nurseries, nine larval rearing, and nine broodstock systems were surveyed. All the nursery, rearing and broodstock cases were recorded from the Kolleru carp culture area.

Primary data collection included information pertaining to mash feed ingredients, commercial pelleted feeds, their availability and price, feeding practices, feeding methods, feeding rates, FCR, feed transport, on-farm storage, and feed quality issues. In addition, the perceptions of the farmers of their feed management practices were recorded, and their responses used to identify areas that require future intervention and research. The data pertaining to the different production systems were analyzed independently; although similar feed ingredients are used in the various production scenarios, the quantities used and the feed management practices differ significantly. Selected feed ingredient producers, commercial feed manufacturers and technical personnel representing the commercial feed manufacturing companies were interviewed.

2.2 LIMITATIONS OF THE STUDY

The survey revealed that while the majority of the farmers maintained basic farm input and production records over a given production cycle, information such as monthly production data was either missing or not recorded, or the information that was recorded was incomplete and of little analytical use.

To address the lack of monthly production/farm input data, feeding rates for different sizes of Indian major carps were calculated from the historical data sets recorded at the government fisheries research station in West Godavari district, and from data that farmers had previously provided to the government extension service. Where appropriate, feeding rates were either determined for specific size classes of fish, or in polyculture systems as the total biomass stocked in the ponds.

2.3 DATA ANALYSIS

All the case studies data were entered into a Microsoft Excel (MSExcel) spreadsheet for analysis. An analysis to determine production costs and the income derived from each of the selected culture systems was conducted.

Industrially produced soya-based (28% crude protein) floating pelleted feed for carp culture, Bhubaneswar, India.

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3. Results and discussion

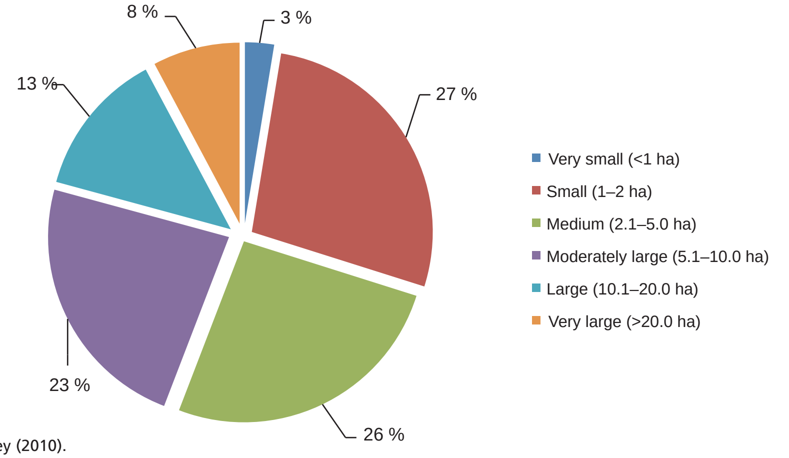
3.1 FARM SIZE

The grow-out farmers were grouped according to farm size: very small <1 ha; small 1 to 2 ha; medium 2.1 to 5 ha; moderately large 5.1 to 10 ha; large 10.1 to 20 ha and very large >20 ha (Figure 3). The number of small, medium and moderately large farmers was similar (27, 26 and 23 percent), there were fewer large farms (13 percent), and even fewer very large farms (8 percent). The number of very small farmers was negligible (3 percent).

Farm data was combined and used to estimate the size composition of the broodstock, nursery and rearing[3] (on-growing) farms (Figure 4). Within these groups, the medium sized farms formed the single largest group (46.2 percent) followed by the small farms (18.4 percent). The very small and moderately large farms were similar, at 14.1 and 14.3 percent respectively. The large farms comprised 7.0 percent of the group, and very large farms were conspicuous in their absence.

FIGURE 3

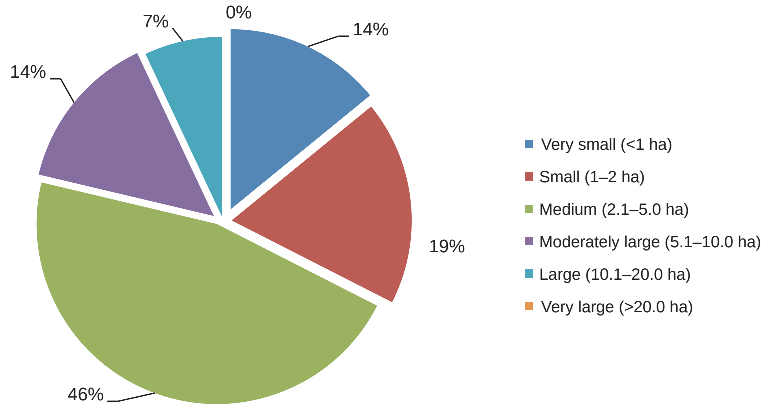
Composition of grow-out farmers by area of land owned



Source: Field survey (2010).

FIGURE 4

Composition of nursery, rearing and brood stock farmers by area of land owned



Source: Field survey (2010).

[3] Rearing ponds are the facilities where fry are grown to fingerling and further to yearling size.

3.2 FARMERS' EXPERIENCE

The average number of years of farming experience that the farmers reported in Kolleru, Nellore and Godavari districts was 14, 12 and 5 years respectively (Table 7). The first generation of carp farmers in the Kolleru district started farming operations about 30 years ago; thus the average number years of experience reported by the farmers in this area suggests that the current farmers are second generation producers. In 1985, fish culture was initiated in Nellore district. During the initial years, the growth of the sector was slow - between 1989 and 1992 farmers concentrated their efforts on black tiger shrimp production; between 1998 and 2002 they favoured giant river prawn culture. After the start of decline of the giant river prawn sector in 2002 farmers started moving over to Indian major carp production. The average number of years of experience that the farmers reported in this area reveals that those covered in the survey were experienced practitioners, and belonged to the founding group of carp farmers. The East Godavari farmers are relatively new entrants to the sector. In 2002, farmers started to produce Indian major carps in their polyculture systems. Carp culture was initiated in this area as an alternative to giant river prawn production, which had become associated with recurring disease problems.

TABLE 7
Farmers' experience in aquaculture of Indian major carps

Culture area	Average number of years of experience
West Godavari + Krishna	14
East Godavari	5
Nellore	12

Source: Field Survey (2010).

3.3 PRODUCTION CHARACTERISTICS

The consolidated production characteristics accumulating to the different aquaculture production systems that were surveyed are presented in Tables 8 to 12.

3.3.1 Mash feed ingredients

Between July 2009 and June 2010 the national production of de-oiled rice bran was 2 403 740 tonnes (B.V. Mehta, Executive Director, Solvent Extractors Association, Mumbai, India, personal communication, 2010). According to the Andhra Pradesh Rice Bran Solvent Extractors Association (Vijayawada, Andhra Pradesh), there are currently 50 rice bran oil extraction factories in Andhra Pradesh. Five of these are operated by fish farmers who recently entered the sector. Between July 2009 and June 2010 the association reported a production of 747 916 tonnes of processed rice bran, and 622 902 tonnes of de-oiled rice bran. In addition, independent producers processed a further 60 000 tonnes of de-oiled rice bran. The survey revealed that approximately 80 percent of the de-oiled rice bran that is produced in the state (about 546 321 tonnes) is utilized as the principal mash feed ingredient for Indian major carp production. Assuming an FCR of 3:1 is attained when using mash feeds, a total of 2 250 000 tonnes of mash feed would be required to produce the annual 750 000 tonnes of Indian major carps that are produced in the state. De-oiled rice bran comprises approximately 85 percent of the required mash feed, equating to 1 912 500 tonnes of bran (Plate 8). Thus, there is an estimated deficit of 1 229 598 tonnes between the requirements and what is locally available in the state. As a consequence, the deficit is currently being imported from other states.

Between 2005 and 2010, the price of de-oiled rice bran and raw rice bran increased from INR2.7 to INR6.2/kg (US$0.06–0.13/kg), and INR6.7 to INR9.7/kg (US$0.14–0.21/kg) respectively. While the price of de-oiled rice bran price increased by 229 percent over this period, the farm-gate price of Indian major carps increased by only 162 percent (Figure 5). The relative increase in feed prices is often cited as problematic for the farmers, as it reduces the profitability of their farming operations.

TABLE 8

Production characteristics of "typical culture (on-growing semi-intensive polyculture)" production system

Type of culture	Stocking size/density								Size at harvest				Feed type	Feeding frequency (day)	FCR	Organic manure use (kg/ha/annum)	Inorganic fertilizer use (kg/ha/annum)	Average production (kg/ha/annum)
	Rohu		Catla		Mrigal		Striped catfish		Rohu (kg)	Catla (kg)	Mrigal (kg)	Striped catfish (kg)						
	Size (kg)	Density (number/ha)	Size (kg)	Density (number/ha)	Size (kg)	Density (number/ha)	Size (kg)	Density (number/ha)										
Typical – IMC: mash	0.010–0.150	1 850–8 204	0.010–0.200	282–1 236	0.010–0.100	148–463	-	-	0.9–1.4	1.0–2.5	0.5	-	Mash	1	2.3–4.1	184–7 482	32–121	6 417
Typical–IMC: mash–pellet	0.010–0.025	5 436–6 177	0.010–0.100	494–617	-	-	-	-	1.4	1.6	-	-	Mash Pellet	1	1.04–2.25	3 912– 11 377	18–80	9 969
Typical – IMC – striped catfish: mash – pellet	0.010–0.100	1 976–2 471	0.010–0.150	123–494	-	-	0.004–0.034	1 730–12 849	0.9–1.3	1.0–1.5	-	1.2–2.6	Mash Pellet	1	1.9	6 202–11 120	-	6 047
Typical – IMC: mash – Nellore	0.030–0.150	3 954–13 591	0.010–0.150	247–1 236	0.050–0.070	247–449	-	-	0.60–0.95	1.25–2.0	1.0–1.5	-	Mash	1	1.1–4.0	2 471– 8 923	126–411	6 241

Source: Field Survey (2010).

Note: FCR = feed conversion ratio.

TABLE 9

Production characteristics of "zero point culture (semi-intensive polyculture fattening) and zero point stock culture (semi-intensive juvenile polyculture)" production systems

Type of culture	Stocking size/density								Size at harvest				Feed type	Feeding frequency (day)	FCR	Organic manure use (kg/ha/annum)	Inorganic fertilizer use (kg/ha/annum)	Average production (kg/ha/annum)
	Rohu		Catla		Mrigal		Striped catfish		Rohu (kg)	Catla (kg)	Mrigal (kg)	Striped catfish (kg)						
	Size (kg)	Density (number/ha)	Size (kg)	Density (number/ha)	Size (kg)	Density (number/ha)	Size (kg)	Density (number/ha)										
Zero point culture – IMC: mash	0.150–0.500	3 707–6 354	0.200–1.200	210–706	0.100–0.150	62–206	-	–	1.0–2.3	1.9–3.0	1.0–3.0	–	Mash	1	1.9–4.7	209–4 826	78–4 124	6 177
Zero point culture –IMC: mash –pellet	0.125–0.500	3 552–7 413	0.250–0.700	412–623	0.020–0.250	15–198	-	–	0.9–2.2	1.4–3.3	1.0–1.5	–	Mash Pellet	1	2.4–3.6	1 482–8 586	35–258	6 530
Zero point culture – IMC – striped catfish: mash	0.100–0.350	4 118–8 063	0.250–1.000	494–5 869	0.010–0.100	99–520	0.010–0.500	111–9 266	0.9–1.1	1.5–2.6	1.0	1.4–4.5	Mash	1	2.8–3.8	1 793–10 296	95–274	10 860
Zero point culture – stock – IMC: mash	0.010–0.125	13 237–30 887	0.010–0.165	1 182–2 471	-	-	-	–	0.11–0.26	0.15–0.32	–	–	Mash	1	1.97–3.36	4 324–5 383	53–168	8 906

Source: Field Survey (2010).

TABLE 10
Production characteristics of a "polyculture grow-out (IMC and exotic carp)" production system

Type of culture	Stocking size/density								Size at harvest				Feed type	Feeding frequency (day)	FCR	Organic manure use (kg/ha/ annum)	Inorganic fertilizer use (kg/ha/ annum)	Average net production (kg/ha/ annum)
	Rohu		Catla		Mrigal		Grass carp		Rohu (kg)	Catla (kg)	Mrigal (kg)	Grass carp (kg)						
	Size (kg)	Density (number/ ha)	Size (kg)	Density (number/ ha)	Size (kg)	Density (number/ ha)	Size (kg)	Density (number/ ha)										
Polyculture IMC – grass carp: mash	0.080–0.120	2 471–7 824	0.250–0.500	411–686	0.010–0.030	686–800	0.010	274–460	0.8–1.2	1.0–2.7	0.8–1.0	1.5–3.0	Mash	1	1.1 - 3.7	2 951 – 11 325	86 - 108	7 518

Source: Field Survey (2010).

TABLE 11
Production characteristics of a "polyculture grow-out (IMC and tiger shrimp)" production system

Type of culture	Stocking size/density								Size at harvest				Feed type	Feeding frequency (day)	FCR	Organic manure use (kg/ha/year)	Inorga-nic fertilizer use (kg/ha/ annum)	Average net production (kg/ha/ annum)	
	Rohu		Catla		Mrigal		Tiger shrimp		Rohu (kg)	Catla (kg)	Mrigal (kg)	Tiger shrimp (kg)							
	Size (kg)	Density (number/ ha)	Size (kg)	Density (number/ ha)	Size (kg)	Density (number/ ha)	Size (kg)	Density (number/ ha)										Tiger shrimp	IMC
Polyculture IMC-tiger shrimp: pellet	0.060–0.200	494–2 965	0.010–0.200	62–988	0.100	1 235	0.002–0.005	3 088–12 355	1.0–1.3	1.5–2.0	1.0	0.030–0.050	Pellet	2	1.7–3.2	1 482–2 471	74–135	914	2 757

Source: Field Survey (2010).

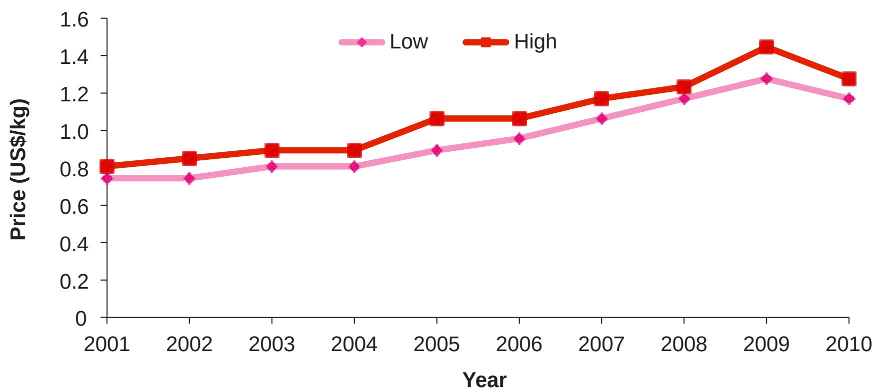
TABLE 12
Production characteristics of a "polyculture grow-out (IMC and giant river prawns)" production system

Type of culture	Stocking size/density								Size at harvest				Feed type	Feeding frequency (day)	FCR	Organic manure use (kg/ha/ annum)	Inorganic fertilizer use (kg/ha/ annum)	Net production kg/ha/annum	
	Rohu		Catla		Mrigal		Freshwater prawn		Rohu (kg)	Catla (kg)	Mrigal (kg)	Giant river prawns (kg)							
	Size (kg)	Density (number/ ha)	Size (kg)	Density (number/ ha)	Size (kg)	Density (number/ ha)	Size (kg)	Density (number/ ha)										Giant river prawnSs	IMC
Polyculre -IMC - giant river prawns: pellet	0.050–0.100	296–2 471	0.050–0.100	50–247	–	–	0.002–0.005	741–7 413	1.0–1.35	2.0–2.5	-	60–100 g	Pellet	2	0.69–3.42	1 976–3 212	74–173	628	1 845

Source: Field Survey (2010).

PLATE 8
Mash feed ingredients and preparation
Top: de-oiled rice bran, groundnut cake and cottonseed cake
Bottom: thorough mixing of ingredients before loading into feed bag

FIGURE 5
Farm-gate price of Indian major carps in Andhra Pradesh, 2001–2010

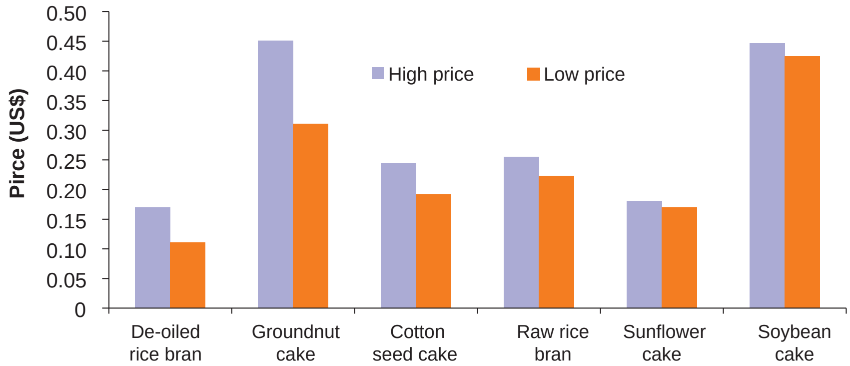


US$1 = INR 47.03

Source: Field survey (2010).

Between 2009 and 2010, 1.54 million tonnes of groundnut oil cake, 7.78 million tonnes of cottonseed cake, 5.1 million tonnes of soybean meal and 740 thousand tonnes of sunflower cake were produced in India (B.V. Mehta, Executive Director, Solvent Extractors Association, Mumbai, India, personal communication, 2010). During this period, oil cake production in Andhra Pradesh was estimated as 809 600 tonnes of groundnut cake, 769 200 tonnes of cottonseed cake, 194 700 tonnes of sunflower cake, and 116 100 tonnes of soybean cake (Agricultural Statistics of Andhra Pradesh, 2010-

FIGURE 6
Price fluctuations of the main mash feed ingredients in 2009–2010



US$1 = INR 47.03

Source: Field survey (2010).

2011).The estimated quantities of the groundnut cake and cottonseed cake that were used during this period for the production of mash feeds were 180 000 tonnes and 150 000 tonnes respectively. Almost all this demand was met from the state production. The price fluctuations of the major mash feed ingredients between 2009 and 2010 are presented in Figure 6.

The average price of different feed ingredients per kg in 2009/2010 were: de-oiled rice bran INR6.6 (US$0.14); groundnut cake INR17.9 (US$0.38); cottonseed cake INR10.25 (US$0.22); raw rice bran INR11.25 (US$0.24); sunflower cake INR8.25 (US$0.17); and soybean cake INR20.5 (US$0.43).

A local fish meal factory in West Godavari district annually produces 2 000 tonnes fishmeal and 1 000 tonnes tiger shrimp head meal, through steam boiling method. High and low grades of fishmeal are produced at INR36 (US$0.76) and INR25 (0.53) per kg. The price of tiger shrimp head meal is INR20/kg (US$0.43). The producers said that the commercial pellet feed factories in the region buy the fishmeal this factory produces.

Unconventional feed ingredients for using in the mash feed of Indian major carps, such as meat meal and maize based beer industry by-products, are also available for irregular periods and at uncertain quantities.

3.3.2 The marketing chains for mash feed ingredients

There is a well-developed network of mash ingredient producers, dealers, and buyers (farmers) in the state. Currently, there are about 10 to 15 dealers in each of the major production regions in west Godavari and Krishna districts. With respect to the procurement of feed ingredients, the farmer usually approaches a local dealer who provides information about the products available, their price, and quality (e.g. protein level). The farmer agrees a price and places an order with the dealer for a given quantity. Once the order is placed and the price agreed upon, it is binding on all three parties (producer, dealer and farmer), irrespective of future price fluctuations.

The dealer informs the feed ingredient producer of the sale. The producer delivers the feed ingredients to the farm site using various types of transport - usually within a day or two of placing the order. Transport costs are normally between INR1 and INR2/kg (US$0.02–0.04/kg) and are included in the price paid by the farmer. While the dealer pays for the feed ingredients within seven to ten days of delivery, the farmers are usually given 10 to 25 days to make payments. If payment is delayed, the dealer charges an annual interest rate of 24 percent. In the event that the farmer is unsatisfied with the quality of the feed ingredients delivered, he has the right to reject the shipment, and return it to the producer.

The dealer charges the producer a commission of INR500 (US$10.63) for every 10 tonnes of ingredients sold. The producer deducts 10 percent of the commission, and uses this money to pay the dealers' income tax. The producer does not provide the farmer with credit, and the dealer takes the responsibility for the payment. At present, farmers can purchase de-oiled rice bran from 16 production centres that are located throughout the state. Other states that supply de-oiled rice bran include Madhya Pradesh, Delhi, and West Bengal. At present, groundnut oil cake can be purchased from thirteen producers throughout the State. Cottonseed cake is less easily procured, and is primarily available from only four producers.

Groundnut and cottonseed cakes are sold in a similar fashion to the other oilseed cakes, the exception being that the transport costs are paid by the producers. Currently, the value added tax (VAT) payable on both de-oiled rice bran and oil cakes is four percent - these costs are ultimately borne by the farmer.

3.3.3 Quality monitoring of feed ingredients by farmers

While some farmers send their feed ingredients for laboratory analysis, the majority accept the quality assurances provided by the dealers. Feed ingredient quality assurance certificates are rarely used. In 2003, and with the assistance of a qualified feed analyst, a group of progressive fish farmers in the Kolleru carp culture area (the Delta Fish Farmers Welfare Association) opened their own feed analysis laboratory at Eluru (the capital of West Godavari district).The laboratory analyses feed samples for crude protein, moisture and fibre content. The results of the analysis of 104 samples of de-oiled rice bran analysed at this laboratory during 2009 to 2010 are presented in Table 13. A second feed analysis laboratory is operated in West Godavari by the Fisheries Department of Andhra Pradesh. The results of proximate composition analysis of some of the feed ingredient samples primarily used for preparation of mash feed, mash feed and a semi-commercial pellet analysed at this laboratory are presented in Table 14.

TABLE 13
Ranges of moisture, crude protein and crude fibre content (% as fed basis) in de-oiled rice bran samples used by farmers

No. of samples analysed	Moisture	No. of samples analysed	Crude protein	No. of samples analysed	Crude fibre
49	3–5	1	8–10	12	8–10
23	6–8	5	11–12	14	11–13
24	9–11	38	13–14	31	14–16
–	–	–	–	21	17–19
2	12–14	60	15–16	13	20–22
0	15–17	–	–	13	23–25
5	18–20	–	–	–	–

Source: Field survey (2010).

TABLE 14
Proximate composition analysis (% as fed basis) of selected feed ingredients used for the preparation of mash feed, two mash feed and a semi-commercial pellet

Feed ingredients/mash feed/commercial pellet	Moisture	Crude protein	Crude lipid	Crude fibre	Ash	NFE*
De-oiled rice bran-1	4.0	18.0	1.20	21.00	19.00	36.80
De-oiled rice bran-2	3.5	13.4	1.80	20.00	19.00	42.30
De-oiled rice bran-3	3.9	13.0	1.92	16.00	14.20	50.98
De-oiled rice bran-4	4.2	12.2	2.10	18.00	15.80	47.70
De-oiled rice bran-5	6.1	10.0	2.10	30.00	16.30	35.50
De-oiled rice bran-6	14.2	12.0	10.60	10.00	18.00	35.20
Groundnut cake	4.0	39.0	7.20	10.00	16.00	23.80
Sorghum	9.8	11.0	4.14	2.80	1.54	70.72
Pearl millet	8.4	14.5	4.13	5.60	2.12	65.25
Meat meal	12.0	16.5	11.00	16.16	36.00	8.34
Soy mixed mash-1	9.8	17.2	4.50	9.40	10.20	48.90
Soy mixed mash-2	7.5	18.0	5.00	7.40	8.60	53.50
Semi-commercial pellet	9.4	23.9	2.50	25.00	23.70	15.50

*NFE: Nitrogen free extract.

Source: Field survey (2010).

3.4 MANUFACTURED PELLETED FEEDS

At present, Indian aquafeed production capacity is estimated at 408 000 tonnes per annum; by 2012, this figure is expected to grow to 1 000 000 tonnes (Vijay Anand, Cremer and Ramesh, 2010). In 1994, a few Indian major carp farmers in West Godavari started to use pelleted feeds. At the time, the amount of manufactured pelleted feed that was available for freshwater fish production was restricted to 10 000 tonnes per annum (Suresh, 2007). The initial formulations were designed for cattle, with little feed being specifically formulated for Indian major carps. At that time, their use did not gain widespread acceptance amongst the farming community.

TABLE 15
Feed formula of ASA-32/6 of American Soybean Association-International Marketing

Ingredients	% inclusion rate
Soybean meal, 47.5% CP*	50.00
Wheat flour, 11.7% CP	26.40
Corn gluten meal, 60% CP	6.00
Rice bran, 15% CP	5.00
Wheat middling, 15% CP	4.00
Fish oil, unspecified	3.50
Calcium phosphate, mono	2.30
Blood meal, ring-dried, 93% CP	1.00
Soy lecithin	1.00
Vitamin premix	0.50
Mineral premix	0.25
Stay C 35%**	0.03
Ethoxyquin-100%	0.02
Total	**100.00**

Notes: * Crude protein: ** Stay C 35% (dry mixture) is a fine powder containing mono-, di and triphosphate esters of L-ascorbic acid in a suitable carrier. It provides a minimum of 35% of ascorbic acid by weight equivalent to 150 grams of ascorbic acid per kg of dry mixture.

Source: Vijay Anand, Manomaitis and Ramesh (2006).

In 2004-2005, the American Soybean Association - International Marketing (ASM - IM), evaluated the use of soya-based extruded floating pellets (Table 15). The evaluation was a component of a programme to promote the use of soybeans in aquafeeds, and focused on feed acceptance in rohu and catla. The evaluation resulted in soya being adopted as a viable feed ingredient.

Though the exclusive use of pellet feeds was a new and interesting concept to the Indian major carp farmers in the state, they were not very convinced of its regular use. However, the rapid expansion and intensification of striped catfish culture during 2007 provided the impetus for the adoption of commercial aquafeeds in Andhra Pradesh. The high production levels associated with striped catfish production (up to 50 tonnes/ha over a seven month production cycle) required the use of relatively large quantities of pelleted feeds. The increased demand for feed resulted in investment into the aquafeed manufacturing sector, which significantly increased the capacity to produce floating and sinking pellets. In addition, and as a result of the demise of the black tiger shrimp sector, most of the commercial feed producers that had experience in producing feeds for black tiger shrimp were able to shift production to striped catfish and Indian major carp aquafeed production. Sensing the ascending trends in the commercial aquafeed industry, new investors were attracted to the sector. Currently, the annual production of floating and sinking feeds by the 11 largest commercial aquafeed companies is 525 000 and 300 000 tonnes respectively (Annex 3). At present, an additional 430 000 tonnes/annum of production capacity is being installed in the state. The details of commercial pelleted feed producers in Andhra Pradesh and their products are provided in Annex 4 and some samples of the products available are illustrated in Plate 9.

In addition to the large scale commercial aquafeed producers, there are seven local feed mills in West Godavari and Krishna districts that produce their own brands of pelleted feed. In addition, some feeds that are manufactured at the local mills are formulated by individual farmers. The feed mills charge INR 2/kg (US$0.04/kg) to manufacture their formulations. Some entrepreneurs have gone as far as formulating and branding their own pelleted feeds and having them manufactured at the local feed mills. In total, the local feed mills produce approximately 30 000 tonnes of sinking pellets per annum.

An emerging trend is for the larger farmers (100 to 200 ha farms) to invest in their own feed production facilities. Typically, these facilities have a production capacity

PLATE 9
Samples of sinking and floating feed pellets of various sizes produced by a commercial feed company

of two to eight tonnes per hour of sinking pellets. The production machinery is manufactured in India, and is designed to produce sufficient volumes of feed to satisfy the on-farm feed requirements of the larger farms. For example, a mill that is capable of producing three tonnes per hour and operated for 20 hours/day for 300 days a year can produce 18 000 tonnes of sinking feed per annum.

The quantity of commercially produced floating and sinking pellets sold to fish farmers in the state is estimated at 250 000 to 270 000 tonnes and 90 000 to 95 000 tonnes respectively. It is anticipated that in the near future, the production of floating feeds will rise to 430 000 to 450 000 tonnes/annum. With respect to Indian major carp aquafeeds, floating feeds account for ten percent of the feeds used, with the remaining 90 percent being sinking feeds. In contrast, 70 percent of the feeds used by the striped catfish farmers are floating feeds, with the remaining 30 percent being sinking feeds. Evidently, the majority of the farmers prefer to use floating pellets for striped catfish production. However, due to supply constraints, some farmers have no option but to use sinking feeds.

3.4.1 Marketing of manufactured pelleted feeds

There are approximately 50 aquafeed dealers that sell manufactured pelleted feeds in the state. The dealers are located throughout the fish culture areas of West Godavari and Krishna districts. Pelleted aquafeeds are almost exclusively sold through feed dealers. The dealers operate on a commission basis, and pay the feed manufacturers a deposit for their feed stock. Transport costs amount to INR1/kg (US$0.02/kg), and are paid by the manufacturing companies. The feed prices are usually fixed for periods of several months at a time. Normally, the farmer pays the dealer once the feeds are delivered. Where payment is delayed, an annual interest rate of 18 percent is usually applied. In general, the farmers develop long-term business relationships with their local feed dealer. Feeds are primarily transported by roads. While 10 to 15 tonne

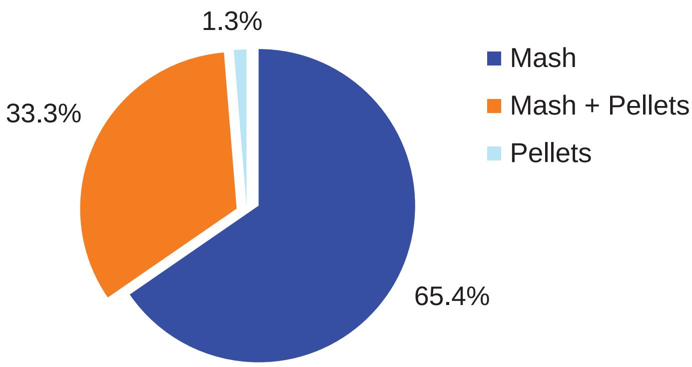
PLATE 10
Main types of vehicles used for transportation of feed in the state
Top: lorries and trucks
Bottom: minivans and boats

vehicles are used for long distance deliveries, local deliveries use small lorries (trucks) with a capacity of seven tonnes, minivans (three to five tonnes) and autos (one to two tonnes). Boats (two to ten tonnes capacity) are used to transport feed to the interior areas of Kolleru Lake (Plate 10).

3.5 THE TYPES OF FEED USED BY THE FARMERS

The survey revealed that 65.4 percent of Indian major carp farmers used mash feed as their sole feed source. A further 33.3 percent of farmers used a combination of mash and pelleted feeds, and 1.3 percent of farmers reported using pellets as their sole feed source (Figure 7). In 1993, a survey conducted in Andhra Pradesh revealed that at

FIGURE 7
Types of feed used in Indian major carp production

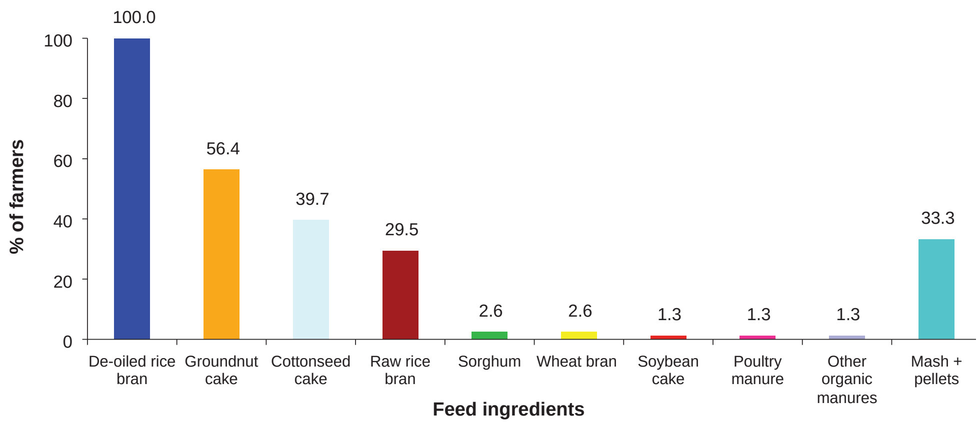


Source: Field survey (2010).

that time, all the farmers used mash feeds (Veerina, Nandeesha and Gopal Rao, 1993). De-oiled rice bran was used by all the farmers, followed by groundnut cake (83 percent) and cottonseed meal (63 percent). Feed sources that were used at lower levels included sunflower cake (23 percent), meat meal (22 percent), and raw rice bran (8 percent). The present survey revealed that de-oiled rice bran, groundnut cake and cottonseed cake were still the primary three ingredients used in mash feeds, however, fewer farmers were using groundnut cake (56.4 percent) and cottonseed cake (39.7 percent), while increased numbers reported using raw rice bran (29.5 percent; Figure 8). In addition, the data also suggests that the farmers' strict adherence to mash feeds was diminishing, and evidenced by the fact that 33.3 percent of the farmers reported using combinations of pelleted and mash feeds, the mash being applied through bag feeding techniques (Plate 11).

The survey revealed that the farmers use their mash feed ingredients at various inclusion levels (Table 16).

FIGURE 8
Feed ingredients used by Indian major carp farmers



Source: Field survey (2010).

PLATE 11
Mixing of sinking pellets with mash feed ingredients to be dispensed through bag feeding

The survey revealed that 87.3 percent of farmers reporting using de-oiled rice bran at an inclusion level of more than 70 percent in their mash feeds. In contrast, all the farmers reported using groundnut cake, cottonseed cake and raw rice bran at levels of less than 30 percent (Table 16). The survey also indicated that in attempt to reduce feed costs, a few farmers add poultry manure and other organic manures to their mash feeds.

TABLE 16
Feed ingredients used in mash feeds - expressed as the percentage of farmers at each inclusion level

Ingredient	Inclusion levels of feed ingredients (% as fed basis)				
	>70	51–70	31–50	11–30	<10
De-oiled rice bran	87.3	11.2	1.5	0	0
Ground nut cake	0	0	0	34.1	65.9
Cotton seed cake	0	0	0	17.6	82.4
Raw rice bran	0	0	0	31.8	68.2
Wheat bran	50	0	0	50	0
Soybean cake	0	50	0	50	0
Sorghum	0	100	0	0	0
Poultry manure	0	100	0	0	0
Other organic manures	0	25	0	25	50

Source: Field Surveyr (2010).

3.6 NUTRITION AND FEED MANAGEMENT OF INDIAN MAJOR CARPS UNDER PRACTICAL SEMI-INTENSIVE POND CULTURE CONDITIONS

Tacon (1995) stated that "little or no information exists concerning the dietary nutrient requirements of the top five most cultivated fish species, under practical semi-intensive pond farming conditions. If meaningful conclusions are to be drawn from nutrient requirement studies it is essential that the experimental fish be reared under conditions mimicking as far as possible those of the intended farm production unit and environment". Currently, there are two unique freshwater fish culture systems in Asia to which this comment remains applicable. One is striped catfish culture in Viet Nam, which in terms of production densities supersedes any other form of primary production (Phuong and Onah, 2009). Despite the growth in striped catfish culture, there have as yet been no detailed studies to determine the nutritional requirements of the species. Improvements to feed formulations, feed management strategies including reductions in feed wastage and improvements to FCR, and reductions in nutrient loadings in effluent waters have all been recommended as mechanisms with which to improve the economics of striped catfish culture in Viet Nam (DoA, 2008; Sub-Institute for Fisheries Economics and Planning in Southern Vietnam, 2009). Similarly, there is very little published information pertaining to the nutritional requirements of Indian major carps under commercial semi-intensive culture conditions. In the absence of this information, the farmers in Andre Pradesh have developed their mash feed formulae and feed management practices through a process of trial and error.

3.6.1 A comparison of mash and pelleted feeds

The successful introduction of soya-based floating aquafeeds to Chinese carp farmers has resulted in many farmers adopting the new feeding technology, and reducing their dependence on the use of mash feed and pond fertilization to promote natural pond productivity (Vijay Anand, Manomaitis and Ramesh, 2006). The American Soybean Association suggests that it is eventually inevitable that Indian major carp farmers in Andre Pradesh will discard their current mash feeding practices, and embrace formulated pelleted feeds. Among Indian major carp farmers in India, there remains a persistent dilemma about whether to adopt pelleted feeds: at present opinion is divided. The perceived advantages and disadvantages of using different types of feeds (floating *versus* sinking pellets and mash *versus* pelleted feed) are presented in Tables 17 and 18.

In general, farmers will probably continue to use of mash feeds until they are convinced that pelleted feeds are a more cost-effective feed solution.

TABLE 17
The perceived advantages and disadvantages of using floating and sinking pellet feeds

Sinking pellets	Floating pellets
ADVANTAGES • Cheaper than floating pellets of a similar nutritional status. • Multiple feed ingredients are suitable for use as dietary components in sinking pellets. • The density of sinking pellets is lower than that of floating pellets, and a larger quantity of sinking pellets can be stored in a given storage or transport space. • The fish do not need to surface to feed, or move through stratified pond waters. • Sinking pellets can be easily mixed with mash feeds and fed using traditional demand bag feeding techniques. DISADVANTAGES • Fish feeding behaviour cannot be observed. Adjustments to feed rations are difficult to determine empirically, and are thus based on consumption estimates and farmer experience. • Since uneaten feed cannot be collected, it may increase the organic loading of the pond waters and result in a deterioration in water quality. • Dispensing sinking feeds is labour intensive.	ADVANTAGES • Farmers can directly observe the feeding behaviour, the quantity of feed consumed and adjust ration sizes accordingly. • Feeding is easier when using floating as opposed to sinking feeds, and can be managed with less labor. • Uneaten feed pellets can be removed from the pond, thus reducing the potential for reductions in water quality associated with increased levels of nutrient loading. DISADVANTAGES • More expensive than sinking pellets of a similar nutritional status. • The feed ingredients that are suitable for inclusion in floating pellets are limited. • The fish have to spend more time at surface for feeding, increasing the rates of bird predation. • Floating pellets are not suitable for mixing with mash feeds, and dispensing through traditional bag feeding techniques.

Source: Field Survey (2010).

TABLE 18
The primary reasons that farmers advance for using pelleted and mash feeds for Indian major carp production

Pellet feed	Mash feed
• Much of the mash feed remains uneaten by the fish, results in feed wastage and increased organic loading/poor water quality. • The profitability and long term sustainability of the culture system is threatened. • Compounded pellet feed is nutritionally complete, and hence nutritional deficiencies are minimized • Comparable fish growth and production can be achieved using lower quantities of feed. • Reduced levels of disease as water quality is superior when using pellet feeds. • Farmers are relieved of the tedious tasks of feed ingredient procurement and quality evaluation. • Cost savings on labour, transport and storage. • Feeding is easier.	• Over the past 25-30 years, sustainable and satisfactory levels of production have been achieved using mash feed. • There is no evidence to suggest that significant quantities of the mash feed is wasted or pond water quality deteriorates when using mash feeds. • Farmers have more control over the feed ingredients that are used.

Source: Field Survey (2010).

3.6.2 Feeding practices in grow-out ponds

Two types of feeding practices are illustrated in Plates 12 and 13. One of the defining characteristics of Kolleru carp culture and general carp culture in the state is the use of ‘demand bag feeding’. The feed ingredients are mixed, and 3–8 kg of the mixture is placed in used perforated fertilizer bags. Standard (50 kg) fertilizer bags are used. Holes are made in the bags, usually in four rows, about 1 to 1.25 inches from the bottom of the bag. The bags are transported to the middle or bed areas of the pond, and tied to fix feeding poles or ropes. The feeding method is known as ‘pole or rope feeding’ (Plate 13). The simplicity, efficiency and popularity of this feeding method is evidenced by the fact that it is the only major farm management practice that has not changed for the past 30 years.

The rate at which damaged feed bags have to be replaced depends on the culture species. In general, the feed bags in Indian major carp ponds are changed less frequently than those in the striped catfish or pirapatinga ponds. The carp have no teeth, and tend not to damage the bags.

PLATE 12
Feeding pelleted feeds
Left: in a net enclosure; right: in a pond

PLATE 13
Other methods of feeding
Left: rope-bag feeding; right: pole-bag feeding

Farmers have reported a number of advantages of the traditional bag feeding system. These include the ease with which large quantities of mash feed can be fed with minimum feed wastage and water quality deterioration. The system enables feeding behaviour to be easily observed, and promotes the uniform distribution of the feed throughout the pond. In addition, the quantity of leftover feed can easily be estimated and subsequent feed rations adjusted accordingly. The practice enables feed additives and therapeutants to be easily administered. Furthermore, feed wastage through consumption by non-target species is minimized because smaller fish, such as the tilapias and *Puntius* spp. are unable to compete with the larger Indian major carps at the feed bags. Finally, the system is easy to maintain using cheap locally available materials.

Feeding rates

The survey revealed that there was a high degree of variability in the total quantity of feed that the farmers were feeding to a given size class of fish each day. For example, fish up to 250 g were fed between 1–1.5 and 5.1–5.5 percent of body weight per day. Larger fish (1–1.25 kg) were being fed between 1.6–2.0 and 5.1–5.5 percent of body weight per day. This suggests that some farmers are finding it difficult to determine the ration sizes that they should be feeding to a given size class of fish. These rates contrast with the general feeding rates presented by Suresh (2007) for intensive carp farming systems in the Kolleru area of Andhra Pradesh.

There are no standard feed guidelines describing feeding rations that are based on animal size and stocking density. At present, farmers base their feed rations on their personal experience. The survey revealed a large variation in daily feeding rates for similar size classes of fish, suggesting that farmers are determining their feeding rates subjectively, and as a result some are likely to be wasting significant quantities of feed.

The commercial aquafeed manufacturers provide feed tables to assist farmers to optimize their feed management. Typical feeding rates that are recommended by the commercial aquafeed manufacturers for both Indian major carps and striped catfish are presented in Tables 19 and 20. The recommended feeding rates apply to sinking pellets and de-oiled rice bran that are fed in combination. The feeding rates recommended for the floating feed are for its sole use - rice bran and oil cakes are not used in combination with floating pellets.

There is no published information specifically pertaining to the optimization of ration size in semi-intensive Indian major carp production systems that solely use pelleted feeds. The feeding rates that are advocated by the commercial feed manufacturers do not take into consideration the role of natural feeds in the production systems.

Currently, Indian major carp farmers base their daily feeding regimes on a number of factors. These primarily include monthly growth parameters, the number of days that the fish have been cultured, the standing biomass, and the average fish weight. Some farmers base their feeding regimes on simple feed responses. Many farmers have a poor understanding of how to calculate feed rations, and often find it particularly difficult to adjust rations to take into consideration fish size and stocking densities. Given the large number of factors that affect ration size, and the paucity of information pertaining to feeding rates in the semi-intensive systems, it is not possible at this time to provide the farmers with accurate ration guidelines. This is an issue that needs to be resolved as a matter of urgency.

TABLE 19
Generally suggested feeding rates (% body weight per day) for industrial sinking and floating pellets for Indian major carps and striped catfish (Bharat Lux Indo Company)

Sinking pellet (18-20% crude protein)			Extruded floating pellet (28% crude protein)		
Fish size (g)	Indian major carps	Striped catfish	Fish size (g)	Indian major carps	Striped catfish
<100	3.0	3.0	< 100	2.8	3.0
101–300	2.0	2.5	101–150	2.3	2.5
301–500	1.5	1.8	151–200	1.8	2.0
501–700	1.2	1.5	201–250	1.6	1.8
701–900	1.0	1.3	251–500	1.3	1.5
>900	0.8	1.0	501–1000	0.8	1.0

Source: Field Survey (2010).

TABLE 20
Feeding rate for Indian major carps [CP (India) Private Limited]

Initial weight (kg)	Anticipated monthly growth (kg/month)	Sinking feed *	De oiled rice bran	Total feeding rate (percent body weight per day)	Floating feed **
		Feeding rate (percent body weight per day)	Feeding rate (percent body weight per day)		Feeding rate (percent body weight per day)
0.100	0.10	2.64	4.00	6.64	3.30
0.200	0.12	1.60	2.40	4.00	2.00
0.320	0.12	1.00	1.50	2.50	1.40
0.440	0.12	0.72	1.10	1.82	1.15
0.560	0.15	0.70	1.10	1.80	1.00
0.710	0.15	0.56	0.80	1.36	0.80
0.860	0.18	0.55	0.80	1.35	0.75
1.040	0.18	0.46	0.70	1.16	0.75

* 20% protein feed; ** 22% protein feed.

Source: Filed Survey (2010).

Despite the difficulties and complexities of developing feeding tables for major carp production in semi-intensive culture systems, practical feeding tables have been developed and successfully applied in commercial carp culture in Israel (Marek, 1975, Tacon, 1988). The potential to apply this model to the development of feeding tables for Indian major carp culture could be considered.

Feed conversion ratio

The mean food conversion ratios (FCR) recorded in the various aquaculture production systems are presented in Table 21.

TABLE 21
Mean food conversion ratios in different culture systems

Culture system	FCR (SD*)
Typical-IMC-mash	3.05 (±0.85)
Typical-IMC-mash-Nellore	3.38 (±1.07)
Zero point culture-IMC-mash	3.57 (±0.92)
Zero point culture-IMC-mash-pellet	1.78 (±0.61)
Zero point culture-IMC-striped catfish-mash	2.85 (±0.75)

* SD: Standard deviation.
Source: Filed Survey (2010).

The FCR recorded across all the culture systems ranged between 1.78 to 3.57:1. The most efficient food conversion was recorded in the zero point IMC culture systems using mash-pellets. In all the production systems, the FCR cannot be attributed to the sole use of the supplementary feeds. In every case, phytoplankton and zooplankton and other natural food organisms significantly contribute to the nutrition of the fish. Nevertheless, it is evident that the use of pelleted aquafeeds generally improves the FCR recorded in these systems. Of those farmers that reported using pelleted feeds, 86 percent reported using sinking pellets with protein inclusion rates that ranged between 16 and 22 percent. The pellets contain similar crude protein content to the mash feed that is used by the farmers when their mash formulations incorporate 80 percent de-oiled rice bran, 10 percent groundnut cake and 10 percent cottonseed cake (Ramakrishna, 2007). Despite the lower quantities of feed materials that are used in the manufacture of the pelleted feeds, they are based on different formulations to those used in the mash feeds; in part, this may account for the improved FCR recorded when pelleted feeds are used. For example, soybean cake is not normally used in the mash feed, but is used in the pelleted feeds. Edwards (2008) noted that the high average FCR (2.5–3.5:1) attained in Kolleru carp culture system represents low levels of nutritional efficiency, and reported that an FCR of 1.0:1 is attainable in experimental fertilized ponds in which the fish are fed manufactured pelleted feeds.

The costs associated with feeding commercial pellets are high, and many farmers in the survey were concerned that these were associated with the manufacturing/production process. In general, the farmers reported that, in terms of growth and economic returns, they were satisfied with the mash feeds that they used. Many farmers suggested that as mash feeding practices had not changed over the past thirty years, they were clearly satisfied with the culture practice. In this regard, it is likely that mash feeds will remain an integral part of their production systems for many years to come. However, consideration could be given to developing high quality pelleted feeds to be used in conjunction with the feed ingredients used in the traditional mash feeds. Prior to adoption by the farmers, the production and economic efficiencies accruing to these types of combined feeding regimes needs to be evaluated.

Feeding frequency

All the farmers, including those using a mixture of sinking and mash feeds, reported feeding Indian major carps at least once a day. Feeding was undertaken in the morning.

A number of the farmers that used a combination of floating pellets and mash feeds reported feeding twice a day at 0600 to 0800 hours and again during the evening hours at 1400 to 1600 hours. Under this feeding regime, the mash was fed in the morning and the floating pellets in the evening. While there was no technical or scientific rationale for feeding in the morning, it became a standard practice as it was a convenient time for the farmers and farm workers to feed. The farmers usually inspect their ponds between 0600 and 1200 hours, and attend to other business during the rest of the day. Generally, the farmers monitor the feed preparation, feeding, and feed response, and provide instruction to their workers. The farm workers are usually family members.

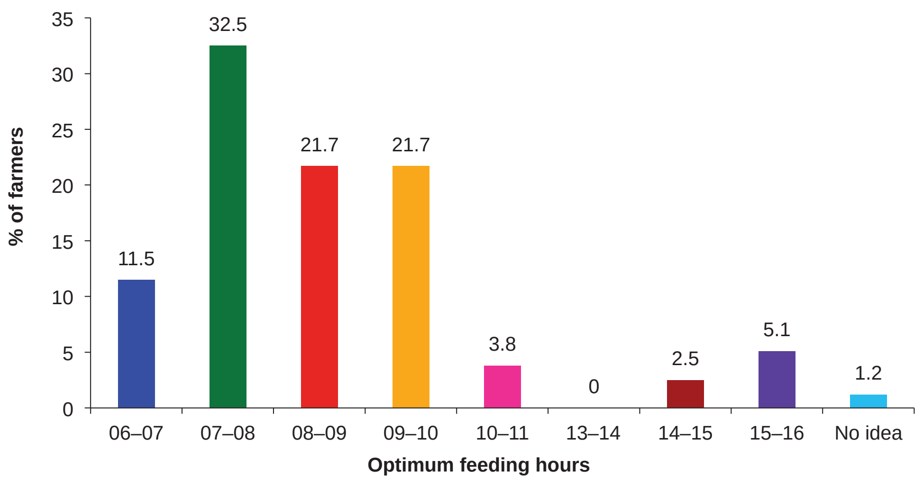
De Silva and Davy (1992) demonstrated that feed utilization can be optimized by increasing feeding frequencies, and that the growth response to differential feeding frequencies is both species-specific and specific to the life history stage of the fish. For example, in common carp production using demand feeders, Hepher (1988) established that growth parameters were not affected by feeding on a continual basis. In contrast, when applying a fixed ration feeding regime in channel catfish culture, an increase in the number of meals from two to four improved food conversion efficiencies (Greenland and Gill, 1979).

Under field conditions, and in the presence of natural food in the form of plankton, Biswas *et al*. (2006a, 2006b) established that feeding Indian major carp fry and fingerlings once a day using a formulated powdered supplementary feed was sufficient for optimum growth and survival. However, Biswas *et al.* (2006a) observed that higher feeding frequencies resulted in improved FCR in rohu, and that rohu required higher feeding frequencies as compared with catla and mrigal. To date, there have been no studies to determine the effect of feeding frequency on the grow-out of Indian major carps in commercial semi-intensive systems in India.

Feeding time

Farmers apply different feeding strategies to their Indian major carp production systems. While 42.5 percent of the farmers surveyed reported feeding between 0600 and 0800 hours, 43.4 percent fed between 0800 and 0900 hours, with the remaining 3.8 percent feeding between 1000 and 1100 hours (Figure 9). The farmers were of the opinion that the feeding periods that they used were optimal for the species and production systems. Of those farmers that used pelleted feeds, 12.5 percent and 5.1 percent reported feeding a second ration between 1400 and 1500 hours and 1500 to 1600 hours respectively. A further 11.2 percent reported feeding at irregular

FIGURE 9
Feeding hours considered optimum by the farmers



Source: Field survey (2010).

PLATE 14
Rohu piping at surface during early morning

times before noon. The relative efficiency of the two types of feeding regimes, i.e. convenience-based and those that are empirically determined, needs to be evaluated and the optimum feeding times determined.

Bolliet, Azzaydi and Boujard (2001) reported that to optimize growth, feeding schedules should correspond to the natural peak of the feeding activity of the culture species (e.g. Plate 14). It is not evident whether the daily peak in the feeding activity of all of the three Indian major carps are similar.

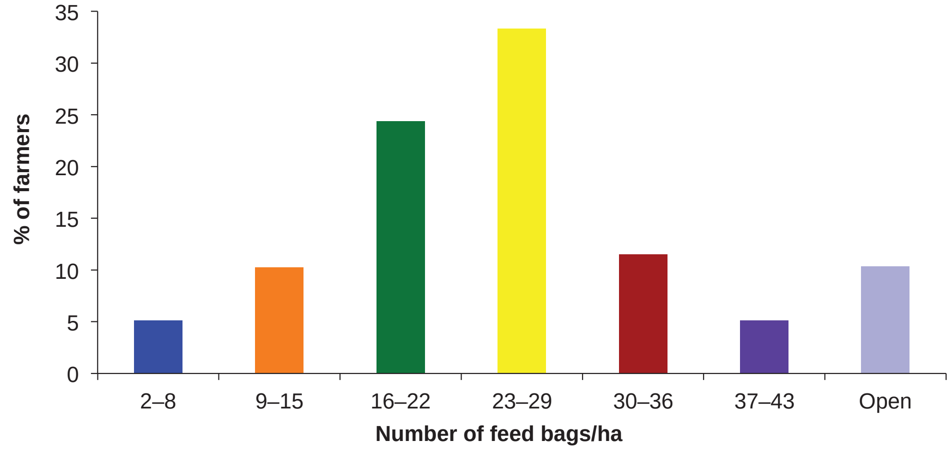
Carp culture in the state primarily employs still water systems, with some capacity to compensate for water loss through evaporation and seepage. There is rarely capacity for frequent water exchange. Aeration using purpose-built mechanical aerators is not used; the pond waters generally remain well oxygenated. Surfacing behaviour was reported by 35 percent of the farmers, and it increased during the months of March to June, coinciding with the rainy season. Aeration is only undertaken during periods of acutely low dissolved oxygen and during pond de-stratification and phytoplankton crashes. To aerate, diesel water pumps that are mounted in boats are used. Cyprinids show signs of suffocation when dissolved oxygen concentrations fall to 1.5 to 2 ppm, and they may die if the concentration falls still lower for prolonged periods (Svobodova *et al.* 1993).

Number of feed bags or feeding points

The number of feeding points per hectare of pond surface is presented in Figure 10. A third of the farmers reported 23 to 29 feed points per hectare, a further 10.4 percent reported distributing their feed throughout the pond ('open'; see Figure 10); however, the latter practice was limited to the first month of production. In general, the farmers use between 5 to 8 feeding points per hectare at the start of the production cycle when the feed requirements are low. As the feed requirements increase, they gradually increase the number of feed points in the pond; usually a maximum of 25 feed points per hectare are used. The number of feed bags or points fixed during the initial months of the culture period is also based on other factors, such as the total weight of stocked fish, the level of natural pond productivity, the size variations in the stocked fish, and finally the compatibility of species stocked which affects the rate at which damaged feed bags need to be replaced.

In Nellore district, carp farmers use pole and simple hapa feeding techniques. The farmers rarely change their the feed bags. Each day, mash feed is delivered to the feeding points, and the required quantity of mash is placed in the bag. Hapa feeding

FIGURE 10
Usage of feed bags (numbers/ha)



Note: Open means no bag; feed is distributed throughout the pond, not in bags.
Source: Field survey (2010).

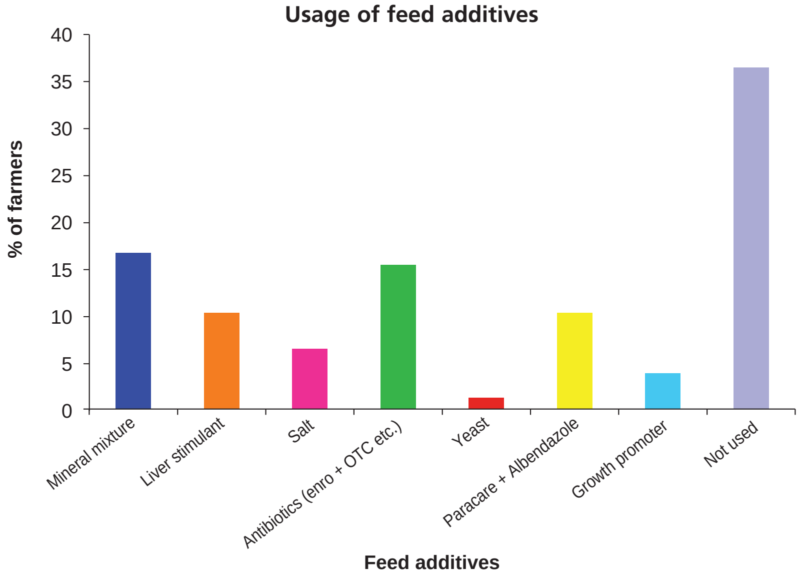
involves the use of different sizes of hapas that are made of discarded perforated fertilizer bags. The dimensions of the hapas are either 2 × 1 × 0.75 m or 4 × 4 × 0.75 m, and accommodate 25 to 40 kg of mash feed. The fish access the feed through the perforations in the bottom of the hapas.

In Indian major carp, black tiger shrimp or giant river prawn polyculture ponds in East Godavari district, the fish are fed using bag or enclosure feeding techniques. Pelleted feeds for black tiger shrimp or giant river prawns are distributed by broadcast feeding. In all Indian major carp culture systems, sinking pellets are either mixed with mash, or fed exclusively using the bag feeding technique.

Feed additives

The feed additives that were used by the mash farmers are presented in Figure 11. The most frequently used feed additives were mineral and vitamin mixtures (17 percent of farmers). Antibiotics that were used to treat bacterial diseases were used by 15 percent

FIGURE 11
Usage of feed additives



Notes: Enro - enrofloxacin; OTC - oxytetracycline.
Source: Field survey (2010).

of the farmers, and crustacean and helminth anti-parasitic drugs were reported by 10 percent of them. The use of herbal liver stimulants was reported by 10 percent of the farmers. The other feed additives that were used to a lesser extent included salt, yeast and unidentified growth promoters.

Feed additives

The feed additives that were used by the mash farmers are presented in Figure 11. The most frequently used feed additives were mineral and vitamin mixtures (17 percent of farmers). Antibiotics that were used to treat bacterial diseases were used by 15 percent of the farmers, and crustacean and helminth anti-parasitic drugs were reported by 10 percent of them. The use of herbal liver stimulants was reported by 10 percent of the farmers. The other feed additives that were used to a lesser extent included salt, yeast and unidentified growth promoters.

Nutritional supplements

The different types of nutritional supplements that are commonly used in Indian major carp production in the state, their composition, cost, and application are presented in Table 22.

TABLE 22
A representative categories of nutritional supplements, their contents, prices and usage

Feed additives	Content	Cost (INR/kg)*	Dosage and use
Mineral mixture			2–10 kg/1 000 kg feed for irregular periods
Calcium	280 g	50	
Phosphorus	90 g		
Manganese	1.2 g		
Iodine	1.0 g		
Iron	6.0 g		
Copper	1.0 g		
Cobalt	0.2 g		
Magnesium	13 g		
Zinc	2.15 g		
Lysine Mono HCl	4.5 g		
DL–methionine	2.0 g		
Fluroine	0.5 g		
Mineral and vitamin mixtures			1–2 kg/1 000 kg feed for irregular periods
Chlorine chloride	400 g	95	
Liver extract	15 g		
L-lysine	3 000 mg		
DL-methionine	2 000 mg		
Vitamin A	5 000 IU**		
Vitamin D_3	1 000 IU		
Vitamin E	2 000 mg		
Vitamin C	4 000 mg		
Zinc	2 500 mg		
Copper	5 000 mg		
Magnesium	1 500 mg		
Iron	2 000 mg		
Phosphate	Filler material		
Calcium	Filler material		
Probiotics plus enzymes		200	1–2 kg/1 000 kg feed for 7–10 days or irregular periods
Lactobacillus acidophilus	500 000 CFU		
Saccharomyces cervisiae	500 000 CFU		
Amylase	250 000 Units		
Lipase	20 000		
Cellulase	30 000		
Phytase	45 000		
Galactosilase	45 000		
Glucanase	70 000		
Pectinase	120 000		
Xylanase	35 000		

TABLE 22 (CONTINUED)

Feed additives	Content	Cost (INR/kg)*	Dosage and use
Probiotics plus enzymes plus vitamins		250	
Bacillus coagulans	45 000 million CFU		
Lactobacillus acidophilus	45 000		
Lactobacillus lactis	30 000		
Bacillus licheniformes	30 000		
Saccharomyces cervisiae	125 000		
Sea weed extract	100 g		
Enzyme complex			
· Amylase	24 000 IU		1–2 kg/1 000 kg feed for 7–10 days or irregular periods
· Phytase	11 000 IU		
· Protease	200 000 IU		
· Cellulase	150–250 IU		
· Beta-galactosidase	800–1 000 IU		
· Lipase	50–100 IU		
Coated Vitamin C	20 g		
Vitamin B_1	1 g		
Vitamin B_6	1 g		
Sodium benzoate	6 g		
Herbal liver stimulants	*Emblica officianalis* *Phyllanthus amarus* *Carum copsium*	90	3–5 kg/1 000 kg feed consecutively for 10 days or for irregular periods
Yeast dried	*Saccharomyces cervisiae* (cells)	200	2–5 kg/1 000 kg feed consecutively for 7–10 days or for irregular periods

* US$1 = INR47.03; ** IU = International units, CFU = Colony Forming Units.

Source: Field Survey (2010).

Studies in Israel have suggested that despite the essentiality of vitamins in dietary formulations, tilapia grown in ponds, cages or concrete tanks at densities as high as 100/m^2 and yields up to 20 tonnes/ha did not show any beneficial effects from the addition of dietary vitamin supplements (Viola, 1989). Many farmed fish species, including Indian major carps, are filter-feeders and derive much of vitamin and mineral requirements by consuming fine particulate matter (phytoplankton, zooplankton, bacteria and detritus; Colman and Edwards, 1987). Of concern is whether the addition of mineral and vitamin mixtures to the mash diets has any measurable effect in terms of increasing feed efficiency and optimizing growth. This is an issue that requires further study.

The increasing occurrence and severity of disease events and the development of drug resistant pathogens represents a serious production issue. Regulations to control the use of drugs and chemicals in aquaculture have been developed, and increasingly consumers are becoming more conscious of issues related to drug residues in fish flesh and effluent waters. These concerns highlight the need to develop novel strategies to prevent and control disease outbreaks, optimize the growth and health of the fish, and develop products and techniques that are environmentally sustainable and ensure product health. To date, two approaches have been advocated to address these issues, viz. the use of probiotics as nutritional supplements and the use of herbal therapeutants.

The development of probiotics focuses on the isolation of bacteria that naturally occur in fish intestines and contribute to growth and disease resistance. The role of these bacteria and enzymes in improving FCR, growth characteristics, as well as in reducing some forms of environmental pollution - most notably feed derived phosphorus effluent loadings - is well established. Ghosh, Sinha and Sahu (2007) isolated four probiotic strains of bacteria from the intestines of rohu, catla and mrigal. All four strains proved antagonistic against the pathogen *Pseudomonas fluorescens* and one strain, identified as *Bacillus subtilis*, was found to be non-pathogenic to mrigal fingerlings and inhibited the pathogenic *P. fluorescens*, *Aeromonas hydrophila* and *Edwardsiella tarda*. Kumar *et al.* (2006), evaluated *Baccillus subtilis* against a virulent strain of *A. hydrophila* that causes haemorrhagic septicaemia in rohu and catla. Based on a survival rate of 87.5 percent in challenged rohu, it was concluded that *B. subtilis* can be used effectively as a commercial probiotic. Nevertheless, it is probable that it will be some time before the practical application of *B. subtilils* in dietary formulations will be available to the farmers.

Although regularly used in poultry feeds, phytase is not used in dietary formulations for Indian major carp production. Baruah *et al*. (2007) reported that the supplementation of microbial phytase in carp feeds is likely to provide both economic and environmental benefits. Phytase releases phytate-bound phosphorus, thus increasing its bioavailability to the fish, improving crude protein digestibility, and decreasing the need for dietary mineral supplements. It also provides environmental benefits through the reduction of phosphorus and mineral outputs in effluent streams. Taking these issues into consideration, it would be appropriate to investigate the potential to incorporate phytase into the feed formulations used in Indian major carp production.

Ghosh, Sen and Ray (2002) isolated bacilli from the intestines of rohu fingerlings and tested their efficacy in improving digestive processes in the fish. The bacilli were identified as *Bacillus circulans*, *Bacillus pumilus* and *Bacillus cereus*, and were found to produce digestive proteases, amylases and cellulases. The results suggest that the bacilli may prove useful in improving the digestibility of formulated compound feeds. If the commercial use of enzyme-producing bacteria in feed formulations becomes a reality, their application could, for example, result in the enhanced digestion of cellulose-rich plant feed materials and phytoplankton.

Consumers take product characteristics such as freshness, natural flavour, nutritive value, taste, flesh texture and natural pigmentation into consideration when purchasing fish. In terms of Indian major carp production, the major product quality issues include;

- a black discoloration that can occur on the fish (common in catla);
- the fish muscle becoming soft;
- a white discoloration that occurs when the fish are harvested during periods of low dissolved oxygen;
- off-flavours;
- female fish with developed ovaries; and
- an unacceptable appearance resulting from either the clinical signs of disease or body deformities.

Fish with a black discoloration and with clinical signs of disease are not usually harvested by the buyers until the discoloration and the signs of disease disappear. Presently the farmers are not using any specially formulated finisher diets to improve the quality of fish during the pre-harvest culture period.

Therapeutants

The use of permitted antibiotics and other therapeutants to treat bacterial and parasitic diseases cannot be avoided. As previously indicated, the Ministry of Commerce has banned the use of twenty antibiotics and other pharmacologically active substances in Indian aquaculture.

Some important feed-based therapeutants that are used in Indian major carp production are presented in Table 23.

The list of antibiotics outlined in Table 23 has been adopted by the Fisheries Department of the Andhra Pradesh State Government. In addition, the State legislature has laid down a condition in the GO[4] Ms. No. 83 stating that fish farmers that apply for registration of their ponds or farms with the state government should not use any of the banned antibiotics specified in GO Ms. No. 83 for fish health management, control

[4] Government Order of the State of Andhra Pradesh.

TABLE 23
Typical therapeutants used in Indian major carp feeds

Feed additive	Content (percent AI*)	Cost	Dosage and use
Branded antibiotics			
Oxytetracyclin	10		
Enrofloxacin	10	600 INR/kg (US$12.7/kg)	
Sulphamethoxisole + Trimethioprim	10+2		100 mg AI/kg fish weight (consecutively for 7 days)
Chlorotetracyclin	15		
Crustacean parasiticides			
Ivermectin	0.2	280 INR/kg (US$5.9/kg)	1 kg brand product/1 000 kg feed) (consecutively for 5 days)
Anthelminthics			
Albendazole	5	260 INR/kg (US$5.5/kg)	1 kg brand product/1 000 kg feed (consecutively for 5 days)

* AI = active ingredient.
Source: Field Survey (2010).

of fish diseases or for any other purpose. The relevant sentence is reconstructed as "It becomes mandatory for any farmer who registers his fish culture facility with the state Government of Andhra Pradesh, not to use any of the banned antibiotics specified in GO Ms. No. 83, for fish health management, control of fish diseases or for any other purpose".

Enrofloxacin is an antibiotic that farmers use to control the haemorrhagic septicaemia caused by *Aeromonas hydrophila* in rohu, catla and striped catfish. Gopal Rao, Mohan and Seenappa (1992) reported the use of six types of antibiotics or combinations of antibiotics used as feed additives to control bacterial diseases in Indian major carps.

The Marine Products Export Development Authority (MPEDA) of India, in co-ordination with the local drug authorities and the State Government Fishery Officials, monitor and regulate the use of antibiotics in both black tiger shrimp and fish culture. In March 2009, the MPEDA conducted awareness raising programmes to highlight the negative effects of antibiotic use in fish culture at several production areas in West Godavari, Krishna and East Godavari districts. In general, the monitoring and implementation of the regulations is effective in the black tiger shrimp and giant river prawn sectors - sectors that primarily supply export markets. In contrast, the monitoring and implementation of these regulations in the freshwater fish production sector, which primarily supplies the local market, is currently poor - but gaining in momentum. The MPEDA only has control over those drugs specified in the regulations, and has no control over other types of feed additives.

The use of plant-based medicines and herbal derivatives play a major role in 'Ayurveda'. 'Ayurveda' is a traditional medicinal system, recognized by national and state governments. The significant limitations that have been placed on the use of antibiotics in aquaculture have focused attention on potential to use of plant-based medicines in fish culture (Gatesoupe, 2008). A number of authors have reviewed the role of plant-based medicines in aquaculture (Wang *et al*. 2010; Direkbusarakom, 2004). In Brazil, the antibacterial activity of 46 different plant extracts have been tested against pathogenic bacteria (Castro *et al.* 2008). More recently, Citarasu (2009) reviewed more than 50 herbal plants for their efficacy in addressing a wide range of biological parameters, including growth and disease control. Notably, *Aeromonas hydrophila* infection in spotted snakeheads (Channa punctatus) has been controlled by treatment with a leaf extract of *Solanum nigrum* (Rajendiran, Natarajan and Subramaniah, 2008). This observation provides some potential for resolving infections of *A. hydrophila* in Indian major carp culture systems.

While it is convenient to apply plant-based medicines directly into the culture waters under laboratory conditions, farmers prefer to use these products as feed additives.

PLATE 15
Antibiotic administration
Left: antibiotic mixed in a starch solution; right: antibiotic solution being added to pelleted feed

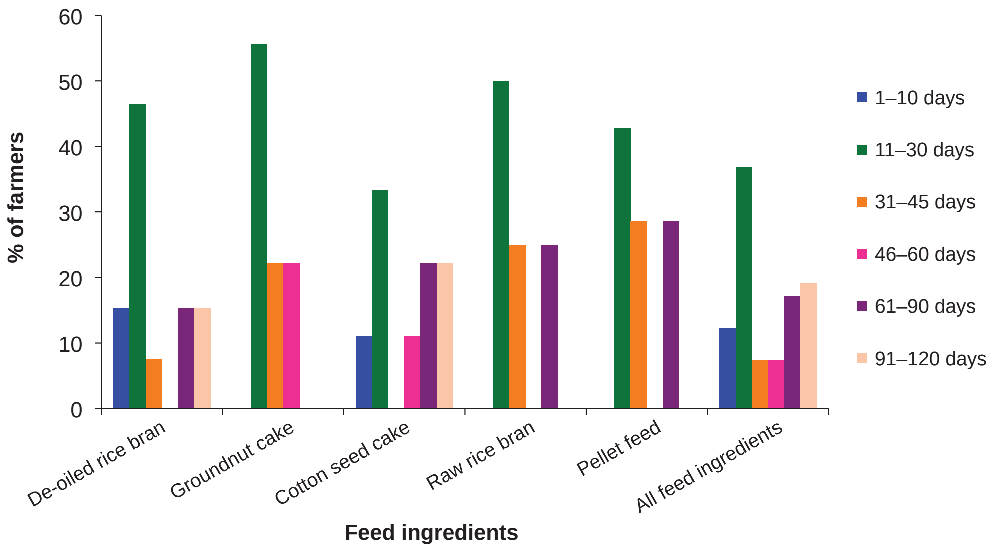
Using them in this manner means that large quantities of water do not need to be treated and thus the dosages that are required are relatively small. Furthermore, the farmers are familiar with the administration practices, which are easy and convenient and, if necessary, can be undertaken over consecutive days. For the purpose of treating fish diseases, the selected antibiotics are used by mixing with mash feed or by first mixing them with a starch solution (heated and cooled) and then applying to the pelleted feed (Plate 15).

On-farm storage

Typically, farmers store their feed and feed ingredients and feeds for different time periods (Figure 12). While six percent of the farmers used their feeds and feed ingredients within one to ten days of purchase, nine percent reported storage periods that ranged between 91 and 120 days. The most common storage period (44.2 percent of farmers) was between 11 and 30 days.

The feeds, either mash or pellets, were stored in three basic storage systems. The majority of farmers (58 percent) reported storing their feeds in well protected

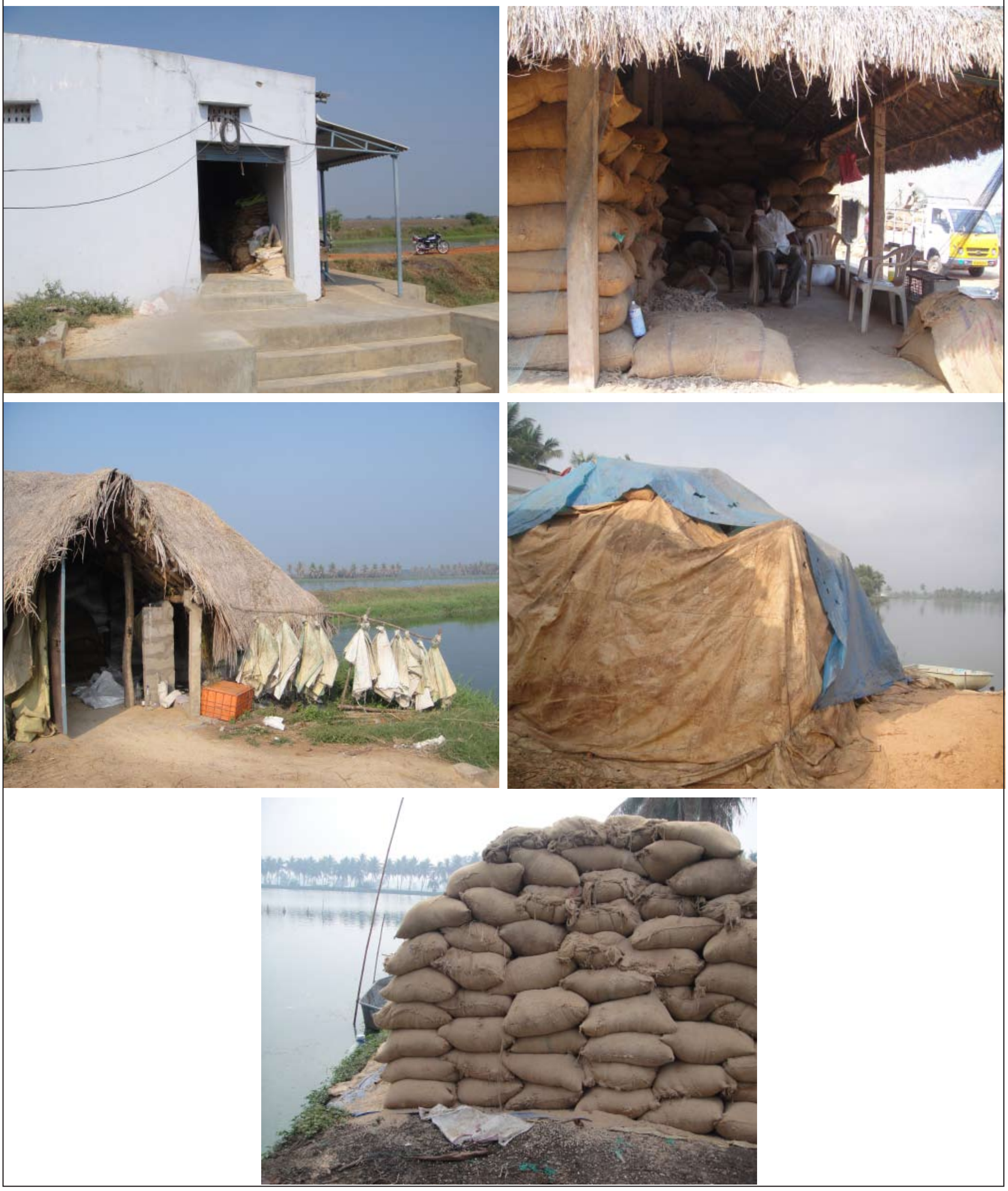
FIGURE 12
Duration of on-farm feed and feed ingredient storage



Source: Field survey (2010).

permanent storage facilities constructed with bricks and mortar. Semi-permanent structures were used by 13 percent of the farmers, and 29 percent reported using open areas on the pond embankments. Feed stored in the vicinity of the ponds is covered by polythene/plastic sheets or tarpaulins to prevent rain, heat, and animal damage. The main types of storage facilities the farmers use for on-farm storing of feed ingredients are shown in Plate 16.

PLATE 16
Feed storage facilities
Top: permanent and semi-permanent structures
Middle: temporary structures and open areas covered with polythene/plastic sheets or tarpaulins
Bottom: open areas (used during summer and winter for very short storage periods)



3.6.3 Nutritional status for grow-out fish

In the absence of natural feeds, stunted Indian major carp yearlings have been shown to require a dietary formulation comprising 25 percent protein and 37 percent carbohydrate; in the presence of natural feeds, the protein component of the dietary formulation can be reduced to 20 percent (Nandeesha *et al.* 1994). Veerina, Nandeesha and Gopal Rao (1993) found that while supplementary feeds used in carp culture contribute to 15 to 20 percent of dietary protein, there is no information to describe the optimum levels of dietary carbohydrate required for Indian major carp production in intensive, heavily fed and fertilized systems, such as those practiced in Andhra Pradesh. The carbohydrate level of typical supplementary feeds used in carp culture is about 45 percent. These feeds contain de-oiled rice bran (80 percent inclusion), groundnut cake (10 percent) and cottonseed cake (10 percent). In comparison with the natural food derived from pond production, this represents a higher dietary carbohydrate level, and thus formulated feeds probably include carbohydrates at higher levels than required for optimal growth. Typically, excess dietary carbohydrate results in fat deposition, and indeed it is often observed that there is excessive fat in the viscera of the larger pond-cultured catla and rohu (<500 g).

3.6.4 Nursery feeds and feeding practices

In nursery production systems, three to four day old spawn is procured from hatcheries and transported in oxygenated polythene bags to the nurseries. Pond water depth in the nursery systems is maintained at 1 to 1.25 m. The principal feed ingredients used in nursery production are groundnut cake, de-oiled rice bran and raw rice bran (Plate 17). Typical nursery production cycles are between 20 and 30 days. Groundnut cake is used exclusively during the initial seven to ten days of the production cycle. On day 11, rice bran is added to the groundnut cake. In rohu nurseries, the farmers use groundnut cake exclusively until the seed grows to a size of 1.5 to 2 inches (3.8 to 5.1 cm), at which point (to save costs) the feed source is changed to de-oiled rice bran. This change in feed is most common when the seed is held for extended periods in the nursery.

Normally, the feed ration used during nursery production is based on the initial stocking density of the system or the size of the pond. Rations are not based on fish biomass. On average, the amount of groundnut cake that is fed (broadcast feeding) equates to 30 kg/ha (range 30 to 185 kg/ha). A week post-stocking, the groundnut cake is mixed with rice bran at ratios of 2:1 or 1:1. After assessing growth and survival rates, some farmers increase feed rations by 25 to 30 percent per week. Another practice is to a fix rations until the spawn attain a size of 1.5 to 2 inches (3.8 to 5.1 cm).

PLATE 17

Principal feed ingredients used in nursery production
Left: soaked groundnut cake ready for application
Right: de-oiled rice bran being distributed in a rohu nursery

All the nurseries follow similar pond preparation procedures that promote the production of natural feeds, especially zooplankton. In general, the ponds are dried after each production cycle. Drying is undertaken over a ten day period, and zinc sulphate (10 kg/ha), and lime (75 to 125 kg/ha) are applied. Usually, quicklime is applied to the pond bottoms. The majority of farmers do not use organic manures during the initial production period, and they are rarely applied during the culture cycle. Three to five days before stocking the spawn, SSP is applied at 50 to 60 kg/ha. Fertilizers are applied during the production cycle. Typically, 75 to 175 kg/ha of groundnut cake is mixed with 12 to 65 kg/ha SSP. Cattle dung is sometimes applied as a fertilizer at 1 000 kg/ha; to improve water quality, some farmers apply zeolite at 25 kg/ha. To promote zooplankton growth, the majority of the farmers apply groundnut cake one day before stocking at 180 to 250 kg/ha.

Nutrition and feeding fry

In order to support good growth, the fingerlings and fry of Indian major carps require a ration containing 35 and 40 percent protein respectively (Sen *et al.* 1978). Farmers use high protein feed ingredients such as groundnut cake for their high value species (catla) and low protein ingredients such as de-oiled rice bran for their low value species (rohu). Feeding these ingredients is unlikely to satisfy the protein requirements of the fish during the nursery production phase. In addition, as the groundnut and de-oiled cake is readily dispersed throughout the water column, it is difficult to establish the amount that is available to the fish or that remains to fertilize the pond.

Due to the sub-optimal feeding practices in these systems, consideration could be given to introducing commercial crumbles or small pellets to improve production characteristics. Since the fish are small, commercial feeds would be required in limited quantities, and hence farmers would probably be in a position to afford them. These commercial feeds are more water stable than de-oiled rice bran and groundnut cake, and are easily ingested by the fry/fingerlings. Using pelleted feeds that have better physical and nutritional characteristics to those of the current feeds may result in improved survival, growth and production.

Hasan and Macintosh (1992) described the optimum pellet sizes for different size classes of common carp fry (Table 24). This information could be used to establish the appropriate pellet sizes required by Indian major carp fry of different sizes.

TABLE 24
Details of common carp fry size, total length and preferred pellet size

Fry size (mg)	Total length (mm)	Preferred pellet size (µm)
15–23	13–18	125–300
46–97	17–22	300–500
105–209	20–25	300–790
210–466	24–31	500–1 000

Source: Hasan and Macintosh (1992).

3.6.5 Grow-out feeds and feeding practices

The survey revealed that grow-out fish are reared at a mean density of 408 836 fry/ha (range 170 050 to 993 400 fry/ha). Grow-out periods of three to four months were reported. The grow-out seed is obtained from nurseries. The size range of the stocked fish varies between 0.5 and 1.0 g. Catla is usually stocked at lower densities than rohu. Farmers rearing seed for their own use stock rohu and catla together, however, those that plan to sell their seed, stock the rohu and catla in separate ponds - separate stocking facilitates the sale of either species.

The feeds used in the rearing systems comprise groundnut cake, de-oiled rice bran and raw rice bran. The most common feed ingredient combination comprises raw rice bran and groundnut cake at a ratio of 1:1. This ratio is used for the initial 30 days post-stocking, and subsequently changes to a feed containing de-oiled rice bran and groundnut cake at a ratio of 4:1. Another commonly observed trend is the preference shown by growers to feed catla during the initial production phase with groundnut cake, and later to shift to raw rice bran. In comparison, the initial feeding regime that is applied to rohu culture uses raw rice bran followed by de-oiled rice bran. Thus the high or low price of the species directly influences the quality and the cost of the nutrition that is provided.

The feeding rate is dependent on stocking density. The amount of groundnut cake and rice bran that is used to feed 100 000 fry varies between 5 and 45 kg and 10 to 20 kg respectively. The daily feeding rate is adjusted periodically with adjustments being based on the standing biomass of the pond.

The pond preparation and fertilization practices that are used to promote natural food productivity are similar to those employed in the nursery production systems. Nevertheless, there are some differences in the quantities of organic and inorganic fertilizers used. For example, fertilization rates of 4 000 kg/ha are used for poultry manure, and 3 000 kg/ha for cattle dung. Inorganic fertilizers such as DAP are applied at 50 to 125 kg/ha, and urea at 25 to 125 kg/ha. Potash is applied at 25 to 30 kg/ha. During the on-growing period, cattle dung is applied at 1 000 to 2 000 kg/ha.

3.6.6 Broodstock feed and feeding practices

The broodstock ponds are usually small with an average surface area of 0.2 ha (range: 0.1–2.5 ha). Rohu that are over two years old (1 to 2 kg), and three year old catla (3 to 3.5 kg) are used as broodstock. At present, almost all the hatcheries select their rohu broodstock from their grow-out ponds. The rohu broodstock are used for one breeding season, and the spent fish are subsequently marketed. In contrast, the catla broodstock, including those collected from the grow-out ponds, are used for three to four consecutive seasons. In general, the broodstock of both species are selected in April, and conditioned until the peak breeding season in June to September.

The rohu broodstock that are procured from non-farm sources are acclimatized for two to three days in unfertilized, clear water ponds. Rohu and catla stocking densities range between 2 000 and 2 500 kg/ha and 1 500 to 1 800/ha respectively. The broodstock are not fed during the hypophysation process, which usually lasts for 5 to 15 days.

The processes that are used to develop Indian and Chinese carp multi-species broodstock require stocking fish of 30 to 40 mm at 20 000 to 25 000/ha. These fish are the basis of the future broodstock. Prior to stocking, the ponds are prepared by applying lime at 20 kg/ha, cattle dung at 7 500 to 9 000 kg/ha, groundnut cake at 200 to 300 kg/ha, and SSP at 350 to 400 kg/ha. Subsequent fertilization includes the application of DAP at 50 to 75 kg/ha at a usual interval of 15–30 days. During the second year of culture, about 5 000 kg/ha of poultry manure is applied as required. The stock is maintained for two to three years, and subsequently sorted according to species. The fish are usually sorted into species in December, and restocked at 2 500 to 5 000/ha in separate broodstock ponds.

Typically, the broodstock mash feeds comprise de-oiled rice bran (70 percent), soybean cake (10 percent), dry fishmeal (14 percent), groundnut cake (5 percent), and mineral and vitamin mixtures (1 percent). Some broodstock growers prefer to feed broodstock to satiation with a 1:1 mixture of de-oiled rice bran and groundnut cake.

The supplementary feeds that are provided to spent catla comprise a mixture of raw rice bran and groundnut cake at a ratio of 6:1. Approximately 140 kg of this mixture would be fed to 4 000 to 5 000 kg of fish per day. Some farmers use fertilized village ponds (0.5 to 5 ha) to rear their broodstock on natural food. These hatchery owners feel that the broodstock grown in these pond are more fecund, and also that the quality of the ova and seed produced is better. To date, no studies have been undertaken to confirm these opinions.

The rations and the dietary formulations that are used to condition the broodstock can significantly affect maturity and fecundity, and the size of ova produced (Bromage, 1995). Likewise the type of feed used (natural or compound), and its quality, effects broodstock production characteristics. No specific dietary interventions are used during the pre-spawning conditioning of broodstock of either species of Indian major carps. However, an exception is that some farmers use powdered fishmeal as a dietary component (which is not used in nursery, rearing or grow-out production) and add mineral and vitamin mixtures to their feeds.

With the promulgation of the Seed Act of the Andhra Pradesh government, some aspects of broodstock production and maintenance will become mandatory. However, this will only be achieved once standard operating procedures have been developed and implemented.

Hand feeding (broadcasting) in a carp culture pond in Myanmar.
COURTESY OF FAO/S.S. DE SILVA

4. Farmers' perceptions

4.1 FEED QUALITY RELATED PROBLEMS

Of those farmers surveyed, 36 percent expressed significant doubts about the quality of the de-oiled rice bran that was available for use in their mash feeds. De-oiled rice bran is the most important and most commonly used feed ingredient in mash feeds. A further 14 percent of the farmers complained that the quality of groundnut cake and cottonseed cake was poor, and four percent of the farmers were not satisfied with the quality of the feed pellets that they were using. The remaining 42 percent expressed satisfaction about the quality of both the mash feed ingredients and pelleted feeds available to them (Figure 13).

The complaints about the quality of the de-oiled rice bran focused on:

- the unacceptably high moisture content, resulting in fungal growth;
- high fibre levels;
- lower crude protein levels than specified and paid for;
- the adulteration of the product with a high percentage of rice husk or saw dust; and
- adulteration with urea to indicate a higher crude protein level than was the case (urea adulteration is usually suspected if the protein content of the rice bran exceeds 16 percent).

The quality problems reported for groundnut cake include:

- contamination with fungal growth (Plate 18);
- high fibre contents due to excessive levels of shell debris;
- adulteration with powdered tamarind seeds and fine sand to increase the weight; and
- inaccurate weight measurements being used to package and sell the product.

Fewer quality problems were reported about the cottonseed cake that was available to the farmers. However, it was reported that some consignments contained unacceptably high fibre contents and high levels of anti-nutrition factors such as gossypol. In some consignments, it was reported that between five and ten percent of the cottonseed cake formed hard balls which could not be used as feed. The quality problems related to industrially manufactured pellets included the presence of fungal

FIGURE 13
Farmers reporting quality related problems in feeds and feed ingredients

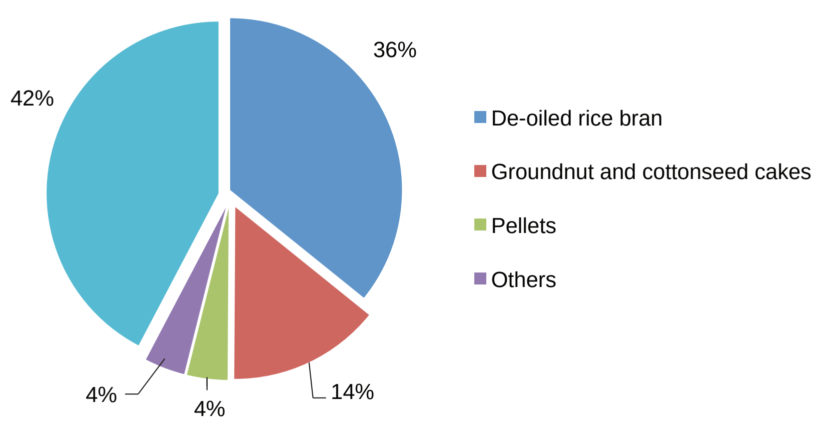


PLATE 18
Fungal growth on feed ingredients
Top: groundnut (left) and cottonseed cake (right)
Bottom: rice bran (left) and wet maize distillers' grains (right)

growth that was attributed to a high moisture content. This high moisture content was the result of inadequate drying. It was also noted that some of the extruded feeds that were designed to float sank in the water, and *vice versa* that those that were designed to sink sometimes floated.

The inferior quality of mash feed ingredients is of concern to many farmers and is discussed within farmer groups. In addition to direct economic losses, low quality feed ingredients result in elevated FCR, increased culture periods, deterioration in fish health and an increase in the susceptibility to disease, and reductions in water quality, especially during the later phases of culture period. The Delta Fish Farmers Association (Eluru) emphasizes the need to develop standard specifications for all feed ingredients and pelleted feeds. In addition, there is a need to develop a practical manual that is designed to assist farmers to identify feed ingredients and their quality.

It is generally accepted that nutritionally well balanced diet are an essential prerequisite to maintaining normal immune function (Stoskopf, 1993). At present, the impact accruing to the use of inferior quality feed ingredients on the health status of Indian major carps is unknown. In addition, the environmental impacts accruing to the use of poorly digested feeds of inferior quality may result in increased volumes of undigested matter in the faeces and increase the potential for the eutrophication. Another issue that needs to be resolved is whether those fish that are fed inferior feeds can utilize natural foods in the pond waters as efficiently as those that are fed high quality feed ingredients. As poor ingredient quality will probably result in suppressed growth rates, extended culture periods, and higher production costs.

The local feed companies that manufacture pelleted feeds and their technical representatives are answerable to farmers for the growth performance of their products. In contrast, it is harder for the farmers to hold the mash feed ingredient producers accountable for the quality of their products. The ingredient producers have no direct interaction with the farmers. The adulteration of feed and feed ingredients remains an important issue that needs to be resolved, and while there are existing feed analytical laboratories, the state government needs to establish additional diagnostic laboratories to detect cases of feed adulteration.

4.2 ROPE OR POLE FEEDING

Rope feeding (Plate 19) represents the most common feeding practice, and was reported by 69 percent of the farmers. Twenty three percent of the farmers reported using pole feeding, followed by eight percent that used hapa feeding or other feeding techniques (Plate 19).

PLATE 19
Rope, pole and hapa feeding techniques
Top: feed bags filled with mash feed - bottom perforations visible (left), tying feed bags to a rope (right)
Middle: tying feed bags to a pole (left), empty feed bags being sun-dried (right)
Bottom: hapa showing bottom perforations for mash feed dispensation (left) and filled hapa (right)

Although rope and pole feeding are variants of the bag feeding technique, the farmers that selected one method over another reported a number of advantages. The advantages of the rope method were reported by those farmers who favoured them to be:

- fast feed distribution, as the feed bags can quickly be tied to the feed rope;
- easiness to monitor and determine how many bags contain uneaten feed after a feed round - the bags that contain a significant quantity of feed remain submerged in water. Based on estimates of the uneaten feed, the farmers can easily make ration adjustments; and
- the support system required to set up rope feeding stations fixed to poles are easy to install or remove at the time of harvest.

In contrast, those farmers that adopted the pole feeding methods highlighted the disadvantages of rope feeding to be:

- partially filled feed bags that are tied to the rope between filled bags can become submerged by filled feed bags. This gives the impression that there is more feed available to the fish than there is. Under such circumstances, feed rations may be reduced over a significant period of time (10–20 days) as the farmers mistakenly assume that there is still sufficient feed in the ponds;
- in the ponds that become oxygen depleted, some farmers aerate the water by running an engine powered boat through the pond. In those ponds that use pole feeding, the boat can move freely between the poles and thus aeration is optimized. This is not possible in ponds that use rope feeding techniques as the ropes obstruct boat movement, and thus aeration efficiencies are reduced; and
- the ropes provide perches for piscivorous birds that predate on the fish that feed from the bags. However, birds only perch on the ropes when the filled feed bags are tied far above the water surface. The position of the feed bag in the water can be easily adjusted when tying them to the rope.

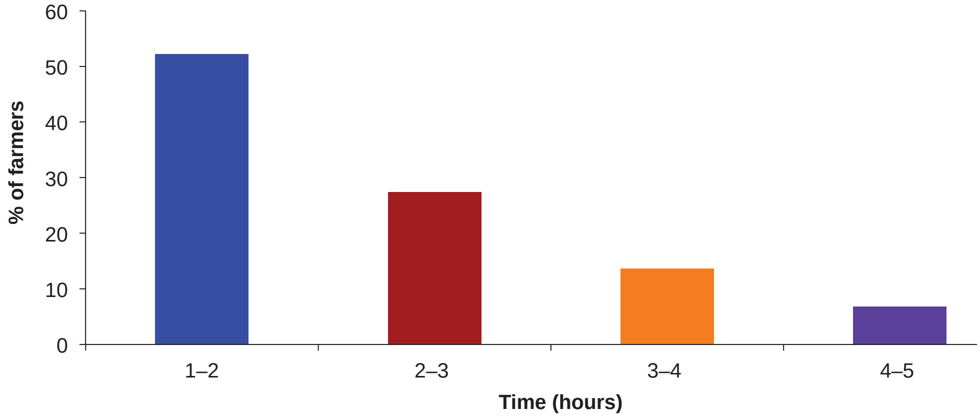
Notwithstanding the disadvantages associated with rope feeding, over a number of decades it has become the most popular feeding method; at a practical level, it is considered the most successful feeding method.

4.3 FEEDING AND FEED CONSUMPTION

Farmers gauge the feeding response by noting how long it takes for a full ration of feed to be consumed. Approximately half the farmers (52.2 percent) reported that it took between one and two hours for a ration to be consumed. A further 27.4 percent of the farmers reported that this period was between two and three hours, 13.6 percent of farmers indicated that it was between three and four hours, and 6.8 percent reported it to be between four and five hours (Figure 14).

Depending upon the feed response to a given meal, those farmers that feed to satiation adjust their rations by between five and ten percent. The length of time that

FIGURE 14
Feeding responses of fish recorded by feed consumption time

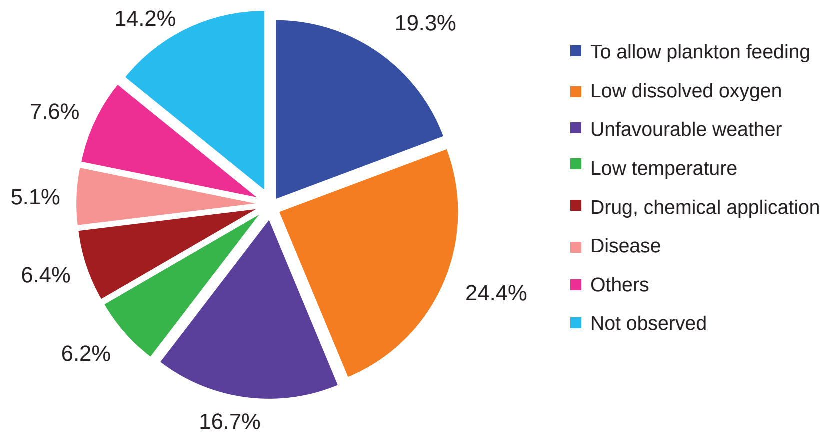


Source: Field Survey (2010).

it takes for the fish to finish a given ration is influenced by a number of factors. These include ration size, water temperature, fish health, fish size, stocking density, species composition, size variation within the population, the time of feeding, interspecific competition, the composition of the mash feed ingredients, nutrient levels, and the abundance of plankton and other natural foods.

Feeding is stopped or restricted under adverse culture conditions. The most common reason for this is the development of low dissolved oxygen levels in the early morning. These are characterized by the fish rising to the surface of the pond. Feed may also be restricted to encourage the fish to consume naturally occurring phytoplankton and zooplankton, and thus reduce feed costs and conserve supplementary feeds. Feed may also be restricted under rain and overcast weather conditions, in periods of low temperatures during winter, during the application of manures, fertilizers and chemicals, and finally in the presence of disease (Figure 15).

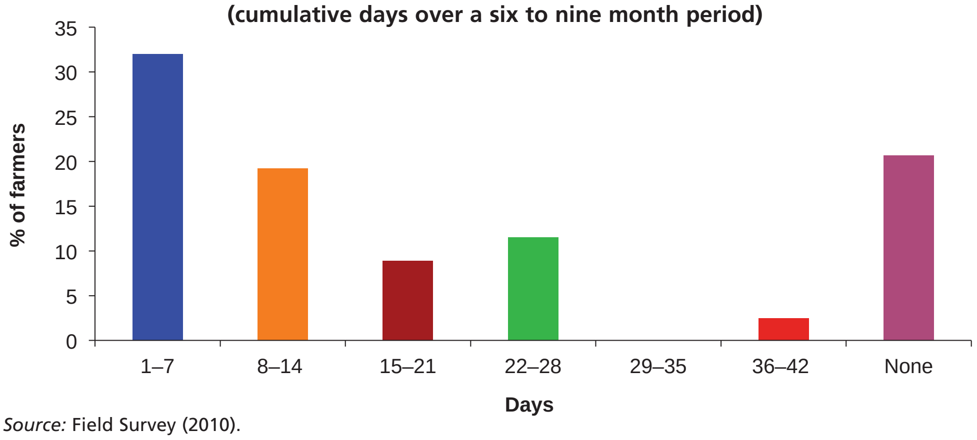
FIGURE 15
Reasons for not feeding fishsh



Source: Field Survey (2010).

The number of cases in which partial rations were fed was not recorded; however, over the past four to five years four percent of the farmers reported ceasing feeding completely once a week, and indicated that the practice did not negatively affect fish growth and production. The practice reportedly saved significant feed costs. The number of days that the farmers did not feed their fish over a six to nine month culture period is presented in Figure 16. The majority of farmers (32 percent) did not feed fish

FIGURE 16
Number of days that farmers did not feed
(cumulative days over a six to nine month period)



Source: Field Survey (2010).

for one to seven days followed by 19.2 percent of the farmers who ceased feeding for 8 to 14 days. 11.5 percent ceased feeding for 22 to 28 days, and 20.7 percent indicated that they never stopped feeding; however, in some cases they reduced rations and started their feed rounds later than usual in the morning.

There are three distinct seasons (summer, winter and rains) in Andhra Pradesh. After prolonged periods of heat that are followed by heavy rains, frequent water exchange takes place in pond waters in the Korellu region. The ponds in this region are not equipped with aerators and, due to a lack of available water during some periods in the year, the possibility for water exchange is limited. Nevertheless, during these periods of water scarcity, feeding schedules are continued as normal, and the ponds continue to be manured and fertilized. Under these conditions, the ponds often become enriched with phytoplankton, and in the early morning hours dissolved oxygen levels can drop to critical levels. The majority of the farmers understand that fish growth is dependent on the utilization of both the supplementary and natural feeds, and of the fact that the economic efficiency of their production system is enhanced by optimizing the use of natural food. In this regard, farmers monitor the prevailing pond conditions every morning and in particular in advance of cyclones and heavy rains. They instruct their workforce to change their feeding schedules accordingly.

In the event of a disease outbreak, the majority of the farmers do not cease feeding unless the disease condition becomes serious, at which point many fish naturally stop feeding. Some farmers believe that feeding fish in infected ponds aggravates the infection and thus, on the identification of a disease, they cease feeding completely. Others find that the need to mix therapeutants with the feed often negates the possibility of reducing the feed ration during disease events. It is rare that an entire pond of fish is lost to disease. Normally the farmers observe their fish on a regular basis, and when they note that even small numbers of fish are dying they adopt remedial measures. Relative to other bacterial and parasitic diseases, bacterial gill disease in rohu, and paradactylogyrosis in catla can result in rapid mortality. The primary method of applying therapeutants to combat bacterial and parasitic diseases is *via* the feeds. In contrast insecticides such as deltamythrin are applied directly into the water.

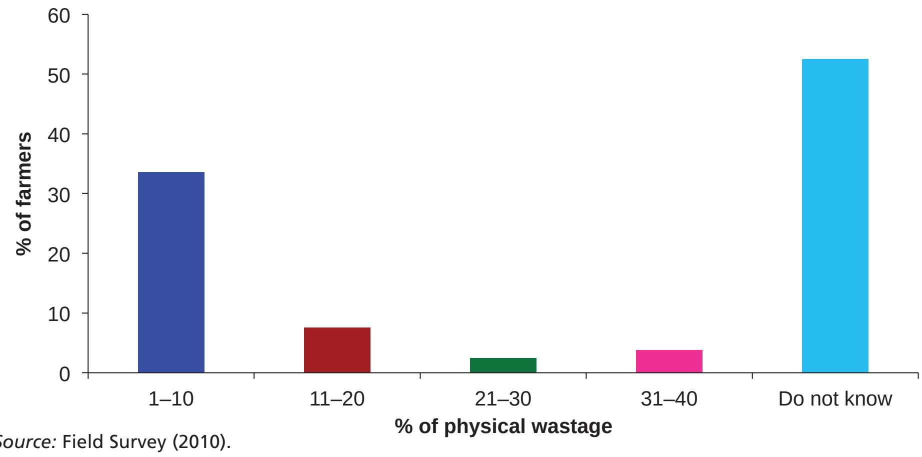
4.4 FEED WASTAGE

Feed wastage and loss of mash feed are quite common in aquaculture practices in Andhra Pradesh and that include wastage during loading and unloading, at storage, during feeding and dispensation (Plate 20). The amount of mash feed that is physically wasted during transport (the loading and unloading of the feed ingredients) and filling the feed bags was assessed (Figure 17). A third of the farmers (33.6 percent) indicated that between one and ten percent of the feed was wasted during these processes. A further 7.6 percent believed that wastage was 11 to 20 percent. 2.5 percent said that 21 to 30 percent of the feed was wasted and 3.8 percent believed that 31 to 40 percent was lost. The remaining 52.5 percent reported that they did not know how much was wasted.

Depending on stocking densities, an average of 300 to 400 fish actively feed at each feed bag. The disturbance caused by the fish at and around the feed bag increases with the size of the fish. Disturbance is also species-specific; for example striped catfish are more active and aggressive feeders than Indian major carps. Also, within the Indian major carps, the rohu appears to be more aggressive than catla or mrigal. Generally, the farmers appear to be unconcerned about the physical wastage that occurs during the feeding process as they believe that the majority of the feed spilt will be consumed by the fish. The commercial feed producers cite the loss of feed using mash ingredients as a major impediment to their use. In order to establish the most effective feeding method, it would be useful to quantify these losses.

PLATE 20
Physical wastage and loss of mash feed
Top: during loading and unloading (left), at storage (right)
Bottom: during feeding through feed bag (left), through feed dispensation in a hapa (right)

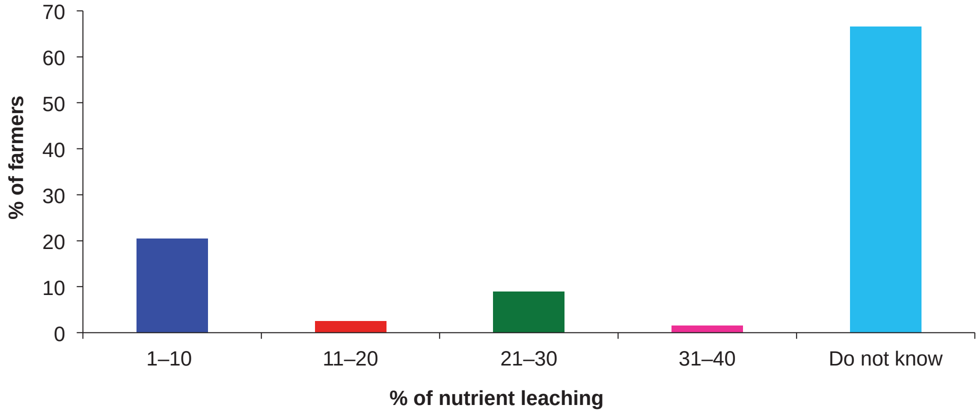
FIGURE 17
Physical wastage of mash feed during transport as perceived by the farmers



Source: Field Survey (2010).

Of those farmers surveyed, 20.5 percent believed that the use of the bag feeding system resulted in nutrient leaching from feed to be between one and ten percent (Figure 18). A further 8.9 percent of the farmers believed it to be between 11 to 20 percent, 2.5 percent of farmers reported it to be between 21 to 30 percent, and 1.5 percent of farmers said it was as 31 to 40 percent. Most farmers (66.6 percent) indicated that they did not know the level of feed losses associated with the bag feeding method. Evidently, the dynamics that feed losses and nutrient leaching have on pond primary productivity are poorly understood. An improved understanding of these dynamics could assist in the development of better feed management practices.

FIGURE 18
Nutrient leaching from mash feed during bag feeding as perceived by the farmers



Source: Field Survey (2010).

4.5 GUT EVACUATION TIME

Ranade and Kewalramani, (1986) investigated gut evacuation times associated with different species of phytoplankton and zooplankton fed to the three species of major carps, establishing that gut evacuation times were influenced by plankton type and the species of fish. Generally, *Anabaena* was evacuated between 48 and 60 hours, *Microcystis* between 42 and 60 hours, *Chlorella* between 48 and 60 hours, *Daphnia* between 18 and 30 hours, and rotifers between 18 and 24 hours. It was also established that the digestibility coefficients of the processed, formulated feeds were five to ten percent lower than those of natural food organisms, supporting the hypothesis that high energy, small food particles are evacuated most rapidly from the stomach of fish (Jobling, 1985). Farmers usually correlate the partial or complete gut evacuation period with the time at which the fish leave the feeding area and start nibbling plankton at the water surface or the periphyton on weeds and other hard surfaces near the pond banks. The survey data revealed that farmers use a wide variety of mash feed ingredients with widely differing physical and nutritional qualities, and that they use these nutrients in combination with a diverse number of natural feeds. Establishing the gut evacuation times of Indian major carps under commercial culture conditions could assist in establishing optimum feeding schedules, and most notably assist in the development of feeding schedules for pelleted feeds.

4.6 THE CONTRIBUTION OF NATURAL FEEDS TO FISH GROWTH

In general, the farmers understand that the presence of natural feeds in the ponds (Plate 21), especially the presence of good quality phytoplankton, contributes significantly to the growth of their stock, and often comment that FCR increase in those ponds that do not maintain optimal levels of phytoplankton.

Plankton plays a major role in sustaining fish growth and optimizing FCR. The contribution of phytoplankton to the nutrition of the fish is of major importance, as it comprises the majority of the naturally produced food, and is the preferred natural food of the dominant species, rohu. However, the food that is derived from the natural productivity of the pond waters is not taken into consideration when calculating FCR. Nevertheless, it is considered a supplementary feed to both mash and pelleted feeds. While the FCR reported in this case study are therefore 'apparent FCR', it is of practical significance to differentiate between the nutritional contribution associated with the application of supplementary feeds and of naturally occurring food. An understanding of this dynamic would be of use in terms of establishing the contribution that expensive supplementary feeds, both mash and pelleted, have on

PLATE 21
Presence of plankton in pond water
Phytoplankton (represented by the green colour of pond water) (left) and zooplankton (collected by the plankton net) (right)

FCR. Furthermore, such analyses could be expanded and used to evaluate whether the current feeding rates that are applied to a given culture system are optimal, and assist in establishing the impact that different supplemental feeds have on growth, and the development of least-cost feed regimes. The technology to undertake these analyses has been demonstrated by Anderson, Parker and Lawrence (1987), who applied stable isotope analysis to differentiate the contribution of supplemental feed and benthic biota on prawn growth. Likewise, Schroeder (1983) established the relative contribution that formulated feeds and algae have on the growth of the blue tilapia (*Oreocromis aureus*). Using stable isotope analysis, Gu *et al*. (1996) determined the contribution that natural and formulated feed sources had on the growth of silver and bighead carp. Similar stable isotope studies could be used to determine the relative contribution of supplementary and natural feeds (phytoplankton, zooplankton and benthic fauna) on the growth characteristics of Indian major carps and other species grown in polyculture. In this regard, Azim *et al*. (2002) used stable nitrogen and carbon isotopes to determine the contribution of natural food to the diets of rohu and catla in periphyton-based ponds.

Establishing the relative contribution that natural and supplementary feeds have on the growth of Indian major carps would provide useful insight into the level of dietary overlap between the species, and most importantly the two major culture species, rohu and catla. During grow-out production rohu is traditionally considered as a predominantly phytoplankton feeder and catla a zooplankton feeder (Chondar, 1999; Jhingran, 1991). Stable isotope analysis could establish the degree of feeding specialization between the species, and the relative importance of using supplemental feeds during the production cycle. Current research efforts are beginning to challenge long held views pertaining to feeding habits and feed preferences. For example, a recent tank study using common carp, orangefin labeo and rohu, demonstrated that rohu shifted from consuming zooplankton to phytoplankton when it had to compete with orangefin labeo for zooplankton (Rahman *et al.*, 2008). In experimental rohu monoculture systems and rohu/common carp polyculture systems, it was established that in the presence of formulated supplemental feeds, rohu shifted its preference from phytoplankton to zooplankton. Furthermore, under tank culture conditions and in the presence of common carp, the rohu spent more time close to the bottom, presumably to increase their consumption of zooplankton; in the process the rohu temporarily switched from being a column feeder to a bottom feeder. Stable nitrogen and carbon isotopes ratios have been used to show that, under polyculture periphyton-based culture conditions, rohu grazes on periphyton and catla targets planktonic food organisms (Azim, *et al.* 2002). Furthermore, in an investigation to establish the optimum stocking density of catla and rohu, Azim *et al*. (2001) found that phytoplankton biomass decreased with increasing catla biomass, and fish growth was density dependent. In contrast, rohu growth was not affected by fish density, but was correlated to the availability of periphyton.

Stable isotope analysis could be used to distinguish between fish that are cultured in ponds using supplementary feeds, and those that are harvested from the wild and have not been exposed to supplementary feeds. Consumers generally prefer Indian major carps that have been harvested from natural water bodies such as rivers and reservoirs. These fish are considered to have superior organoleptic properties to those that have been cultured. Consumers are generally prepared to pay a premium price for wild-caught fish. While it would be difficult and costly to introduce a stable isotope analysis programme to differentiate between wild capture and cultured fish, the protocol could be used to monitor markets and improve product transparency.

The significant nutritional contribution associated with natural feeds provides some scope for developing mixed feeding schedules. Nandeesha *et al*. (1994) improved the growth performance of rohu and catla by alternating the feeding schedules between high and low protein diets. Alternating between the two diets reduced the amount of protein fed to the fish by between 15 and 31 percent, and reduced overall feed costs by 10 to 20 percent. These results were confirmed by Mahanty and Samal (1994), who describe similar results using rohu. These findings also apply to common carp, where alternating feeds with plant and animal protein sources of varied protein levels have been shown to save more than 30 percent of the dietary protein without compromising fish growth (Nandeesha, De Silva and Murthy, 1995). At the farmer level, mixed feeding schedules are now being promoted and adopted in tra catfish farming in Viet Nam. Under farm conditions, a variable feeding schedule in which feeding a ration that is seven to ten percent higher than the norm, followed by the cessation of feeding the following day, results in a cost saving of US$20 200 per production cycle; however, the reduction in feed costs results in a concomitant increase in the production cycle by one month (NACA, 2009). The economic efficacy of applying mixed or alternate feeding schedules has implications for the development of Indian major carp culture and the potential efficacy of applying the technique under semi-intensive culture conditions should be evaluated. In addition, the contribution that plankton and other naturally occurring feed sources makes to the overall nutrition of the fish in these systems needs to be established. Once this contribution has been established it will be possible to reduce and optimize the use of supplementary feeds without compromising fish growth.

In general, the farmers report that the growth of the fish in semi-intensive systems is not affected when the fish are not fed for three to four days - as often happens during the periods of prolonged rain and in peak winter. It is believed that the presence of naturally occurring feeds in the pond waters provides sufficient food during these periods in which the supplemental feeding is restricted. Taking cognizance of the potential to utilize natural productivity to restrict supplemental feeding and reduce feed costs, some farmers have developed novel feeding strategies. The most common strategy is to restrict the feeding of juvenile rohu to de-oiled rice bran (low protein ration) until the fish attain a size of 300 to 500 g. When they reach this size, groundnut cake and cottonseed cake (high protein ration) are added to the feed. This practice appears contrary to the generally accepted concept that smaller fish require a higher dietary protein level than their larger counterparts. However, the farmers contend that the natural food that is available to the fish provides sufficient protein to sustain the growth of juvenile fish. Edwards (2009), suggested that the high protein content in the naturally available feeds provides an inexpensive feed supplement during the initial grow-out period. However, as fish biomass increases, the natural food availability decreases, and hence higher quality supplemental feeds containing higher protein and energy levels are required to provide sufficient nutrients to sustain growth.

The farmers adopt several feeding strategies. For example, some farmers report that they do not feed on Sundays and that this does not negatively affect growth. Other farmers use nets to collect and measure the density of the zooplankton in the ponds and adjust their supplemental feeding rates accordingly. When high levels of zooplankton are observed, they cease feeding supplemental feeds for a day or two to provide an opportunity for the fish to feed on the zooplankton. The farmers assume that the zooplankton density is a good indicator of phytoplankton density and quality.

Farmers monitor the growth of their fish by netting and measuring samples. In the event that growth rates are lower than anticipated, they usually suspect a disease or water quality issue as the causal factor. Fish and water samples are usually tested at diagnostic laboratories to confirm or exclude the presence of disease or water quality issues. In the event that these factors are excluded, the farmers usually attribute the reduction in growth to the quality of the phytoplankton and zooplankton in the ponds. In the event that rohu growth rates reduce, the farmers focus on improving the quality and quantity of the phytoplankton in the ponds by increasing the level of pond fertilization. In the event that catla growth rates reduce, the farmers will attempt to improve zooplankton densities by applying groundnut cake at 75 to 100 kg/ha for two to four consecutive days; alternatively they increase the groundnut cake component of the mash feed by about ten percent. This is done until normal growth rates are restored.

The application of manure and inorganic fertilizers is based on the colour of the pond waters and is not based on nutrient concentrations. As a result, nutrient application rates are unlikely to be optimized. In many cases fertilization may result in nutrients being added to excess or, conversely, remaining limited. Ponds that are limited in essential nutrients will be unable to produce the required levels of phytoplankton production, while nutrients that are added to excess will result in their wastage, and probably result in a deterioration in water quality and possibly stress the fish. To minimize fertilizer wastage, Knud-Hansen (1998) developed an algal bioassay that was designed to help farmers calculate appropriate fertilizer application rates. To date, the bioassay represents a new concept to the farmers, and has yet to be adopted at a large scale.

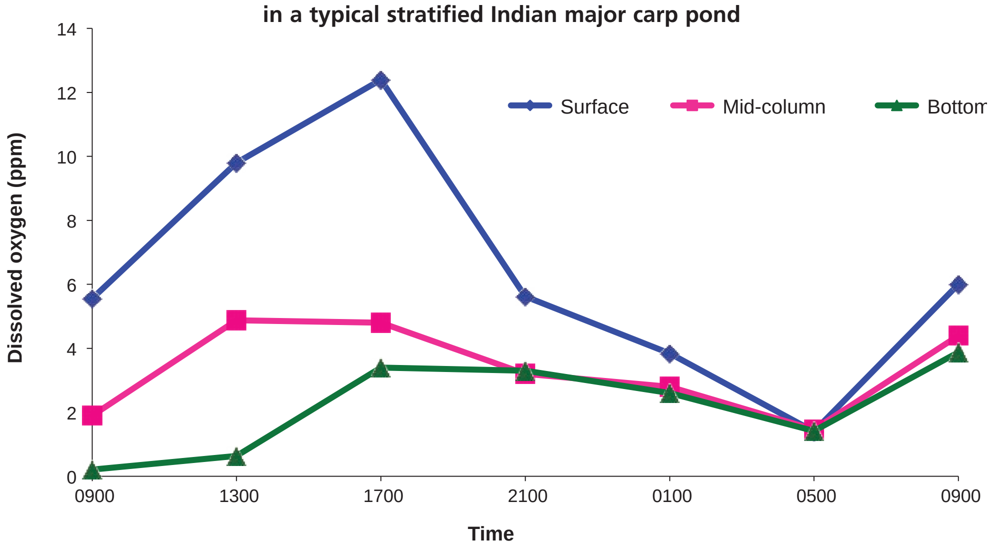
4.7 GROWTH RETARDATION

Many farmers monitor the growth rate of their fish, and assess their growth relative to stocking densities, feed and fertilization rates, and the culture period. Of those farmers surveyed, 15.3 percent indicated that the growth rates that they were achieving throughout the culture period were satisfactory. However, a significant number of farmers said that they were unsatisfactory. Indeed, 8.9 percent of the respondents said that growth either ceased or was reduced for 30 days throughout their culture cycles, and 5.1 percent and 6.4 percent indicated that growth was reduced or ceased for a period 60 and 90 days respectively. The remaining farmers (64.3 percent) indicated that they did not experience reduced growth rates in either of the major culture species. These farmers were also unaware whether the growth rates that they were attaining were optimal.

Many farmers experience problems attaining maximum growth rates. For example, many observe that growth rates are reduced in mature female rohu during gonadal regression (egg reabsorption), and indicated that such fish usually stop growing for one to two months during a typical culture period of 6 to 10 months. The reason why the fish stop growing remains unresolved; however, the farmers report that it does not correspond to seasonality, fish health, feed supply, water quality, or to a specific period in the culture cycle. Evidently, the loss of growth has serious economic implications for the farmers, and is an issue that needs to be resolved.

FIGURE 19

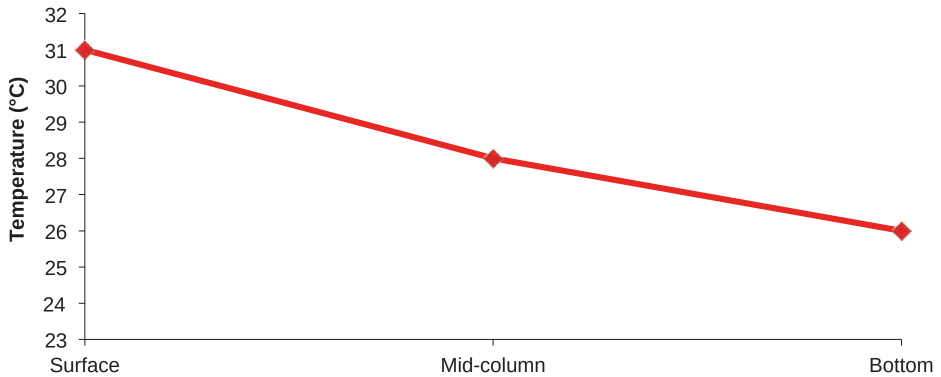
Changes in dissolved oxygen levels at various depths over a 24-hour period in a typical stratified Indian major carp pond



Source: Field Survey (2010)..

FIGURE 20

Changes in temperature (°C) at various depths over a 24-hour period in a typical stratified Indian major carp pond



Source: Field Survey (2010)..

Pond water stratification could be an additional issue that negatively affects growth rates. Grow-out ponds are usually 2 to 2.2 m deep. The accumulation of organic matter on the bottom of the ponds often results in localised anoxic conditions. The dissolved oxygen concentrations and temperatures at the surface, column and bottom levels of a typically stratified Indian major carp pond are presented in Figures 19 and 20, respectively. The water temperature at surface, mid-column and bottom are 31°C, 28°C and 26°C respectively.

Gebhartand Summerfelt (1978) noted that lake stratification and a consequent loss of viable fish habitat reduced growth rates in fish. It is theoretically possible that stratified pond waters could affect the growth rates of rohu more than catla. As rohu are a bottom dwelling species they are more likely to be adversely affected than the catla that reside further up in the water column, where dissolved oxygen levels will be higher.

The semi-intensive Indian major carp grow-out ponds are an average of 2 m deep and are static and not aerated. When stratification occurs, the farmers are advised to mix the pond water to break the thermocline. Thermoclines usually develop on sunny days, and farmers are advised to break the stratification between 1200 and 1500 hours, when dissolved oxygen levels in the ponds are satisfactory. Unfortunately this practice is rarely adopted by the farmers. They have a number of mechanisms with which to mix the pond water, including:

- pumping freshwater into the pond;
- replacing existing pond water with freshwater; and
- aerating the pond waters by running a motor boat across the pond or fixing a boat engine to the bank of the pond and running it for an appropriate period of time.

During periods of critically low dissolved oxygen, the farmers can apply calcium peroxide[5] (60 percent $CaCO_2$) (3 to 5 kg/ha) and hydrogen peroxide (6 percent) (3 to 5 l/ha) to increase dissolved oxygen concentrations in the pond water (Boyd and Tucker, 1998). Boyd and Tucker (1998) noted that when 0.05 ml 6 percent hydrogen peroxide was added to 1 litre of water, approximately 1.5 mg of oxygen could be released. Similarly, 2.7 kg of granular of calcium peroxide containing 60 percent of CaO_2 can release 1 kg of oxygen. However since Indian farmers use commercial grade hydrogen peroxide and calcium peroxide purchased from many different manufacturers and retailers, it is assumed that the oxygen yield capacity of these chemicals vary significantly and hence the efficacy of these chemicals needs to be established.

4.8 SATIATION OR SUB-SATIATION FEEDING

The survey revealed that 45 percent of the farmers believed that the fish should be fed to satiation in the morning and a further 22 percent said that the most efficient feeding strategy was to feed a ration that was approximately 10 percent lower than that required to produce satiation. The remaining farmers (33 percent) did not consider satiation levels when determining ration size but varied their rations according to stocking densities, fish size, plankton density, season, and anticipated growth rates.

Those farmers that fed to satiation generally held the belief that sub-satiation feeding resulted in depressed growth rates, and that the practice could lead to poor fish health. In contrast, those farmers that practiced sub-satiation feeding felt that the practice encourages the fish to consume more natural food, thus saving feed costs. These farmers also claimed that sub-satiation feeding limits the potential for water quality to deteriorate. It is difficult to establish empirically which feed management practice represents best practice. In this regard, a complicating issue is that cyprinids have the ability to sort food items from non-food items (Lamb, 2001); thus feed quality plays an important role in whether a farmer is in fact feeding to satiation or not. Poor quality feeds that contain a high percentage of non-food items (such as husk, seed shells, sand, etc.) may not be ingested; thus, while a farmer believes that the fish are being fed to satiation, it is possible that they are rejecting a portion of the feed.

4.9 PREFERRED PELLET TYPES

The survey revealed that many Indian major carp farmers are reluctant to use pelleted feeds. Only a third used pelleted feeds. The majority of these used sinking pellets that were mixed with mash feed. The majority of the farmers also had no practical or theoretical understanding of the efficacy of using either floating or sinking feeds to improve growth rates, or the impact that their use had on the economic efficiency of their production systems.

4.10 MANURES AND FERTILIZER USE

Manuring and pond fertilization is undertaken during the pond preparation period and throughout the production cycle. The description provided below outlines the manure and fertilizer application rates in grow-out ponds, including zero point stock

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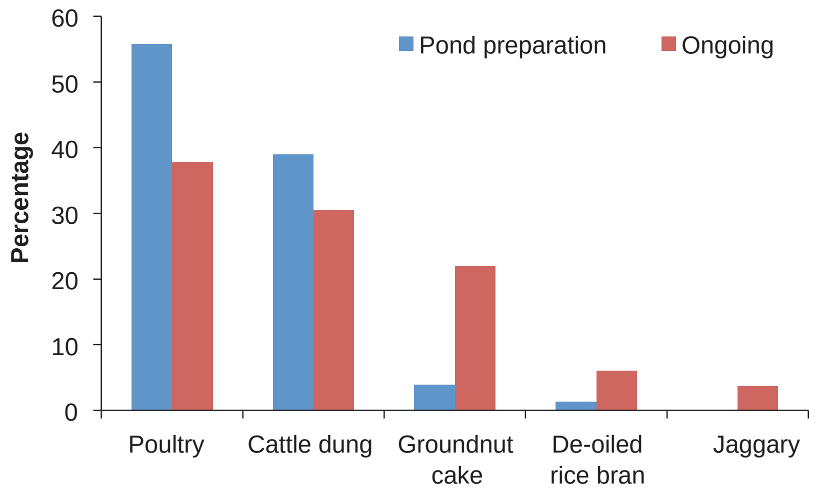
[5] Granular calcium peroxide containing 60% $CaCO_2$.

production. The details of feeds and fertilizers used in the different culture systems are presented in Appendices 5 to 9.

4.10.1 Manures

The types of manures available and their use in pond preparation and grow-out culture are presented in Figure 21. In both production phases, farmers primarily used poultry manure, followed by cattle dung, groundnut cake, de-oiled rice bran and, finally, other miscellaneous manure types.

FIGURE 21
Manure use in pond preparation and during grow-out production

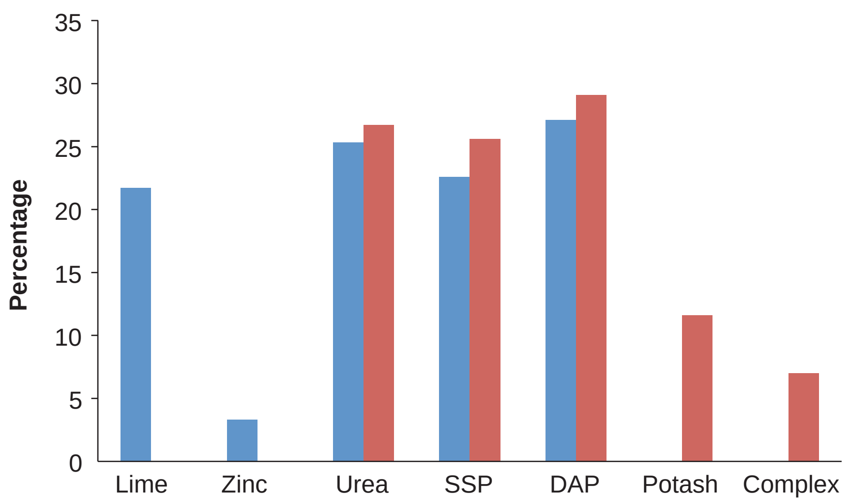


Note: Jaggary is a type of traditional unrefined uncentrifuged whole cane sugar.
Source: Field Survey (2010).

4.10.2 Fertilizers

The fertilizers commonly used during pond preparation and grow-out include SSP and DAP. During grow-out, potash and complex fertilizers were also applied; however, these were not applied during the pond preparation process (Figure 22).

FIGURE 22
Chemical fertilizer use in pond preparation and during grow-out productionn



Source: Field Survey (2010).

In some farming areas, farmers apply of zinc to the ponds to restore soil zinc imbalances that negatively affect phytoplankton production. Zinc sulphate is usually applied at 40 to 60 kg/ha; alternatively, chelated zinc is applied at 1 to 2.5 kg/ha. Zinc products are usually applied as a component of the pond preparation procedures, and if they are not used during this period, half the doses outlined above are added directly to the pond waters during the grow-out period. The agriculture departments of the state government have identified certain agriculture zones in the state as zinc deficiency zones, and the use of zinc has therefore been encouraged in these areas.

The chemicals that are applied to improve soil quality include lime, mostly as calcium oxide, calcium carbonate or dolomite (calcium, magnesium carbonate). The use of lime materials is designed to reduce soil acidity, produce slightly alkaline water, and enhance phytoplankton production (Boyd and Tucker, 1998).

The soils in the primary carp culture areas in the state are relatively neutral (pH 6.5 to 7.5), and thus attaining low alkalinity in the pond waters is not problematic. As a result, few farmers need to use lime. Nevertheless, some farmers continue to lime their ponds in the mistaken belief that the practice improves pond sanitation, and reduces the possibility of oxygen depletion in the early morning hours.

As feed represents the greatest single production cost, it is useful for the farmers to develop an understanding of the way in which they can reduce feed costs by increasing the natural productivity and food in their ponds. Milstein (1995) calculated that a production level of between 5 148 and 7 416 kg/ha/annum could be achieved using filter feeding fish at a stocking density of 3 500 to 15 000 fish/ha but that by applying organic manures, yield could be increased to 12 600 to 37 800 kg/ha/annum. In contrast, Edwards, Little and Yakapitiyaga (1997) estimated that the level of production that could be attained using manured ponds was in the region of 2 000 to 10 000 kg/ha/annum. In the absence of supplemental feeds, Sahu *et al.* (2007) used manures and fertilizers to achieve a production level of 875.2 kg/ha of Indian major carps in 6 months (1 750 kg/ha/annum). When supplemental feeds were also applied, the level of production increased to 1 341 kg/ha/6 months (2 683 kg/ha/annum). The stocking ratios and densities used in these production trials were 35 percent catla, 35 percent rohu, and 15 percent orangefin labeo at a combined density of 7 500 fish/ha. The results of the study suggest that 65.2 percent of the total production could be attributed to manures and fertilizer use, with the remaining being attributed to supplemental feeds. There are no records of commercial scale production of Indian major carps in Andhra Pradesh by farmers that have relied solely on manures and fertilizers to produce natural feeds. Once the levels of production that are possible through the sole use of manures and fertilizers are established, it will be possible to develop a better understanding of the way in which production parameters could be optimized so that minimal quantities of supplemental feeds are used.

The economics of manure and fertilizer use is likely to be attractive to marginal, small- and medium-scale farmers Investment in supplemental feeds will be limited, and as production costs will be lower, farming methods based on manures and fertilizers will be more affordable.

Generally, Indian major carp farmers believe that the use of organic manures is more cost effective than using inorganic fertilizers. However, the cost of nutrients in dry chicken manure (on an available nutrient basis) is seven times greater than for nitrogen in urea and four times greater than phosphate in triple super phosphate (Knud-Hansen, 1998). An economic analysis of nutrient costs in manures and fertilizers used in Indian major carp culture may prove to be similar. In comparison to manures, chemical fertilizers produce faster results as their nutrients rapidly dissolve in the water column, are readily available, and do not impact on dissolved oxygen levels. In addition, they are easier to apply and need less labour. While the complete elimination of organic manures is not necessarily advocated, farmers should be advised to use inorganic fertilizers instead of organic manures when they are available.

An important aspect of phytoplankton production and management is the species composition of the phytoplankton. This is particularly true for those production systems that do not use supplemental feeding but rely on the natural productivity of the system to supply food. In Andhra Pradesh, the presence of toxic phytoplankton such as *Mycrocystis*, *Oscillatoria* and *Anabaena* is common, and they are believed to result in reduced growth rates. It is suspected that chronic exposure to these toxic species results in chronic, low levels of fish mortality. Padmavathi and Durga Prasad (2004) demonstrated that in comparison with ponds in which *Arthrospira platensis* was the dominant bloom, Indian major carp production was reduced with a concomitant increase in fish mortality in ponds that were under the influence of *Microcystis aeruginosa*. The problems associated with the occurrence of *M. aeruginosa* blooms and microcystins in rain-fed striped catfish pond culture in Bangladesh has also been reported by Ahmed, Hiller and Lukas (2008). Currently, the farmers do not have reliable practical management strategies to prevent the development of toxic blooms or to suppress them once they occur. In terms of remedial action that could be developed, Puerto *et al*. (2010) reported the protective role of N-acetylcysteine in *O. nilotinucs* exposed to microcystin producing cyanobacterial blooms.

4.11 COST OF PRODUCTION AND NET INCOME

An economic analysis was undertaken for four Indian major carp production systems in the Kolleru carp culture area. The unit cost associated with different mash feed ingredients and other inputs and the sale price of fish are presented in Annex 10. The major production costs and the gross and net incomes of these culture systems are provided in Table 25. The number of cases selected for these culture systems ranged between 7 and 14. Due to the relatively small sample size, the results presented here should be considered as indicative. The lower production costs associated with the 'Typical IMC-mash' system was primarily attributed to the lower lease and feed costs that accumulated to the 'Zero point culture-IMC-mash' system.

Of all the zero point culture systems, the total production costs were highest for the 'Zero point culture-IMC-striped catfish-mash' system, followed by the 'Zero point culture-IMC-mash' and 'Zero point culture-IMC-mash-pellet' systems. The total production costs accruing to the 'Typical-IMC-mash' was the lowest of all the systems in the analysis. Net income was also highest for 'Zero point culture-IMC-striped catfish-mash'. For the 'Zero point culture-IMC-striped catfish-mash' system, the introduction of high-yielding striped catfish significantly enhanced gross incomes when compared to similar systems that did not include catfish. The net income of the 'Zero point culture-IMC-mash-pellet' system was far higher than 'Zero point culture-IMC-mash' system. The difference in net incomes was attributed to the higher lease costs in 'Zero point culture-IMC-mash' system, and the inclusion of pelleted feeds as a component of supplementary feeds, which probably improved the efficiency of the production system. This observation is supported by the fact that average FCR observed in the 'Zero point culture-IMC-mash-pellet' system was 1.78:1, and thus significantly lower than the FCR of 3.57:1 that was recorded in the 'Zero point culture-IMC-mash' system (please see Tables 8–12 for details and Table 21 for mean of FCRs in different aquaculture production systems as practised In Andhra Pradesh). The net income of the 'Typical-IMC-mash' system was significantly higher than that of the 'Zero point culture-IMC-mash' system.

The production economics outlined in Table 25 were calculated when the market demand for striped catfish was optimal, and the farm gate price for the species was INR55/kg (US$1.17/kg). Since September 2010, the price of striped catfish has fallen by INR20–30/kg (US$0.42–0.64/kg). The drop in the price negatively impacted those farmers practicing striped catfish monoculture or stocking it as the primary culture species in their polyculture systems. These farmers experienced significant economic losses.

TABLE 25
Primary production costs, income and cost and benefit ratio of different production systems (US$/ha; INR/ha in parenthesis)

Culture system	Inputs costs								Total	Gross income	Net income	Net income/ ha/year	Benefit-cost ratio
	Lease	Seed	Manure	Fertilizer	Feed	Labour	Harvest	Power and diesel					
Typical-IMC-mash	1 314 (61 775)	449 (21 107)	232 (10 919)	68 (3 180)	3 558 (167 317)	716 (33 678)	84 (3 936)	128 (6 027)	6 548 (307 939)	7 700 (362 120)	1 152 (54 181)	1 536 (72 241)	1.17
Zero point culture-IMC-mash	1 997 (93 898)	1 321 (62 130)	236 (11 122)	123 (5 777)	4 058 (190 844)	376 (17 685)	65 (3 071)	331 (15 582)	8 507 (400 109)	9 013 (423 885)	506 (23 776)	933 (43 894)	1.06
Zero point culture-IMC-mash-pellet	946 (44 478)	1 367 (64 279)	113 (5 321)	120 (5 625)	3 173 (149 234)	423 (19 916)	76 (3 562)	258 (12 114)	6 475 (304 529)	8 537 (401 500)	2 062 (96 971)	3 807 (179 023)	1.32
Zero point culture-IMC-striped catfish-mash	1 818 (85 496)	1 862 (87 565)	347 (16 338)	75 (3 521)	4 225 (198 721)	307 (14 452)	70 (3 294)	1 652 (77 691)	10 356 (487 078)	13 480 (633 985)	3 124 (146 907)	5 355 (251 841)	1.30

Automatic silo feeders used in a carp culture pond in Myanmar.
COURTESY OF FAO/M.C. NANDEESHA

5. Conclusions and recommendations

5.1 CONCLUSIONS

The primary areas of Indian major carp production in the state comprise Kolleru lake and the surrounding areas in the West Godavari and Krishna districts; the Nellore and East Godavari districts represent secondary culture areas. In comparison with the West Godavari and Krishna districts, production in Nellore district is undertaken at a lower intensity. In the East Godavari district, polyculture systems based on Indian major carps, black tiger shrimp and giant river prawns have been developed. In these systems, Indian major carp production represents a relatively small component of total production.

The survey revealed that the great majority of farmers have been using semi-intensive culture practices based on natural pond productivity and supplemental feeds that were initially developed three decades ago. The basic feeding systems are based on mash feed ingredients, including de-oiled rice bran, groundnut cake and cottonseed cake. The ingredients are fed using a bag technique.

Over the years, the basic semi-extensive polyculture system has been improved. Farmers have started to stock progressively larger fish, effectively shortening the culture period. This enables more production cycles to be grown over a given period. Indian major carp farmers have shown an increasing interest in polyculture systems that incorporate striped catfish, the Chinese carps, and pirapatinga. Another recent positive trend identified in the survey was that farmers are re-introducing mrigal, which in the past had almost been completely eliminated.

The mash feeds are prepared at the pond site, with the basic feed ingredients being purchased from commercial producers. The mash feed ingredients are sold to the farmers through a network of dealers. Poor feed ingredient quality was the most important feed issue reported by the farmers. The quality problems were most severe with respect to de-oiled rice bran, for which there are currently supply and demand issues. As this represents an important feed ingredient, it cannot be easily substituted in feed formulations. Due to the rapid expansion of the sector, it is unlikely that, in the near future, these quality and supply issues will be resolved. The main quality issues reported with the de-oiled rice bran were excess moisture and fibre contents and lower protein levels than specified by the retailers, adulteration with urea, and fungal growth. With respect to groundnut cake, the quality problems included high levels of shell, adulteration with sand and tamarind seed powder, and fungal growth. Cottonseed cake was reported to have quality problems relating to high fibre and shell contents, with a small quantity of the cake being sold as hard balls that could not be consumed by the fish. A limited number of farmers reported using other types of feed ingredients, such as meat meal, maize distillers dried grains, and jowar/sorghum (*Sorghum bicolor*). A very limited number of farmers also used organic manures such as poultry manure and branded products manufactured from sugar factory wastes in their mash feed formulations.

In 2007, commercially manufactured pelleted aquafeeds were introduced to Andhra Pradesh. These feeds are primarily targeted at the striped catfish culture sector, with carp culture as a secondary market. Commercially produced pelleted feeds are also sold through a network of dealers who are supported by technical services that are supplied by the feed manufacturing companies. In terms of adopting these new feeds, farmers culturing striped catfish and Indian major carps have responded differently. While the striped catfish farmers have readily accepted their use, Indian major carp farmers have shown reluctance and caution. A small group of Indian major carp farmers have started using sinking pelleted feeds to supplement other feeds for either a part of, or the total, culture period. In such cases, the sinking pellets are mixed with the mash feeds, and fed using the bag technique. The primary reason that Indian major carp farmers are reluctant to use commercially manufactured pelleted feeds is that there is no conclusive evidence to suggest that their use improves biological and economic efficiencies.

A significant number of the farmers surveyed indicated that they had a poor understanding of basic feed preparation and feed management practices. Major issues of concern included establishing optimum feeding rates and feeding periods, the physical wastage of feed and nutrient leaching. The contribution that natural pond productivity makes to the nutrition of the fish is poorly understood, as is the computation of feeding rates for mash and pelleted feeds that contain different protein levels. A minority of farmers adopt novel feeding strategies, including the use of restricted feeding regimes, adjusting feed rations on the basis of zooplankton density, or adding poultry manure as a dietary component of their mash feeds.

The positive contribution that phytoplankton makes to the nutrition of the fish is well recognized by farmers, and significant efforts are made by them to produce and sustain phytoplankton and zooplankton blooms. However, there are problems associated with the development to toxic phytoplankton blooms that need to be resolved.

5.2 RECOMMENDATIONS

A number of recommendations can be derived from this study. These comprise:

- Undertake research to quantify the nutrient requirements of Indian major carps under commercial pond culture conditions, including the role of natural productivity, traditional mash, and pelleted feeds on fish production.
- Establish the biological and economic efficiency of using mash feeds, pelleted/mash feed combinations, and commercially produced floating and sinking feeds.
- Establish feeding rates and develop feeding charts for different life stages and sizes of pond-cultured Indian major carps. Establish these parameters for different combinations of mash feed ingredients, and sinking/floating pellets, and determine the impact of dietary protein levels on these parameters.
- Evaluate the nutritional requirements of Indian major carp fry using contemporary nursery feeds and feed management practices. Establish the biological and economic efficiency of using commercial crumbles and small pellet sizes.
- Improve and standardize broodstock nutrition and feed management practices, and develop species-specific dietary formulations for Indian major carps.
- Undertake stable isotope studies to quantify the relative contribution of natural food, especially phytoplankton and zooplankton, and supplementary feed to the overall nutrition of Indian major carps. Determine the dietary overlap among Indian major carp species, and develop realistic feed guidelines for the supplementary feeds.
- Optimize feed management and pond fertilization schedules. Investigate the potential to develop restricted feeding schedules; optimize the use of high and low protein dietary formulations; optimize the use of fertilizers and manures to promote primary pond production and enhance the supply of natural feeds; optimize the use of de-oiled rice brans and oil cakes.
- Investigate and develop production protocols for Indian major carp production based on manures and fertilizers. This should be achieved using only manures and fertilizers (without supplementary feed) and by undertaking bioeconomic analyses of these and the traditional production systems.

- Improve feed and feed management practices. Refine the standard bag feeding techniques; optimize feeding schedules; develop protocols to reduce feed losses, and limit nutrient leaching from mash and pelleted feeds; establish satiation and return of appetite periods, and use these to improve the efficiency of feeding schedules.
- Evaluate the efficacy and economic benefits that add to the use of feed additives such as bacterial phytase. Evaluate the benefits of using mineral and vitamin supplements in the feeds, notably their use under adverse culture conditions such as exposure to blue-green algae, exposure to acute dissolved oxygen depletion, or a severe bacterial or parasitic infection.
- Develop dietary formulations that enhance immuno-competence and resistance to bacterial and parasitic diseases.
- Undertake research to characterize effluent streams and develop appropriate treatment protocols to comply with the existing and proposed environmental controls and regulations that are instituted by the state and central government. Develop water budgets.
- Improve farmer extension services to facilitate the dissemination of research results and the adoption of novel production protocols. Existing information gaps need to be identified, and information and techniques that are already in use or available for other culture species or aquaculture sectors need to be applied to Indian major carp production. These issues/techniques include, but are not limited to: publishing information pertaining to feed ingredients and their nutritional status; disseminating information describing the impacts of species interactions on food partitioning and growth; promoting algal bioassay protocols; disseminating broodstock nutrition and nursery feed management practices; and promoting genetic selection protocols for broodstock.

Paddlewheel aerator in a carp culture pond in Andhra Pradesh, India.
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Harvest of Indian major and exotic (silver, grass and common) carps from a semi-intensive polyculture pond in Mymensingh, Bangladesh.
COURTESY OF FAO/ MOHAMMAD R. HASAN

Annex 1

Common and scientific names of fish species used in aquaculture in Andhra Pradesh, India

Common name	Scientific name
Rohu	*Labeo rohita*
Catla	*Catla catla*
Mrigal	*Cirrhinus cirrhosus*
Common carp	*Cyprinus carpio*
Grass carp	*Ctenopharyngodon idella*
Silver carp	*Hypophthalmichthys molitrix*
Striped catfish	*Pangasianodon hypophthalmus*
Orangefin labeo	*Labeo calbasu*
Pirapatinga	*Piaractus brachypomus*
Asian catfish	*Clarias batrachus*
Stinging catfish	*Heteropneustes fossilis*
Asian seabass/barramundi	*Lates calcarifer*
Striped snakehead	*Channa striatus*
Climbing perch	*Anabas testudineus*
North African catfish	*Clarias gariepinus*
Black tiger shrimp	*Penaeus monodon*
Giant river prawns	*Macrobrachium rosenbergii*
Monsoon river prawns	*Macrobrachium malcolmsonii*

Source: FishBase (available at www.fishbase.org/search.php).

Annex 2

Antibiotics and other pharmacologically active substances prohibited for use in Indian aquaculture

All nitrofurans including Furazolidone, Furylfuramide, Nifuratel, Nitrofurantoin, Nitrofurazone and Nifuroxazide.
Chloroform
Chlorpromazine
Colchicine
Dapsone
Dimetridazole
Metronidazole
Ronidazole
Ipronidazole
Chloramphenicol
Neomycin
Nalidixic acid
Sulphamethoxazole
Clenbuterol
Nitroimidazole
Diethylstilbestrol (DES)
Fluoroquinolones
Glycopeptides
Plants belonging to Aristolochia genus and preparations thereof
Sulphonamide drugs (except approved sulfadimethoxine and sulphamethoxypyridazine)

Source: Field survey (2010).

Annex 3

Annual production capacity of the 10 largest commercial pelleted feed manufactures and local feed factories in Andhra Pradesh, 2010

Name	Annual production capacity (tonnes)	
	Sinking pellets	Floating pellets
Ananda	40 000	40 000
Avanti	90 000	-
Bharat Lux Indo Agri Feeds Pvt. Ltd.	40 000	-
Cargill	50 000	-
CP (India) Private Limited	-	25 000
Godrej	50 000	-
Growel	-	70 000
Indian Broilers	-	300 000
Quality	-	75 000
Uno	-	15 000
Local factories	30 000	-

Annex 4

Products of the pelleted feed manufacturers in Andhra Pradesh

No	Company name	Brand name	Pellet type		Price	Pellet size (mm)		Proximate composition (%)			
			Floating	Sinking	US$ (INR)	Floating	Sinking	Crude protein	Crude lipid	Moisture	Crude fibre
1.	Indian Broilers (IB)	Abis	√	-	0.44 (20.75)	4	-	28	3	-	-
		-	-	-	-	5	-	32	4	-	-
2.	Cargill	Aqua Focus ™ (Partner-partner)	-	√	0.55 (26.00)	-	Crumble	25	6	10	11
		Aqua Focus ™ (Partner-grower)	-	√	0.38 (18.00)	-	4 x 10	18	3.5	10.5	10.5
		Aqua Focus ™ (Partner-Health pack)	-	√	0.70 (33.00)	-	0.8–1.0	8	1	10	5
		Aqua Focus ™ (Pangasius Pre-grower)	-	√	0.53 (25.00)	-	4 x 5–6	25	6	10.5	8
		Aqua Focus ™ (Pangasius - Grower)	-	√	0.49 (23.00)	-	10–12	22	5	10.5	8
3.	CP (India) Private Limited	9910L, 9951, 9952, 9931, 9932	√	-	0.59–0.85 (28–40)	2–7	-	22–30	3– 4	11	7
4.	Growel	Gorfin	√	-	0.44 (20.75)	4	-	28	3.5	10	5
5.	Bharat Luxo Indo	Grofish (carp)	-	-	0.39 (18.50)	-	3.2	19	3.5	9.5	NA
		Lux-Indo (pangasius)	-	-	0.39 (18.50)	-	-	-	-	-	-
6.	Gold Mehar Foods & Feeds	Grow plus	-	√	0.45 (21.00)	-	4 x 6	28	NA	NA	NA
		Bheri	-	-	0.38 (18.00)	-	4 x 6	25	NA	NA	NA
7.	Godrej Gold Coin Aqua Feeds	Popular	-	√	0.38 (18.50)	-	4 x 5–7	24	5	10	NA
		Misha	-	√	0.35 (16.25)	-	4 x 5–6	18	4	10	NA
8.	Avanti Feeds	Mermaid	-	√	0.36 (17.00)	-	2.3	20	4	11	NA
9.	Uno Feeds	UNO 428	√	-	0.45 (21.00)	4	-	28	4	10	5
		UNO 432	√	-	0.51 (24.00)	4	-	32	NA	NA	NA
10	Ananda Feeds	4441, 4442, 4443	√	-	-	-	-	-	-	-	-
		5551, 5552, 5553, 5554	-	√	-	-	1–2	32	NA	NA	NA
11.	Kwality Feeds	203, 243, 283, 304, 326	√	-	0.47–0.70 (22–33)	2–4	-	20–32	3-8	11	6–7

NA = Data not available; US$1 = INR 47.03

Source: Field survey (2010).

Annex 5

Manure and fertilizer use in "typical culture (on-growing semi-intensive polyculture)" production system"

No.	Type of Culture	Manure and fertilizer use (kg/ha)										
		Cattle dung	Poultry manure	Groundnut cake	Rice bran	DAP*	SSP**	Urea	Potash	Complex fertilizers	Lime	Zinc sulphate
1.	Typical culture-IMC: mash	142–6 178	227–8 786	12–549	7–494	49 –148	46–148	6–137	37–124	31–137	5–39	20–37
2.	Typical culture -IMC: mash-pellet	3 707–12 870	4 118–9 884	1 038	-	25–49	-	25	-	-	-	2–165
3.	Typical culture -IMC-striped catfish: mash-pellet	4 942–11 120	7 413–11 120	185	-	-	-	-	-	-	-	-
4.	Typical culture -IMC: mash-Nellore	494–5 491	3 089–12 355	148	-	185–1 112	247	62–218	-	-	-	10–69

* Diammonium phosphate; **single super phosphate

Source: Field survey (2010).

Annex 6

Manure and fertilizer use in "zero point culture (semi-intensive polyculture fattening) and zero point stock culture (semi-intensive juvenile polyculture)" production systems

No.	Type of Culture	Manure and fertilizer use (kg/ha)										
		Cattle dung	Poultry manure	Groundnut cake	Rice bran	DAP*	SSP**	Urea	Potash	Complex fertilizers	Lime	Zinc sulphate
1.	Zero point culture-IMC: mash	167–2 595	251–7 060	120–371	–	106–333	238 –353	7–95	62	27	20	25–23
2.	Zero point culture-IMC: mash-pellet	988–9 266	1 977–7 907	43–82	–	41–247	41–494	41–247	–	–	5	15–46
3.	Zero point culture-IMC-striped catfish: mash	399–8 237	3 188–12 355	93–1 647	2059	148–247	49–618	25–82	62–86	275–412	390	10–37
4.	Zero point culture-stock culture- IMC: mash	3 707	4 942–7 060	7	–	49–198	62–297	49–198	99	–	–	2–49

* Diammonium phosphate; ** single super phosphate

Source: Field survey (2010).

Annex 7

Manure and fertilizer use in a "polyculture grow-out (IMC and exotic carp)" production system

Type of culture	Manure and fertilizer use (kg/ha)					
	Cattle dung	Poultry manure	DAP*	SSP**	Urea	Zinc sulphate
Polyculture - IMC - grass carp: mash	2 608–18 533	3 295–4 118	124	124	69–93	25–93

* Diammonium phosphate; ** single super phosphate

Source: Field survey (2010).

Annex 8

Manure and fertilizer use in "polyculture grow-out (IMC and tiger shrimp)" production system

Type of culture	Manure and fertilizer use (kg/ha)				
	Poultry manure	SSP*	Urea	Lime	Zinc sulphate
Polyculture - IMC - black tiger shrimp: pellet	988–1 482	74	49	494	12

* Single super phosphate

Source: Field survey (2010).

Annex 9

Manure and fertilizer use in a "polyculture grow-out (IMC and giant river prawns)" production system

Type of culture	Manure and fertilizer use (kg/ha)				
	Cattle dung	SSP*	Urea	Lime	Zinc sulphate
Polyculture - IMC - giant river prawns: pellet	1 235–1 976	148	45	247	5

* Single super phosphate

Source: Field survey (2010).

Annex 10

Input and fish sale prices used to estimate production costs and net incomes (July 2010)

Name	Price [US$ (INR)/unit]	Unit
Fish seed	0.04–0.21 (2–10)	1
Fertilizers		
Lime	0.13 (6.00)	kg
Poultry litter/chicken manure	0.03 (1.25)	kg
Cattle dung	0.01 (0.36)	kg
Di-ammonium phosphate	0.37 (17.60)	kg
Single super phosphate	0.11 (5.00)	kg
Urea	0.1 (4.50)	kg
Zinc sulphate	0.63 (30.00)	kg
Feed ingredients		
De-oiled rice bran	0.15 (7.25)	kg
Groundnut cake	0.38 (18.00)	kg
Cottonseed cake	0.24 (11.50)	kg
Feed additives		
Enrofloxacin	39.31 (1 850)	kg
Oxytetracycline	17.00 (800)	kg
Sulpha	23.37 (1 100)	kg
Trimethioprim	31.87 (1 500)	kg
Liver stimulant	1.27 (60)	kg
Other inputs		
Electricity	0.08 (3.75)	kilowatt/hour
Diesel	0.80 (38)	litre
Sale price of fish	1.17 (55)	kg

Note: 1 US$ = INR 47.03

Source: Field survey (2010).

This technical paper reviews the aquaculture of Indian major carps with special reference to current feeding and feed management practices in Andhra Pradesh, India. The study is based on a survey of 106 farmers from four regions in Andhra Pradesh (Kolleru, Krishna, West Godavari, and Nellore). While the study primarily focused on the feed management practices associated with major carp production, management practices that are used under polyculture conditions with other species-groups were also assessed. The study revealed that mash feed was the most popular and widely used feed type. De-oiled rice bran was used as the principal feed ingredient, followed by groundnut cake, cottonseed cake and raw rice bran. The poor quality of the mash feed ingredients, especially the de-oiled rice bran, groundnut cake, and cottonseed cake was an important issue of concern to the farmers. Commercially manufactured pelleted feeds were used by 33 percent of the farmers to complement their mash feeds, with the majority choosing to use sinking pellets. Since 2007, there has been a marked increase in the use of commercial pellets, most notably for the large-scale production of the striped catfish. Grow-out farmers feeding mash feeds used variants of a bag feeding method known as rope and pole feeding. In the nursery and rearing ponds, the commonly used feed ingredients included groundnut cake, de-oiled rice bran and raw rice bran. The most common feeding practice was broadcast feeding. Constraints to Indian major carp production were identified, and research and development needs characterized.

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