

On-farm feed management practices for three Indian major carp species (rohu *Labeo rohita*, mrigal *Cirrhinus cirrhosus* and catla *Catla catla*) in Bangladesh: a case study

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ABSTRACT

Three Indian major carps (rohu *Labeo rohita*, mrigal *Cirrhinus cirrhosus* and catla *Catla catla*) are considered prime aquaculture species in Bangladesh. Three basic production systems are in use, viz. broodstock and fry production systems, nursery systems and grow-out systems. Successful production in these systems is dependent on a number of factors; amongst these supplemental feed and its administration is an important consideration. In the context of improved extensive and semi-intensive aquaculture systems, the supply of nutrients through the application of supplemental feeds represents a pre-requisite for sustainable fish production. In order to determine the characteristics of supplemental feeding in major carp aquaculture, and to inform the development of recommendations to improve the current management paradigm, a field survey of the different production systems was conducted. The study was conducted in the four major production regions of Jessore, Mymensingh, Comilla and Rajshahi. Three questionnaires based on the different production systems were developed, pre-tested and used for conducting the survey. A total of 85 farmers were interviewed, and the information pertaining to different aspects of their production systems was obtained. This information included species selection, species composition, stocking densities, production levels, pond preparation and management practices, natural food production, the use of supplemental feeds, its preparation, presentation and storage. The collected data was synthesized and analysed. In the broodstock systems, variability was observed in terms of the species cultured and stock composition, broodstock management, and supplemental feed and feed management practices. All the hatchery operators had a common attitude towards the provision of supplemental feeds, either in the form of pellets or wet doughs. However, the farmers demonstrated a poor understanding of the genetics of broodstock management and nutrition. Geographically, farmers operating nursery systems applied similar species selection, stocking, rearing and supplemental feeding strategies. Typically, the farmers fed the fry with mustard oil cake – a protein source that is unable to

provide all the nutrients required for optimal growth. This widespread practice suggests that the farmers do not have a good understanding of the nutritional requirements of the fry. With respect to the farming practices used in the grow-out systems, it was found that species selection, stock composition, stocking densities and water management practices varied greatly between the farmers, and that there was a wide regional variation in supplemental feeding practices. The majority of farmers use supplemental feeds on a regular basis and only feed irregularly when financial constraints prevent them from buying feeds. Farm-made supplemental feeds, locally produced and industrially manufactured pellet feed are used. In general, farmers demonstrated a poor understanding of the nutritional requirements of the fish, the impacts associated with nutrient losses during feeding, the use of feed conversion ratios as a management tool, and the need for good on-farm record keeping.

1. INTRODUCTION

The feeding behaviour of the Indian major carps, namely catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus cirrhosus*) is species specific. *Catla catla* is a surface feeder; *Labeo rohita* is a mid-surface or column feeder, and *Cirrhinus cirrhosus* is a bottom feeder (Jhingran, 1991).

Mookerjee (1944) reported that all the Indian major and minor carps show cannibalistic behaviour as fry. According to Alikunhi (1952), large fry (or fingerlings) of catla, rohu and mrigal cannibalise their smaller conspecifics. Jhingran (1991) reported that the food and feeding behaviour of the hatchlings and fry of the Indian major carps differ markedly from those of the fingerlings and adults. George (1963) found that although the major carps ingest a variety of phytoplankton, zooplankton and higher aquatic plants, catla prefer to select plankton, mainly zooplankton, while rohu and mrigal prefer plant matter, including decaying plant materials. Azim *et al.* (2002), comparing the production of three Indian major carps, catla, rohu and orange-fin labeo/kalbasu (*Labeo calbasu*) in periphyton-based polyculture systems, found that while the rohu grazed the periphyton, the catla consumed planktonic food organisms. Ranade and Kewalramani (1956) demonstrated that catla utilize animal food sources better than mrigal and rohu, and that rohu is less adapted to animal food sources than mrigal. Gut content analysis of catla and rohu shows a dominance of phytoplankton at the fry rearing stage (Dewan *et al.*, 1991).

Indian major carps are cultured throughout the country, and under various management regimes. In the past, farmers cultured them in ponds and oxbow lakes (local name: *baors*)¹ with little or irregular supplemental feeding. However, these systems did not supply sufficient feed to the fish. The poor feeding rates applied were attributed to a lack of knowledge pertaining to the nutritional requirements of the fish. With the development of science-based fish culture and its practices, farmers have become aware of the need to provide supplemental food to the fish.

A number of feed and feed management practices are used in Bangladesh. Some farmers depend on natural productivity to supply the nutritional requirements of the fish, while others provide farm-made supplemental feeds, either regularly or irregularly. Commercially made aquafeeds are available, but in many cases their quality is unknown or poor. Farmers use feed supplements such as hormones, enzymes, growth promoters and antibiotics but these additives are not certified by the relevant authorities. To protect the adulteration of products in the feed industry and to ensure the quality of feeds in the market, the Government of Bangladesh recently promulgated the Fish and Animal Feed Act, 2010 (Annex).

¹ Oxbow lakes (local name: *baors*) are semi-closed water bodies, which occupy the dead channels of the rivers in the moribund delta of the Ganges. Normally, an oxbow lake remains part of the river floodplain, to which it is connected by inlets and outlets (Hasan and Talukder, 2004).

2. METHODOLOGY

The study was carried out by conducting interviews at hatcheries, nurseries, and grow-out farms (Table 1). Three sets of questionnaires were developed, one for each farmer group. The interviewees were selected so as to provide a representative sample of farm sizes. In addition to these three groups, information was also collected from feed millers, aquafeed manufacturing companies, and feed dealers. Additional information was collected from other sources such as the scientific and grey literature.

TABLE 1
Number of stakeholders interviewed at different categories and the farm sizes

Stakeholders	Sample size	Farm size range
Hatchery operators	25	0.52 to 14.3 ha
Nursery operators	30	0.17 to 6.0 ha
Grow-out farmers	30	0.52 to 39.6 ha

Source: Field survey (2010).

Although Indian major carp culture is being practiced throughout the country, the major production activities tend to be clustered. Some areas specialise in hatchery and fry production, while others specialise in nursery and grow-out production.

Due to time constraints, it was not possible to visit farmers in all the districts where major carps are produced but farmers from the four most important culture regions were included in the study. In addition to their aquaculture activities, many of the farmers exploited alternative livelihood options, for example, terrestrial farming (e.g. poultry), and had minimal time to respond to the survey. Furthermore, farmers' education constrained data collection as many farmers were unable to clearly enumerate the management practices that they applied.

3. FEED AND FEEDING PRACTICES USED IN INDIAN MAJOR CARP PRODUCTION

Catla, rohu and mrigal are the main culture species in the region, and are normally cultured together. These species feed at different levels in the water column and rearing them in polyculture maximizes feed utilization (Jhingran, 1991; Ahmed, 1992). Although the Indian major carps represent the primary culture species, a number of exotic carps imported from China and Europe are also cultured. The inclusion of these exotic carps increases the competition for food with the Indian major carps. In order to minimise feed competition, most farmers supplement their natural pond productivity with farm-made aquafeeds. The feed and feed management practices vary according to the production phase, viz. broodstock, fry, and fingerling/yearling production.

3.1 Feeding and the rearing of Indian major carp broodstock

In Bangladesh there are 845 private sector and 77 public sector hatcheries. Combined, these hatcheries produce 624 805 kg of fry (both indigenous and exotic carps) per annum. An additional 4 370 kg of fry is wild caught from the rivers (DoF, 2012). The production of high quality broodstock requires the use of good husbandry protocols. In recent years, the quality of seed produced has deteriorated as a result of poor quality broodstock and poor management protocols. Many hatchery operators are unaware of the importance of genetics in broodstock selection and, as a result, inbreeding and hybridization is commonplace. This results in increased mortality rates, reduced growth characteristics, deformities, and increased vulnerability to disease.

3.1.1 Pond preparation for broodstock conditioning

The survey revealed that all the hatchery operators prepared their broodstock ponds using organic and inorganic fertilizers (Table 2). The farmers reported using different pond sizes, ranging from 0.13 ha to 0.80 ha (Figure 1). Ponds are drained and dried once a year to eradicate predatory fish species. In those cases where it is difficult to completely drain the ponds, the farmers apply piscicides, including rotenone, phostoxin, and celphos. After drying or poisoning the ponds, lime is applied throughout the pond and dyke area at 125 to 250 kg/ha followed by cow dung at 250 to 1 250 kg/ha. Cow dung is applied at higher rates in newly constructed ponds, or in ponds in which the bottom clay has been removed. Inorganic fertilizers such as urea and triple super phosphate (TSP) are applied at 25 to 50 kg/ha and 37.5 to 187.5 kg/ha respectively. Some farmers prefer to apply muriate of potash (MP) at 12.5 to 37.5 kg/ha in ponds that have high clay contents. In addition to these practices and to increase primary productivity, some farmers apply mustard oil cake and cow dung at 750 to 1 125 kg/ha. On completion of the process, the ponds are filled with underground water from shallow tube wells or with rain water. The ponds are filled to a depth of four to five feet (~1.2–1.5 m). During the rainy season, the water depth of the ponds sometimes increases to eight to nine feet (~2.4–2.7 m). After administering the fertilizers, and once the pond waters mature, the juveniles or brood fish are stocked. The stocking density of brood fish varies, with total fish biomass was reported to be between 2 000 to 5 000 kg/ha.

FIGURE 1
Carp hatchery (left) and broodstock pond (right)



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TABLE 2
Commonly used organic and inorganic fertilizers

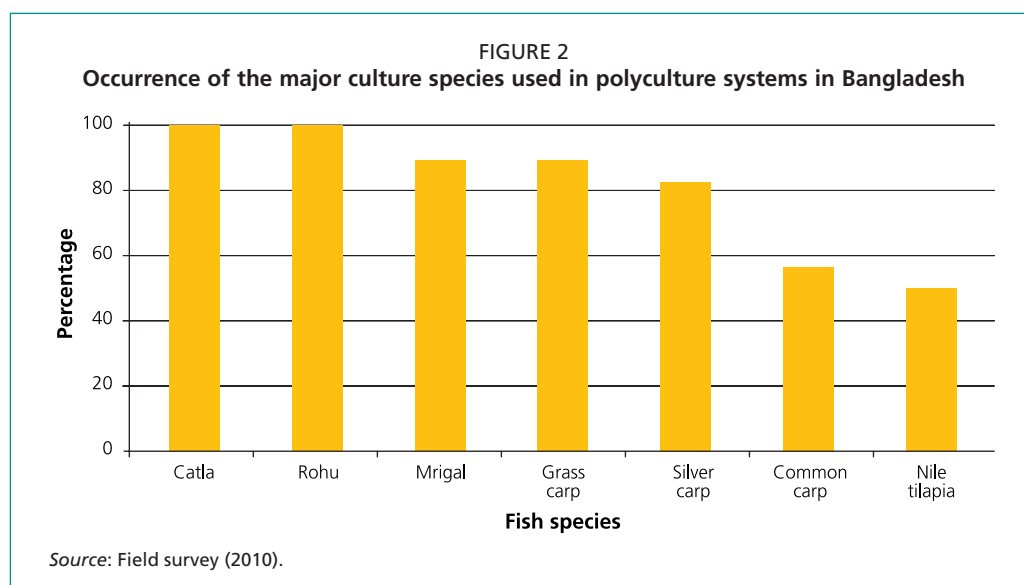
Ingredient	Cost (US\$/tonne)	Application rate (kg/ha)
Lime (calcium carbonate)	174.0	125–250
Cow dung	14.5	250–1 250
Poultry litter	14.5 (wet) 29.0 (dry)	625–875 500–625
Triple super phosphate (TSP)	333.3	37–187
Urea	188.4	25–50
Muriate of potash (MP)	333.3	12–37

US\$1= Bangladesh Taka (BDT) 69.00.

Source: Field survey (2010).

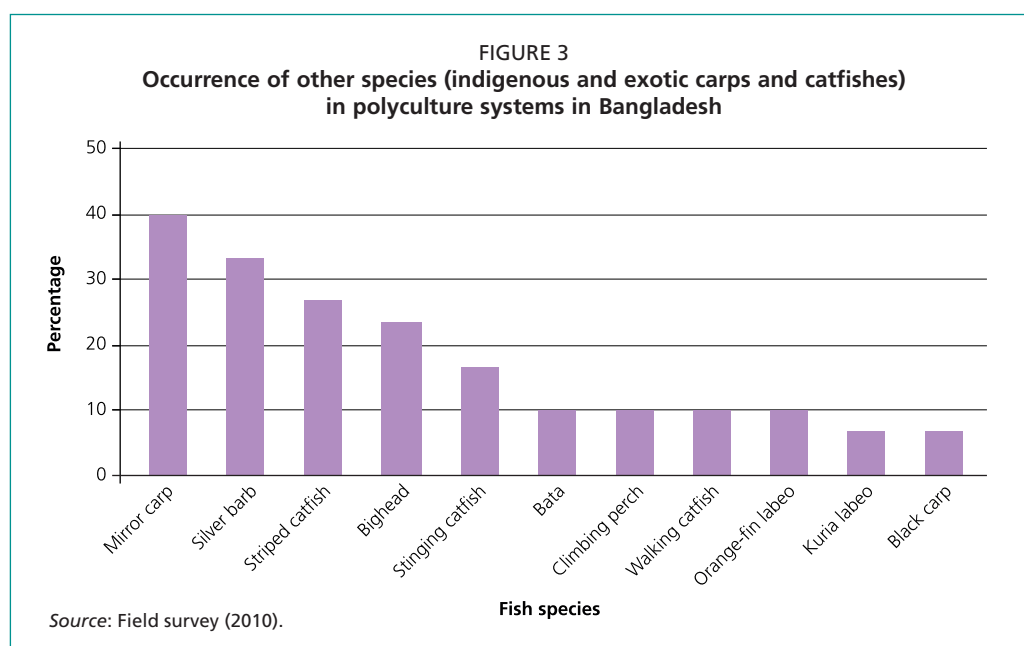
3.1.2 Fish selection and stocking

In the past, only three or four of the major carps (catla, rohu, mrigal and orangefin labeo/kalbasu) were reared together. More recently, exotic carps and catfishes have also begun to be stocked. Currently, 18 species are stocked in various combinations, usually in combinations of four to ten species. The survey revealed that seven fish species, namely catla, rohu, mrigal, silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*), kalbasu and silver barb (*Barbonymus gonionotus*) were the most common species being cultured (Figure 2).



In addition to these commonly stocked species, other species, including a mixture of indigenous and exotic carps and catfishes are also stocked (Figure 3).

In Jessore (southern Bangladesh), catla, rohu and mrigal were commonly stocked and reared. Some hatchery operators in this region reported separating the catla from the other species. In addition, silver carp, grass carp, silver barb, kalbasu, and



sometimes common carp, black carp (*Mylopharyngodon piceus*) and bata (*Labeo bata*), were reared in combination with the major carps. The water depth of the ponds in this region was maintained at approximately six feet (~1.8 m). Outside the breeding season, it was often reported that hatchery operators stocked their fish at high densities (3 500 to 7 500 kg/ha). With the onset of the breeding season, densities were reduced and feeding was increased to promote gonadal development. In some instances the catla were reared separately because, in comparison with the other species, they fare best at lower stocking densities. In eastern Bangladesh (Comilla region), the major carps were reared with silver carp, grass carp, silver barb, bighead carp (*Hypophthalmichthys nobilis*), kuria labeo (*Labeo gonius*) and striped catfish (*Pangasianodon hypophthalmus*). One hatchery owner reported rearing only catla and striped catfish together.

3.1.3 Broodstock nutrition and feeding

Once the ponds have been prepared, filled and matured (green water) they are stocked with brood fish (1.5 to 5.0 kg). The newly stocked fish graze the natural productivity of the ponds, and are supplied with supplemental feeds on a regular basis. Supplementary feeding is an essential component of the broodstock management protocol. To enhance the growth a balanced diet containing at least 25 percent protein should be provided. DoF (2006) suggested that for growing out broodstock from fish weighing 1 kg, a supplementary feed comprising fishmeal, mustard oil cake, soybean meal, rice bran, wheat bran, wheat flour, molasses and a vitamin pre-mix should be supplied at a daily rate of five percent of body mass (Table 3, Feed I). DoF (2006) also suggested that for rearing broodstock, a supplementary feed comprising wheat bran/rice bran, mustard oil cake, fishmeal, wheat flour, molasses and Vitamin E should be provided once a day at two to three percent of total body mass (Table 3, Feed II). Mazid *et al.* (2002) reported that an appropriate broodstock formulation comprised fishmeal, soybean meal, rice bran, wheat bran, mustard oil cake, sesame oil cake, wheat flour, molasses, and a vitamin and mineral premix (Table 3, Feed III). Feed III (Table 3) was reported to produce the best growth and reproductive performance in rohu and catla, compared to the results of using feed formulations I and II. The survey revealed that although all the farmers provided supplemental feeds, their preparation varied. With the exception of those in Jessore, the farmers preferred to use farm-made feeds using locally available ingredients such as mustard oil cake, wheat bran, rice polish/bran, fishmeal, molasses, and soybean meal. In contrast, hatchery operators in Jessore region used manufactured pelleted feeds. The ingredients that are commonly used in the preparation of farm-made feeds are presented in Table 4. To enhance gonadal development, most of the hatchery operators use vitamin and mineral mixtures; a number of companies provide vitamin and mineral mixtures (Table 5).

TABLE 3
Common dietary formulations used for broodstock rearing: farm-made feeds

Ingredients	Feed I (%)	Feed II (%)	Feed III (%)
Fishmeal	16	15	15
Mustard oil cake	10	30	20
Soybean meal	24	-	12
Rice bran	20	45	16.7
Wheat bran	19	-	14.5
Wheat flour	5	5	3
Molasses	5	4	5
Vitamin pre-mix	1	1	1
Sesame oil cake	-	-	12.8

Source: Field survey (2010).

TABLE 4
Common dietary ingredients used in broodstock feeds: farm-made feeds

Ingredient	Inclusion level (%)	Price (US\$/tonne)
Mustard oil cake	30–50	362
Wheat bran	10–20	232–261
Wheat flour	10	290
Rice bran/polish	20–30	174–218
Corn flour	10–20	290
Soybean meal	5–10	580–608
Fishmeal	15	580–652
Meat and bone meal	5	290
Molasses	5	174–218
Crushed snail shell	1	145
Vitamin premix	0.5–1.0 g/kg feed	3 623
Biscuit residue from a bakery*	4–5	258
Common salt*	0.5	170
Di-calcium phosphate*	1	170 (local) 542 (imported)
Binder*	0.5	2 570

US\$1= Bangladesh Taka (BDT) 69.00

*Ingredients that are used by some hatchery operators in Jessore region to improve feed quality.

Source: Field survey (2010).

TABLE 5
Vitamin, mineral mixtures and supplements

Company	Product	Price (US\$/kg)
Novartis Animal Health, Novartis (Bangladesh) Limited	i) Megavit-Aqua (vitamin-mineral and amino acid supplement)	i) 3.77
	ii) AQUA Boost (Non-antibiotic growth promoter)	ii) 5.50
ACI Livestock and Fisheries (Aqua Products Profile)	i) ACImix super-fish (vitamin, mineral and amino acid enriched premix)	i) 1.60
	ii) AQGRO-G	ii) 4.05
	iii) AQGRO-P	iii) 2.60
	iv) AQGRO-L (Herbal growth promoter)	iv) 2.60
Eon Animal Health Products Ltd. EON Group*	i) EON Fish Grower	i) 2.29
	ii) Nutricell Aqua-Non-antibiotic growth promoter	ii) 6.52
	iii) Ecolite (The health stone)	iii) 0.55
	iv) Timsen (Biocide)	iv) 68.98
ACMY Limited	Vitamix F Aqua premium	4.06
Renata	Vitamin premix (Rena Fish)	3.77
Navana Pharmaceuticals Ltd.	Aquavit Plus	3.61
Agronest (Pvt.) Ltd. Dhaka, Bangladesh	Zanvit, Fish grow (Fish feed premix)	3.91

*www.eongroup.net.bd

Source: Field survey (2010).

3.1.4 Feed preparation

Farm-made feeds are prepared by weighing the feed ingredients according to a defined formulation, and mixing them homogeneously. If mustard oil cake is used, it is first soaked in water for at least 24 hours. Once soaked, the other ingredients are added, and the ingredients are mixed and kneaded into a wet dough. The mixed feed is fed to the fish by distributing it between several locations across the pond. The supplemental feed is provided at two to five percent of body mass per day, and at between 10.00 to 13.00 hours (Figures 4, 5, 6 and 7). The feed is normally consumed within 30 to 60 minutes. The protein content of the supplementary feed was unknown as the hatchery operators do not determine the proximate composition of their feeds. However, they assumed that it contained between 20 to 25 percent protein.

FIGURE 4
Water soaked mustard oil cake (left) and fishmeal (right)



FIGURE 5
Mixture of soaked mustard oil cake, and dry wheat bran and fishmeal (left) and hand mixing of the ingredients with water (right)



FIGURE 6
Homogeneously mixed wet feed (left) and dough preparation (right)



FIGURE 7
Wet doughs (left) and feeding the wet dough (right)



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The majority of the hatchery owners believed that the quality of their farm-made feeds was superior to that of the manufactured feeds available in the market. They assumed that by formulating their own feeds, they had a better control over the quality of the feed ingredients used. Supplemental farm-made feeds cost US\$290 to 362/tonne. In comparison, manufactured aquafeeds cost between US\$362 to 435/tonne. The majority of the hatchery operators indicated that in comparison to manufactured aquafeeds, the poor binding properties of the farm-made supplemental feeds resulted in increased levels of wastage - typically between 15 to 20 percent.

In Jessore region, all the hatchery operators used supplemental feeds that were based on locally available feed ingredients. Typically, a private fish and poultry feed company would formulate the feed using ingredients such as mustard oil cake, rice polish, wheat bran, fishmeal, corn flour, soybean meal, vitamins, minerals and other feed additives e.g. probiotic enzymes, hormones etc. The company sold the feed ingredients and provided a feed manufacturing service to farmers. In many cases, the farmers would request the use of specific ingredients and formulations that would then be prepared accordingly.

The 'Maliha Enterprise' feed mill was an example of a feed mill providing these services. Feeds produced in the mill were supplied to the hatcheries in 25 or 50 kg bags. The hatchery operators stored the pellet feed in a storeroom on a cement floor, beneath jute carpets, or on a wooden platform. Storage periods of up to 25 to 30 days were reported. Although the proximate composition of the feeds was unknown, they were assumed to contain 20 to 25 percent of crude protein. The feed cost was US\$362/tonne. The pelleted feed was fed at two to three percent of body weight per day, applied either in a single ration or divided between two per day. Some hatchery operators reported using farm-made pelleted feeds in the morning, and commercially produced feeds in the afternoon.

All the hatchery operators provided supplemental feeds to their brood fish on a regular basis. Supplemental feeding was not undertaken on cloudy or extremely hot days. Supplemental feeding was also suspended after heavy rainfall or when the presence of toxic gases was noted. Gases such as hydrogen sulphide and carbon dioxide in the pond bottom sometimes occur as a result of the decomposition of leftover or uneaten feed. To remove the toxic gases, horra (a long rope with number of small weights attached) are pulled along the bottom of the pond and, where necessary, clean water is added to the pond. In general, the hatchery operators take responsibility for all aspects of pond management; however, in some cases they use hired labour.

To maintain the natural productivity of the pond systems, hatchery operators applied inorganic fertilizers, especially urea and TSP, to their ponds at 15 to 30 day intervals. In this regard, cow dung was applied irregularly and typically at intervals of two to three months. Hatchery operators in the Jessore region use composted manure to maintain the natural productivity of their pond water. Table 6 presents typical ingredients used to prepare composted manures.

TABLE 6
Composition of typical composted manures used in hatchery ponds

Case 1		Case 2	
Ingredient	Quantity (kg)	Ingredient	Quantity (kg)
Cow dung	200	Cow dung	200–400
Mustard oil cake	50	-	-
Rice polish	25	-	-
TSP	10	TSP	20–50
Urea	10	Urea	10–12

Source: Field survey (2010).

3.1.5 Preparation of composted manures

Composted manure is prepared by placing the materials (excluding urea) in an earthen pit or a cement bowl, mixing well, and leaving to decompose for 10 to 15 days. After 12 days the urea is added, and the mixture is left for a further three days. After about 15 days of decomposition, the compost is spread over the pond surface at the rate of 75 to 150 kg/ha, and at seven to ten day intervals. After applying the manure, the availability of phytoplankton and zooplankton in the pond water was established by sampling the pond water in a glass receptacle that is held against the sun to visually observe the plankton or sampling the plankton using a scoop net or a piece of fine cloth.

None of the respondents used Secchi disks to estimate the level of primary productivity, and all the respondents opined that plankton blooms did not normally occur in the broodstock ponds as the plankton was continually eaten by the fish. When plankton blooms did occur, dipterex was applied at 7.5 kg/ha, applied weekly for a period of three to four weeks.

3.2 Fry production and feeding

All the hatchery operators produced fry of the Indian major carps through hypophysation. Matured males and females were collected from the rearing ponds and placed in a cistern. The male and female fish were induced with pituitary gland (PG) extract and/or human chorionic gonadotropin (hCG) hormone. Eggs were collected by stripping the females immediately after ovulation. The fertilized eggs were transferred to an incubator for hatching.

Breeding may also be undertaken by placing the induced males and females in a circular spawning tank. The males and females release their gametes naturally, and the fertilized eggs are retrieved from egg collectors that are fitted to the outlet of the circular tank. The fertilized eggs are placed in an incubator for hatching. The larvae of the major carps normally hatch within 18 to 24 hours after fertilization, and start feeding after the complete absorption of the yolk sac – this usually occurs within 32 to 48 hours of hatching. The fry are fed hard-boiled chicken egg yolk that is mixed with water and spread over the surface waters. Plankton are also collected from pond waters and fed to the fry. In some cases, a specialized supplemental mixed shrimp feed was

used as a nursery feed. After five days, the fry are ready for sale to the nursery farmers and are sold in oxygenated polythene bags.

Despite the presence of natural feed in the ponds, hatchery operators provide supplemental feed to their broodstock every day. The type and ingredient composition of these feeds varied. Many hatchery farmers had a poor understanding of the nutritional requirements of their broodstock. The majority chose to provide farm-made supplemental feeds as wet doughs but some used locally produced pelleted feeds. It was evident that there was a need to improve the quality of the supplemental feeds used, and in this regard, the hatchery farmers need to be provided with training in pellet manufacturing technologies, storage, and feeding. In addition, the establishment of small feed mills close to the hatcheries should be encouraged.

3.3 Nursery production systems

Private nurseries produce most of the Indian major carp fingerlings used in aquaculture in Bangladesh and there are 10 802 private carp nurseries. Their size ranges between 0.17 ha to 6.0 ha. In addition, 35 Government Fish Seed Multiplication Farms provide fry to the farmers. In 2010–2011, approximately 8 204 million fingerlings were produced (DoF, 2012). Between 2009 and 2010, it was estimated 465 396 kg of fry were produced – this level of production is more than enough to meet the demand. Nevertheless, at times the production in the sector is constrained by a lack of quality fingerlings. It is assumed that only 20 to 30 percent of fry survive to the fingerling stage. The water depth of the nursery ponds is maintained at three to five feet (~0.9–1.5 m).

3.3.1 Pond preparation techniques

Both seasonal and perennial ponds are used as nurseries (Figure 8). Seasonal ponds are prepared for nursery production at the end of the winter season when they dry out; piscicides are not used in this process. In contrast, the perennial ponds are prepared by dewatering or by applying toxins such as rotenone, phostoxin and celphos to kill carnivorous or unwanted fish. After drying or poisoning the ponds, lime and cow dung are applied at rates of 250 to 500 kg/ha and 1 250 to ≥ 2 500 kg/ha respectively. Liming and manuring are undertaken five to seven days prior to stocking. Inorganic fertilizer, such as urea and TSP, may also be applied at rates of 25 to 50 kg/ha and 12.5 to 37.5 kg/ha respectively. In addition, muriate of potash (MP) and mustard oil cake may also be applied at rates of 12.5 to 17.5 kg/ha and 62.5 kg/ha respectively.

FIGURE 8
The owner and workers of a nursery with a net (left) and a typical nursery pond (right)



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To enhance plankton production some farmers in the Mymensingh region use molasses and wheat flour mixes that are added to the ponds three days before stocking. The molasses and wheat flour are added at rates of 40 to 43.75 kg/ha and 85 to 87.5 kg/ha respectively. The day before stocking a pesticide, such as dipterex or sumithion, at 0.15 to 0.25 ppm is added to the ponds to eradicate insects and large zooplankton species such as cladocerans. After stocking, some farmers applied urea and TSP at 25 kg/ha. Applications were made three times a month and designed to promote primary production. After stocking, farmers apply TSP and urea at 25 and 20 kg/ha/month respectively. When plankton blooms appeared in the ponds, the farmers reported adding lime and MP at rates of 50 to 62.5 kg/ha and 0.5 to 2.5 kg/ha respectively. In addition, to improve water quality, new water may be added to the ponds and the blooms may be removed using fine nets, or by adding dolomite (natural calcium magnesium carbonate) at 25 kg/ha. If *Microcystis* caused the bloom, copper sulphate may be added at 25 kg/ha. While there are regulations in place to prevent the use of copper sulphate, it was sometimes used by the farmers.

3.3.2 Stocking and rearing

The fry are reared in the nursery ponds for 30 to 40 days. This rearing period was considered a cycle, and due to limited space, many farmers reported using the same pond for at least three to four cycles per season. Two types of nursery systems are used in Bangladesh, *viz.*

- Single stage nursing
- Two stage nursing

The single stage nursing system involves growing the fry to fingerlings in one operation. Stocking densities are maintained at 1.0 to 2.0 million spawn/ha, and the fry grow to 5 to 7 cm fingerlings within 4 to 6 weeks. The two stage nursing system involves the fry being reared for 10 to 15 days in nursery ponds at high densities (>2.0 million spawn/ha), followed by grading and stocking in other nursery ponds at densities of 0.2 to 0.3 million/ha. The fry are reared in the secondary ponds for a further 4 to 6 weeks.

In some cases all the three major carps (catla, rohu and mrigal) are reared in a single pond. However, some farmers reported the rearing of single species, or combinations of only two species. Catla is often reared separately while rohu and mrigal are mostly reared together, often with exotic carp species. The rationale for rearing catla separately appeared to be that many customers only wanted to buy catla, and thus rearing them separately made the harvesting and sales process easier. The choice of species cultured, their combination and density were found to vary between regions. Many species combinations were observed in the survey (Table 7).

TABLE 7
Eight examples of species combinations and stocking densities cultured in nursery ponds

	Name of fish species	Density (kg/ha)
1	Catla	5–12.5
2	Rohu	18.7–20
3	Mrigal	25
4	Catla : rohu : mrigal	3.75 : 7.5 : 3.75
5	Rohu : mrigal	5 : 15
6	Catla : rohu	1.25–2.5 : 5–6.25
7	Mrigal : silver carp	2.5 : 2.5
8	Rohu : mrigal : silver carp	12.5 : 6.25 : 6.25

Source: Field survey (2010).

Farmers in the Comilla region practiced both types of nursery production. They prepared their ponds following the procedures outlined above, and stocked three major carps together. Some farmers stocked 5 day old fry at high densities, and reduced the density after 15 to 20 days of culture. This was achieved by transferring the fry into other ponds. The nursery cycle was initiated using 15 to 20 day old fry (± 1.3 cm) of catla, rohu and mrigal at densities of 3 750–5 000, 32 500–37 500 and 16 250–17 500 fry/ha respectively.

3.3.3 Nursery feeding and rearing

Phytoplankton and zooplankton produced in the newly prepared nursery ponds were the primary source of live feed for four to five day old fry. In addition to the natural food, supplemental feed was provided on a regular basis. Farmers fed hard boiled chicken egg-yolk to the newly hatched spawn for the first two to three days. Three to four eggs were required for each kg of fry. Sometimes 0.5–1.0 kg of cooked and diluted wheat flour was mixed with the egg-yolk. Subsequently the fry were fed wheat flour (1.0 kg wheat flour/kg of fry) for three to four days. The wheat flour was mixed with water and broadcasted across the pond surface. When the fry were seven days old, mustard oil cake was provided at the rate of 2 kg feed/kg fry. Prior to feeding, it was soaked in water for at least 24 hours and further diluted with water before being broadcasted over the water surface (Figures 9 and 10). This feeding schedule was used for the next seven days. After two weeks, most of the farmers switched to mustard oil cake, and continued feeding the same ration until the fry were sold at 4–5 g, some 30 to 40 days after hatching. Some farmers added rice polish to the mustard oil cake when the fry were about 1.2 cm, and the fry could ingest small food particles.

FIGURE 9
Overnight soaked mustard oil cake in a pot (left)
and mustard oil cake diluted with water (right)



COURTESY OF FAO/M.R.I. SARDER.

FIGURE 10
Broadcasting of overnight soaked and diluted mustard oil cake to a nursery pond



COURTESY OF FAO/M.R.I. SARDER.

In addition to farm-made supplemental feeds, commercially manufactured nursery feeds are used by some of the farmers. These are in powder form and are primarily designed for use with striped catfish, Nile tilapia (*Oreochromis niloticus*) or climbing perch (*Anabas testudineus*). Some respondents in the Comilla region reported using commercially manufactured feeds as first feeds, and subsequently changing to farm-made supplemental feeds. To improve the fry health, Megavit-Aqua (a vitamin-mineral and amino acid supplement) was reported being used at 1 g/kg of feed.

In general, during first 7 to 14 days of rearing the fry are fed to satiation. At the end of this period the fry reach 0.5 inches (1.27 cm), are placed in hapas, and the feed ration adjusted. The ration is based on the body weight of the fry. Between 14 and 21 days, the fry are fed at 60 percent of body weight per day. The ration is reduced to 40 percent between 21 to 30 days of rearing. At 2 to 3 g, the ration is reduced to 15 to 20 percent of body weight per day. At 15 to 20 days post hatch, the majority of the farmers reduce their stocking densities by splitting the groups between ponds. Decreasing the density results in faster growth rates. Prior to feeding, some farmers reported pulling horras across the pond bottoms. This was undertaken to stimulate the appetite of the fry and to release toxic gases from the pond sediments. Most of the farmers provided supplemental feeds between two and three times a day during the early rearing stages. During the latter production phase, feeding was reduced to two times a day - in the morning and in the evening. Though small fry require supplemental feeding every day, feeding was partially or completely ceased during heavy rains, on extremely hot days, on cloudy days, or in the presence of toxic gases that originate from the decomposition of uneaten feed. In the event that the pond water contained excessive levels of plankton, some farmers choose to stop supplemental feeding for at least a week.

Farmers rear the fry for a maximum of 30 to 40 days, and start to sell them from 30 days onwards, when they reach approximately 1 to 1.5 inches (~2.5–3.8 cm). In some cases the same pond was stocked for two to three nursery production cycles in succession. Between production cycles, phostoxin or rotenone was used to kill the remaining fish, and the pond was prepared for the next production cycle using lime and organic and inorganic fertilizers. Some farmers, who have grow-out ponds, rear the fry for seven to eight months in their own nurseries and stock them out into their ponds as juveniles (10 to 15 inches/25–38 cm; 70 to 100 g).

Farmers purchase their feed ingredients from nearby markets and transport them to their farms in vans or small vehicles. The distance between the markets and the farms is usually from 5 to 10 km, but may sometimes be a maximum of 20 km. Transport costs can be as high as US\$30/tonne. The ingredients are kept in store rooms for at least

seven days, usually on cement or mud floors. When the feed is stored on mud floors a jute mat is placed underneath the feed to protect it. Feed and feed ingredients are also stored on a bamboo or wooden dais (platform). Despite taking these precautionary measures, cockroaches, mites, rats, and sometimes moisture damage the quality of the feed and the feed ingredients.

Most of the nursery farmers are not well-off and lease their ponds. Due to a lack of funding some farmers are unable to regularly feed their fry, and experience problems with maintaining water quality. The nursery activities are generally totally performed by the farmers. However sometimes they employ casual labourers and, in some instances, they over-feed or under-feed the fry. Taking into consideration of the costs of pond leasing, pond preparation, purchase of fry, labour and other related production activities, it was reported that farmers could make profits of between 20 to 50 percent on their investments.

While fry production is a vital component of the fish culture value chain, its importance is often ignored or overlooked. To date, there have been no government or privately funded programmes to improve nursery and fry production systems in Bangladesh. Importantly, the marginalised subsistence farmers that represent the major stakeholders in the sector are unable to develop initiatives to improve production. This is primarily due to a lack of funding, land, education and leadership.

The farmers provide supplemental feeds to their fry at regular intervals; however, the survival rate of newly stocked fry is often very low. The reason for this is difficult to ascertain, however an inadequate supply of nutrients could be an important factor. It was noted that during the latter stages of the production cycle, farmers only fed mustard oil cake as a supplemental feed. It is unlikely that the mustard oil cake would provide all the necessary nutrients required for optimal growth. As an alternative, mustard oil cake mixed with other feed ingredients such as wheat flour, rice polish, fishmeal and vitamin and mineral mixtures could be used. The use of industrially manufactured nursery feeds could also be considered. If industrially manufactured feeds prove to be too expensive, low-cost feeds could be produced for the farmers in the local feed mills. The quality of mustard oil cake is another important issue; if the oil cake is adulterated or inappropriately stored, it can degrade, and the toxins produced can result in mass mortalities. To preserve the quality, mustard oil cake should be kept on cement floors or on wooden platforms in store rooms.

3.4 Indian major carps grow-out systems

Indian major carp aquaculture is primarily undertaken in pond and to some extent in oxbow lake culture systems. The total area of ponds and oxbow lakes in Bangladesh is 310 513 ha. In 2008, production in these systems was approximately 870 827 tonnes, contributing 33.9 percent to the total national fish production (DoF, 2009). There are two grow-out systems that are used for Indian major carp production in Bangladesh, *viz.*

- Improved-extensive culture in oxbow lakes
- Semi-intensive culture in ponds.

The semi-intensive culture systems are the most commonly used and require feeds to supplement the natural productivity of the ponds (Barman and Karim, 2007). The promotion of semi-intensive polyculture systems has significantly enhanced the production of communal ponds where the water is used for various purposes, particularly in rural areas of Bangladesh (ADB, 2005).

3.4.1 Pond preparation

Pond preparation for grow-out systems were found to be similar to those procedures that are used for broodstock pond preparation, the only difference being the selection of organic manures and inorganic fertilizers. Grow-out ponds were prepared using lime followed by organic (e.g. cow dung) manures and inorganic (urea, TSP, MP) fertilizers.

Most of the farmers showed a preference for cow dung as an organic manure. However some used poultry litter as an alternative at 250 to 1 000 kg/ha. If poultry litter was used to supplement cow dung, the dose of poultry manure was reduced to 250 to 500 kg/ha. In Rajshahi region, where cow dung was sometimes unavailable, the farmers used poultry litter as an alternative. In contrast, some farmers preferred to apply mustard oil cake at 125 to 250 kg/ha. The practice of applying mustard oil cake in this manner increased pond productivity. With respect to the use of inorganic fertilizers, urea, TSP and MP were commonly used. Zeolite and gypsum were reportedly used at 25 kg/ha and 100 kg/ha respectively. The use of organic manures and inorganic fertilizers was deemed essential during pond preparation. Additional fertilizer was sometimes applied at lower doses during the production cycle. The additional fertilizer was used to maintain the natural productivity of the ponds, and was usually applied at 15 or 30 day intervals. Some farmers applied composted manure produced from organic manures and inorganic fertilizers.

In Comilla region, farmers prepared their ponds using the organic and inorganic fertilizers described above; however in contrast to other regions, they also reported using cow dung at higher doses (2 000 to 3 000 kg/ha). No farmer in this region reported using poultry litter. In Comilla, the farmers believed that the poultry litter could introduce disease into the ponds, for example, *Argulus* infestations. All the respondents reported using fertilizers at 15 to 30 days intervals throughout the production cycle. Some farmers applied cow dung daily by mixing it with water, and then broadcasting the mixture over the pond water at 40 kg/ha. The farmers checked the abundance of plankton in the pond water almost daily. This was achieved using Secchi discs, visual observation, or by hand depth measurement and the use of white coloured aluminium plates. This practice was not commonly found in other parts of the country.

3.4.2 Species selection and stocking

The grow-out ponds used in Indian major carp culture varied in size. The smallest was reported to be 0.12 ha and the largest was 7.92 ha. Catla, rohu and mrigal, in combination with other indigenous and exotic carps, were stocked. While farmers in the various regions stocked indigenous and exotic fish in different combinations, it was catla, rohu and mrigal that were most commonly stocked together, thus representing the prime culture species. Amongst the exotic fish used, silver carp, grass carp, mirror carp (*Cyprinus carpio*) and silver barb were the most common; however, striped catfish and common carp (*Cyprinus carpio*) were also found in many combinations. Some indigenous carps for example, the kalbasu, kuria labeo, bata (*Labeo bata*) and even stinging catfish (*Heteropneustes fossilis*) and Asian catfish (*Clarias batrachus*) were also included in a few combinations.

The survey showed that at least 18 fish species including indigenous and exotic species were being cultured in various species combinations across different regions of the country, comprising a minimum of four and a maximum of ten species. Among the species, catla, rohu, mrigal, silver and grass carp were the top ranking species followed by common carp, mirror carp, Nile tilapia and silver barb. The percentages of occurrence of most common fish species cultured in these systems were given in Figure 2. Farmers used combinations of species that optimised feeding behaviour and stocking densities. The choice of species varied markedly and was designed to avoid combinations that would result in inter-specific competition. While some species were reported in all the species combinations, others were reported in just 5.5 percent (Figure 3). Examples of the various species combinations that were observed are presented in Table 8.

TABLE 8
Indicative species combinations used in polyculture systems from different regions of the country

Combination 1	Combination 2	Combination 3	Combination 4	Combination 5
Catla, rohu, mrigal, silver carp, grass carp, mirror carp, bighead carp, striped catfish	Catla, rohu, mrigal, silver carp, grass carp, mirror carp, silver barb	Climbing perch, striped catfish, catla, rohu, silver carp	Catla, rohu, mrigal, silver carp, grass carp, mirror carp, silver barb, Nile tilapia, black carp, bata	Catla, rohu, mrigal, silver carp, grass carp, silver barb, orangefin labeo/kalbasu, kuria labeo, common carp

Source: Field survey (2010).

3.4.3 Feed preparation and feeding in the grow-out systems

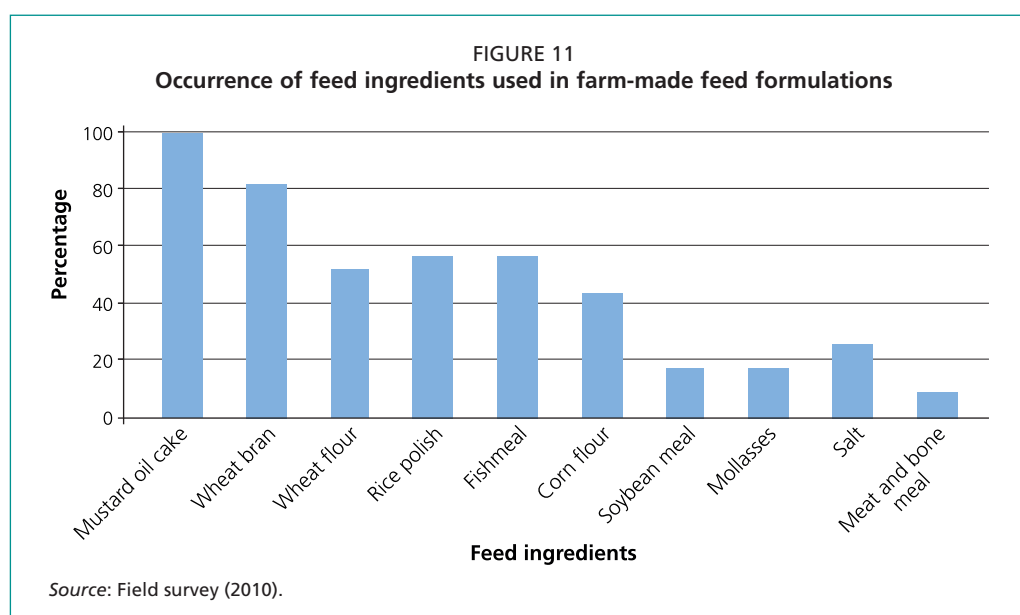
In addition to using the natural productivity of the ponds as feed, most farmers made use of farm-made feeds. A high degree of variability was found in the ingredients and feed formulations used, and their application rates. Table 9 presents the levels of common ingredients commonly used in farm-made feeds.

TABLE 9
Levels of commonly used feed ingredients in farm-made feeds

Ingredient	Indicative inclusion rates (%)
Mustard oil cake	15–30
Wheat flour	5–15
Wheat bran	10–30
Rice bran/polish	25–50
Fishmeal	5–10
Corn flour	5–10
Molasses	1–2

Source: Field survey (2010).

The variability in the feed ingredients used was dependent on their regional availability. For example, while the use of corn flour dominated in Jessore region, soybean meal was used more extensively in Comilla region. Figure 11 shows the occurrence of feed ingredients used in the manufacture of farm-made feeds.



In addition to these ingredients, some farmers used vitamin premixes (0.5 percent), minerals (one percent) and soybean oil (one percent) in their formulations. As a result of financial constraints, some of the poorer farmers were only able to afford to use mustard oil cake and rice polish or wheat bran. These they mixed at equal ratios and used as supplemental feeds.

Farmers primarily depend on mustard oil cake as the major plant protein source in their formulations. The survey revealed that all the farmers used mustard oil cake, and that it was readily available throughout the country. Sometimes soybean meal or linseed oil cake was used as a supplement to mustard oil cake. Fishmeal was considered as the main animal protein source, and the commercial farmers used it in their formulations. Marginal and poor farmers were unable to use it on a regular basis due to availability and cost issues. Fishmeal is primarily produced in Bangladesh using trash fish and by-catch species; however production is insufficient to meet the demand. The Bangladesh Fisheries Development Corporation (BFDC) produces fishmeal at its four fishmeal production plants. The Corporation has a total production capacity of eight tonnes/day (Murtuza, 1998). To satisfy the demand, fishmeal is imported from other countries, e.g. China, Malaysia, and the United States of America. In addition, meat and bone meal is imported from Denmark, Belgium, and Croatia. The protein content of these feed ingredients ranges from 40 to 55 percent (Barman and Karim, 2007).

Farmers in the Jessore, Rajshahi and Mymensingh regions showed a preference for farm-made feeds because they were relatively cheap (US\$260 to US\$315 per tonne), of a high quality, and easy to prepare. However, some regional variability was found in the preparation and administration of these feeds. The feed preparation techniques that were reported included:

- The mustard oil cake was placed in a plastic or cement bowl and soaked in water for at least 24 hours. The other ingredients were added to the soaked mustard oil cake. The material in the bowl was mixed homogeneously by hand until a dough was formed. Between 09.00 and 10.00 hours, the dough was fed to the fish at different locations in the pond. Some farmers fed twice a day, and in these cases the daily ration was divided into two parts; one part was given to fish at between 09.00 to 10.00 hours, and the remainder between 16.00 to 17.00 hours.
- All feed ingredients were measured and placed in an earthen bowl. Water was added and the ingredients mixed homogeneously. The earthen bowl was then dipped into the water in a corner of the pond. In large ponds, the feeds were presented to the fish at a number of locations around the pond. As the feed contained a high water content, some feed materials were lost during ingestion.
- On large farms (60 to 250 tonnes/year) the dry feed ingredients were mixed homogeneously. The mixtures were placed in plastic or jute bags (25 to 50 kg in each bag) and held in a store room. When required, the feed materials were placed in plastic or earthen bowls, and water was added. After two to three hours of soaking, the feed materials were once more mixed and kneaded into a dough. The dough was fed to the fish at different locations around the pond. Feeding was undertaken in the morning, and if necessary in the afternoon.
- Pelleted feeds were manufactured at local feed mills. To obtain the feed ingredients, the farmers could either purchase them from local markets and deliver them to the mill; or alternatively, the mill owner would provide the necessary ingredients from their stock. The miller produced the pellets using the supplied ingredients. To manufacture them, the ingredients were mixed and water added. The moist feed mixture was extruded into pellets (3 to 4 mm). The pellets were sun dried for five to six hours, and placed in plastic bags for storage (as shown in Figures 12, 13, 14 and 15). The pelleted feed was broadcast at two to three percent of body weight per day.

The survey revealed that 23 percent of the farmers used commercially manufactured aquafeeds to supplement their farm-made feeds – this practice was most common in Comilla region. The feeds contained protein contents ranging from 25 to 30 percent. (Food conversion ratios (FCR) were 1.3:1 to 2:1. Farmers fed by broadcast feeding twice a day at 09.00 to 10.00 hours and 16.00 to 17.00 hours. The fish were fed at three to four percent of body weight per day. The commercial feeds were comparatively expensive, ranging between US\$362 and 435/tonne. In contrast, the cost of the farm-made feeds was US\$260 to 315/tonne (Table 10). At times, the high price of the commercially manufactured aquafeeds made them unaffordable to the marginal and poor farmers. The proximate composition of selected commercially manufactured aquafeeds is presented in Table 11.

TABLE 10
Prices of selected commercially manufactured aquafeeds and farm-made feeds

Commercial feed	Price (US\$/tonne)
Quality carp feed	377
Mega feed	435
Aman feed	405
SB super feed	405
Aftab carp feed	377
Madina fish feed	362
Teer fish feed	391
Farm-made feeds	
Various formulations	260–315

Source: Field survey (2010).

TABLE 11
Proximate composition of selected commercially manufactured aquafeeds used in grow-out systems

Ingredients	Dry matter (%)	Crude protein (%)	Crude lipid (%)	Crude fibre (%)	Ash (%)	NFE (%)
CP pangas feed	88.9	31.9	6.6	7.6	14.5	39.4
Quality carp feed	92.5	28.4	6.6	8.4	16.8	38.8
Mega feed	90.3	29.3	4.2	9.0	12.2	45.3
Aman feed	90.3	25.6	7.8	8.7	22.9	35.0
SB super feed	91.1	26.4	8.6	7.9	14.7	42.4
Aftab carp feed	89.2	24.5	6.1	8.7	15.6	45.1
Madina fish feed	90.9	25.6	7.6	10.6	18.9	37.3
Teer fish feed	89.3	26.9	7.9	8.5	16.4	40.3

NFE = Nitrogen free extracts.

Source: Field survey (2010).

All farmers in every region reported using either farm-made feeds or commercially manufactured feeds. In terms of their efficacy, the farmers do not record FCR, and thus it is difficult to establish whether the feeds were well formulated or were being applied effectively.

Fish were reared in the ponds for an 8 to 12 month period, and subsequently harvested and sold (Table 12). The production varied across the regions and ranged from 750 to 15 000 kg/ha. The production costs varied from region to region as the cost of labour, the leasing of the ponds, and even the feed ingredients costs differed. For example, the costs of leasing ponds varied from US\$218 to 4 348/ha/year. While the farmers sold their fish either directly to their customers or to the middle men in the fish market, fish prices varied between locations. The majority of farmers spent a large portion of their investment on supplemental feeds; however, none of them could provide detailed levels of expenditure. It was clear that many farmers do not maintain production cost and income records. Therefore, it was not possible to determine production costs and net incomes. However, from the survey it was estimated that farmers made in the region of 40 percent profit on their initial investments.

The majority of the farmers reported feeding the major carps irregularly and with nutritionally incomplete diets. This was a result of their poor understanding of the nutritional requirements of the fish. In this regard, training on the dietary requirements of fish needs to be provided through the development of suitable workshops and extension materials e.g. leaflets, booklets, manuals etc. The training materials should include information that describes the selection of appropriate feed ingredients, storage, feed preparation and pellet manufacture, the calculation of FCR, record keeping, and the determination of the cost benefit ratios associated with feed use.

4. A CASE STUDY OF AN ADVANCED GROW-OUT FARMER

A case study was undertaken of a fish farmer from Char Fashion village, Mymensingh district. Mr Akand operated a hatchery and grow-out facility, and a feed mill to produce his own feeds as well as feeds for sale. The necessary feed ingredients were stored at the mill, and these were offered to local farmers who required assistance in the preparation of their supplemental feeds. Mr Akand had a good knowledge of fish culture techniques and had received training on various aspects of fish culture from the Department of Fisheries. He had a good understanding of pond preparation techniques, the selection of culture species, density effects, and supplemental feeding practices.

The fish farm comprised four ponds with a total area of 1.7 ha. The largest pond was 0.81 ha, and the smallest 0.3 ha. Prior to stocking, the ponds were fertilized with cow dung and poultry litter, applied at 1 250 to 2 500 kg/ha and 250 kg/ha respectively. Lime was added at 250 kg/ha. TSP and urea were applied at 50 to 62.5 kg/ha and 50 kg/ha respectively. In those ponds that have a clay substrate, MP was applied at 12.5 to 25 kg/ha. In addition, organic and inorganic fertilizers were applied at 15 day intervals throughout the production cycle to maintain the natural pond productivity. The species combination and the stocking density of fish are presented in Table 13.

The feed derived from natural pond productivity was regularly supplemented with farm-made feeds prepared using locally available ingredients (Table 14).

To prepare the feeds, the ingredients were placed on a cement floor and mixed homogeneously. Approximately ten litres of water were added to 100 kg of dry feed mixture. The semi-wet mixture was placed in the pellet machine and extruded. The size of the pellet was regulated using dyes. Normally, 3 to 4 mm diameter pellets were produced (Figures 12, 13, 14 and 15). After sun drying for six hours, the pellet feed was placed in plastic or jute bags, and stored for up to 60 days. While the proximate composition of the feed was not established, the protein content was assumed to be approximately 25 percent. The feed cost was US\$290 per tonne.

TABLE 12
Indian major carp production cycle, feeding schedules, and fertilizer use

Month	Type and size of fish at stocking ¹ and at harvest (month 9)									Feeding schedules			Type of fertilizer	
	Catla (g)	Rohu (g)	Mirgal (g)	Silver carp (g)	Grass carp (g)	Common carp (g)	Silver barb (g)	Feed type	Feeding frequency (times/day)	Feeding rate (% BW ² /day)	Organic (kg/ha) ³	Inorganic TSP/urea (kg/ha) ³		
1	150-500 g	50-250 g	50-250 g	25-250 g	25-250 g	50-100 g	10-15 g	Farm-made dough/pellets	1-2	2-3	250-1 250	250-1 250		
2								Industrial Pellets	1-2	2-3	as above	as above		
3									as above	as above	as above	as above		
4									as above	as above	as above	as above		
5									as above	as above	as above	as above		
6									as above	as above	as above	as above		
7									as above	as above	as above	as above		
8									as above	as above	as above	as above		
9 Harvest	1.5-3.0 kg	0.75-1.5 kg	0.75-1.5 kg	1.5-3.0 kg	1.5-2.5 kg	1.0-2.0 kg	0.25-0.4 kg		as above	as above	as above	as above		

¹ Farmers stock variable sizes and stocking densities; ²BW = body weight; ³ applied at 15-30 day intervals.
Source: Field survey (2010).

TABLE 13
Stocking characteristics of the major aquaculture species in the case study

Species	Density (number/ha)	Age of fish at stocking	Weight of fish (g) at stocking
Catla	250	1 year	200–250
Rohu	1 250	1 year	150–200
Mrigal	1 250	1 year	150–200
Silver carp	1 750–250	1 year	150–200
Grass carp	250–500	1 year	150–200
Silver barb	1 250	1 year	50–100
Nile tilapia (mono-sex)	50 000	40–45 days	10–15
Orangefin labeo/kalbasu	750	1 year	150–200
Common carp	500	1 year	150–200
Mirror carp	250	1 year	150–200

Source: Field survey (2010).

TABLE 14
Ingredients and dietary formulation used in farm-made feed used in the case study

Feed ingredient	% inclusion rate
Mustard oil cake	20
Rice polish	50
Wheat bran	4
Fishmeal	10
Corn flour	15
Nutrimix (vitamin mixture)	0.5
Mega binder (pellet binder-made in China)	0.5

Source: Field survey (2010).

The feed was fed to the fish at three to four percent of body weight per day. The ration was divided into two parts that were fed at 10.00 and 16.00 hours. The feed was normally broadcast, and was usually consumed by the fish within 10 to 20 minutes of application. To adjust the feed ration, the fish were sampled once a month and their weight and length were measured. The health and the presence of parasitic infestations were also noted at this time. Though the feed was supplied regularly, the fish were not fed supplemental feed for one day in every two weeks. This practice was established to ensure that the fish maintained good appetites. Feeding was stopped during adverse environmental conditions – very hot, humid or rainy days. Supplemental feeding was also discouraged when gas bubbles appeared in the ponds; these bubbles (hydrogen sulphide) indicated overfeeding in the pond and the decomposition of uneaten feed.

The fish were reared for at least six to seven months before being sold. Catla, rohu, mrigal, silver carp, grass carp, common carp and kalbasu were sold at a size of 2 kg, 500 to 600 g, 700 to 1 000 g, 1 to 1.5 kg, 3 to 4 kg, 1 to 2 kg, and 500 to 700 g respectively. Tilapia was sold at 250 to 300 g. It was established that production in those ponds (excluding Nile tilapia) was about 6 250 to 7 500 kg/ha, but this increased from 17 500

to 20 000 kg/ha when Nile tilapia was introduced. The average market price of the fish was US\$ 1 884/tonne. Recently, production costs have increased, and these now represent between 50 to 60 percent of total investment costs. The production cost includes the cost for leasing ponds (US\$600 to 4 348/ha/year), fish, feed, fertilizers, and labour (at least two labourers with a monthly salary of US\$72 to US\$87). There was no accurate calculation of the total income generated by the farmer; however it was assumed that he makes in the region of 40 percent on his investment.

FIGURE 12
Soaking of feed ingredients with water (left)
and mixing of feed ingredients in a bowl (right)



COURTESY OF FAO/M.R.I. SARDER.

5. RECOMMENDATIONS

Aquaculture, and especially carp culture has expanded throughout Bangladesh, and the sector now contributes significantly to the total national fish production. However, the production of carp is being hampered by the use of poor quality feeds and their on-farm management. To ensure the long term sustainability of the sector, it is important to identify the problems associated with feed and feed management practices, and to provide solutions. In this regard, the following recommendations are made to promote sustainable aquaculture development:

- The continued expansion of the sector requires the provision of appropriate supplemental feeds. As most of the marginal and poor rural farmers have no knowledge of fish nutrition, information outlining their nutritional requirements, feed formulation, feed quality, management and feeding protocols needs to be provided through extension services and training programmes.
- Farmers should be made aware that the primary productivity of their ponds impacts production. Information describing methods of increasing phytoplankton, zooplankton, benthos and periphyton production through organic and inorganic fertilization should be provided. Farmers need to be

FIGURE 13
Mixed feed ingredients placed in the pellet machine (left),
pellet dyes of different sizes (middle) and pellet production (right)



COURTESY OF FAO/M.R.I. SARDER.

FIGURE 14
Extruded pellets in the basket (left) and their sun drying (right)



COURTESY OF FAO/M.R.I. SARDER.

FIGURE 15
Dried pellets are being packed (left) and stored (right)



COURTESY OF FAO/M.R.I. SARDER.

aware of the implications of using farm-made feeds, and their potential impact on pond water quality.

- Feed ingredients, and especially those that are used by other farming systems, e.g. the poultry and livestock feed industry, should be made available to the fish farmers at cost effective prices. In this regard, government could consider distributing the ingredients through registered distributors or dealers, and could consider providing subsidies to the farmers.
- Since the locally manufactured pelleted feeds are more effective than the farm-made feeds, farmers should be encouraged to use pelleted feeds. To make the pellets, small scale local feed mills need to be established. The government should provide the necessary support to establish such mills. The feed millers would require training to ensure the quality of the feed produced.
- Feed storage and maintaining feed quality prior to use is an important issue. Feed and feed ingredients should be stored on cement floors underneath a jute mat, or on a wooden platform. In those instances where the store room has a mud floor, the feed should be stored on wooden or bamboo platforms. In addition, the store rooms should be well ventilated.
- Although a number of dedicated aquafeed manufacturers have established operations in the country, the quality of many of the feeds that are produced remains questionable. It is often reported that the feed manufacturers use low quality feed ingredients, and add hormones and growth promoters to the formulation. These supplements may result in adverse effects not only to the environment, but also to human health. The Department of Fisheries needs to take appropriate steps to stop these practices. This could be achieved through the implementation of the Fish and Animal Feed Act.
- Fishmeal is an essential component of fish feeds, and at present there is a shortage in the domestic supplies that are available to the sector. The government should take the necessary measures to encourage fishmeal production in the country. If necessary, quality fishmeal should be imported from abroad.
- Farmers are not monitoring their feed use or using FCR to determine feed efficiencies. It is important to encourage farmers to maintain appropriate feed records, calculate FCR and, where necessary, take corrective actions. This could be achieved through the provision of extension services and training programmes.
- Farmers in all the three production categories, and especially in the nursery and grow-out systems, sometimes fail to take appropriate care of their fish, and use supplemental feeds inappropriately. This is primarily a result of their financial situation and a lack of funds to purchase the feeds. Financial support to purchase feeds should be provided by the government or private banks.
- The linkages between government, University laboratories and research institutes needs to be strengthened, and technical support provided to the aquafeed industries, feed millers and, in some cases the fish farmers, to analyze their feed and feed ingredients.

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ANNEX

Unofficial translation of salient features of Fish and Animal Feed Act (Act 2 of 2010)²

- (i) Government i.e. the Ministry of Fisheries and Livestock will fix the standard quality of feed and feed ingredients, and it will be obligatory for the feed mills and industry to maintain the standards.
- (ii) Upon examination in a quality control laboratory, any feed mill or industry that fails to maintain the said quality of feed and feed ingredients may be closed by the regulatory authority and have its licence cancelled.
- (iii) To verify the quality of marketed feed, the Director General of the Department of Fisheries or his nominee can take feed samples from any industries, mills, exporter or dealer at any time and check the quality of the feed.
- (iv) If the feed is found to be adulterated or unsuitable for fish, the whole consignment of feed will be confiscated and the activities of feed miller, exporter or dealer will be considered as a criminal offence.
- (v) No person or company may directly or indirectly produce, import or market any harmful or adulterated fish, or any animal feeds that contain toxic or harmful substances to humans, fish, animals or the environment.
- (vi) Feed will not be allowed to be sold unless it is packaged and labelled with the manufacturers' name or country of origin, address and registration number, production and expiry dates, weight, nutritional information and its ingredient composition.

² Approved by the Government of Bangladesh on 28 January 2010.