COUNTRY REVIEWS AND CASE STUDY: ASIA

Analysis of feeds and fertilizers for sustainable aquaculture development in Bangladesh

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SUMMARY

This study focuses on feeds and nutrients used under different aquaculture farming systems and practices in Bangladesh, which include:

- extensive and semi-intensive systems for the production of carp species (Indian and Chinese major carps, common carp, Java barb) and to a lesser extent tilapia and catfish. Over 89 percent of aquaculture production in Bangladesh is derived from these systems. An overview of feed and nutrient utilisation in these systems as well as their diversity, complexity and production potential are presented;
- intensive culture systems for sutchi catfish (*Pangasius hypophthalmus*) (local name: Thai pangas). These have typically developed in clusters in several regions and depend largely on the use of farm-made feeds, pelleted feeds supplied either by the industrial aquafeed industry or by small-scale aquafeed mills. The increase in the number of small-scale feed manufacturers is a direct response to the growth in demand for pelleted feeds; and
- systems for the production of black tiger shrimp and giant freshwater prawn. These include hatcheries, nurseries and grow-out facilities. Black tiger shrimp (*Penaeus monodon*) and giant freshwater prawn (*Macrobrachium rosenberergii*) production is expanding rapidly and now contributes to the export earning of Bangladesh. Developments in feed manufacturing technology and improved fertilization are critically important for the expansion of the industry. The use of feeds and nutrients in crustacean culture has been analysed based on existing farming practices.

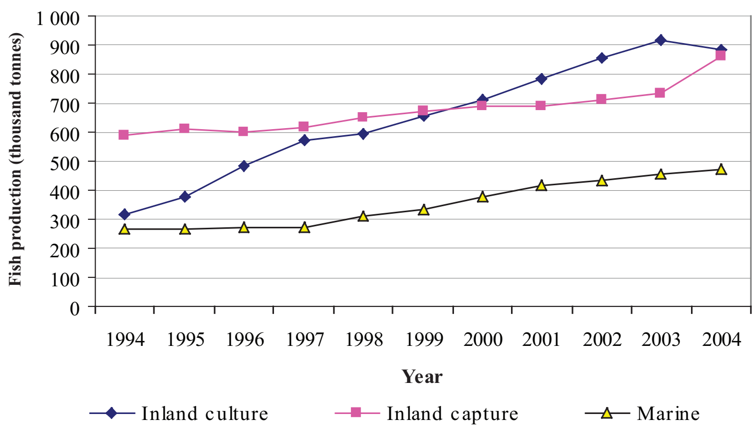
The increase in aquaculture production in many Asian countries is mainly a consequence of the expansion of semi-intensive, small-scale farming systems and the more appropriate use of feeds and nutrients (Hasan, 2001). In Bangladesh, the average yield from fishponds has increased from 0.85 tonnes/ha/year in 1986 to 2.48 tonnes/ha in 2005. Potential exists to further increase production through improved use of feeds and fertilizers. Even minor increases in production levels in the extensive and semi-intensive farming systems would make significant contributions to total fish production in Bangladesh. To achieve this goal there is a need for a better understanding of the production systems, the quality, quantity and frequency of feed and fertilizer application and the use of different species.

Different types of fertilizers and feeds (single ingredient or compounded) are used in the diverse array of systems. The formal and informal aquafeed industries in Bangladesh are developing rapidly, collectively contribute to job creation and improved aquaculture production. This study analyses the potential for development and the constraints facing the aquaculture sector in Bangladesh, with particular reference to feeds and fertilizers. Recommendations are made to facilitate the sustainable development of the sector in the country.

1. INTRODUCTION

The fisheries sector in Bangladesh plays a vital role in the supply of animal protein, creating employment, earning foreign currency and alleviating poverty. The contribution of the sector accounts for 4.92 percent of GDP, 5.7 percent of total export earnings and directly and indirectly employs approximately 12 million people (BBS, 2004). During the period 1995–96 to 2004–05 fish production in Bangladesh increased by 75.3 percent from 1.264 million tonnes to 2.216 million tonnes and the contribution by aquaculture to total domestic fish supply increased from 31 to 40 percent (Figure 1). Similarly, export volumes and earnings of fish and fish-products increased from 39 391 tonnes (US$263 million) in 1999–2000 to 63 377 tonnes (US$373 million in 2004–05 (DoF, 2006). Export earnings are largely contributed by black tiger shrimp, *Penaeus monodon* and giant freshwater prawn, *Macrobrachium rosenbergii*.

FIGURE 1
Trends in fish production from inland aquaculture and capture fisheries in Bangladesh from 1994–95 to 2004–05



Source: DoF (2006).

In 2004–5, pond fish production contributed to 85.8 percent of the total aquaculture production, whilst the remainder was produced in coastal shrimp ponds (13.7 percent) and oxbow lakes (0.5 percent). Overall, aquaculture contributed 39.8 percent to the total national fish production (Table 1). Major species-group aquaculture production and species-wise pond fish production during 2004–2005 are shown in Tables 3 and respectively.

In many Asian countries, the increase in aquaculture production is a direct consequence of the expansion of semi-intensive, small-scale pond aquaculture and more appropriate use of feeds and nutrients (Hasan, 2001). This is particularly true for Bangladesh, where the average yield from fish pond aquaculture increased from 0.85 tonnes/ha in 1986 to 2.48 tonnes/ha in 2005 (DoF, 2006). With the exception of a small proportion of aquaculture production from rapidly growing intensive aquaculture systems, the bulk (87 percent) comes from improved-extensive and semi-intensive culture systems. There is great potential to increase the productivity of these systems even further through better use of feeds and fertilizers and even minor increases in production in these systems would significantly raise total fish production. In order to achieve this goal an improved understanding of the production systems, the use of feeds and nutrients and the various aquaculture species is required.

TABLE 1
Aquaculture production from different water resources in Bangladesh, 2004–05

Sources	Area (ha)	Total aquaculture production (tonnes)	Yield (tonnes/ha)	Percent of total aquaculture production	Percent of total fisheries production
Inland fish ponds	305 025	756 993	2 482	85.8	34.2
Coastal shrimp farms	217 877	120 710	554	13.7	5.4
Oxbow lakes[2]	5 488	4 388	800	0.5	0.2
Total	**513 584**	**882 091**		**100**	**39.8**

Source: DoF (2006)

TABLE 2
Major species-group aquaculture production (tonnes) in Bangladesh, 2004–2005

Major groups	Freshwater Ponds	Brackish-water shrimp farms	Oxbow lakes	Total	% of total
Major carps	413 137	-	1 922	415 059	47.05
Exotic carps	236 088	-	1 779	237 867	26.97
Other carps	6 469	-	-	6 469	0.73
Snakeheads	10 738	-	2	10 740	1.22
Catfishes	8 509	-	4	8 513	0.97
Live fishes	6 552	-	1	6 553	0.74
Other fishes	72 940	38 049	669	111 658	12.66
Shrimps and prawns	2 560	82 661	11	85232	9.67
Total	**756 993**	**120 710**	**4 388**	**882 091**	**100.0**

Source: DoF (2006)

TABLE 3
Species-wise pond fish production in Bangladesh, 2004–2005

Major groups	Species	Tonnes	%
Major carps	Rohu (*Labeo rohita*)	163 190	21.56
	Catla (*Catla catla*)	137 685	18.19
	Mrigal (*Cirrhinus cirrhosus*)	112 262	14.83
Sub-total		413 137	54.58
Exotic carps	Silver carp (*Hypophthalmichthys molotrix)*	158 741	20.97
	Grass carp (*Ctenopharyngodon idellus*)	15 897	2.10
	Common/mirror carp (*Cyprinus carpio*)	16 502	2.18
	Java barb (*Barbonymus gonionotus*)	4 693	0.62
	Mixed carps	34 897	4.61
	Others	5 357	0.71
Sub-total		236 088	31.19
Other carps	Orange-fin labeo (*Labeo calbasu*) and kuria labeo (*Labeo gonius)*	6 469	0.85
Snakeheads	Snakeheads (*Channa* spp.)	10 738	1.42
Catfishes	Long-whiskered catfish (*Sperata aor*) and giant river-catfish (*S. seenghala*)	681	0.09
	Wallago (*Wallago attu*) and other catfishes	7 828	1.03
Sub-total		8 509	1.12
Live fishes	Climbing perch (*Anabas testudineus*)	1 892	0.25
	Catfishes (*Heteropneustes fossilis* and *Clarias batrachus*)	4 660	0.62
Sub-total		6 552	0.87
Other fishes	Feather backs (*Notopterus chitala* and *N. notopterus*)	908	0.12
	Olive barb (*Puntius sarana*)	3 179	0.42
	Tilapias (*Oreochromis niloticus* and *O. mossambicus*)	9 992	1.32
	Punti (*Puntius* spp.)	9 008	1.19
	Others*	49 852	6.7
Sub-total		72 940	9.75
Prawns	Giant freshwater prawn (*Macrobrachium resenbergii*), monsoon river prawn (*M. malcolmsoni*) and other freshwater prawn species	2 560	0.34
Grand total		**756 993**	**100**

*All other freshwater fish species not included above. See Annex A1 for details of major groups of aquaculture species in Bangladesh.

Source: Modified from DoF (2006)

[2] Oxbow lakes (local name: baors) are semi-closed water-bodies, cut off from old river channels in the delta of the Ganges.

2. METHODS

This review was undertaken using secondary information from different sources and supplemented, wherever possible, with primary information obtained through farm visits and interviewing of appropriate stakeholders. The primary stakeholders that were interviewed included operators of finfish hatcheries and nurseries, grow-out farmers, operators of shrimp[3] and prawn hatcheries, nurseries and grow-out farmers, fish feed millers, aquafeed companies and feed dealers.

A brief overview of the areas from which the data was collected is presented below and the location of the areas is shown in Figure 2. Geographically, the country is divided into four regions, viz. Northeast, Northwest, Southeast and Southwest and administratively it is divided into 64 districts. The survey covered all four regions.

FIGURE 2
Map of Bangladesh showing the location (red dots) of the areas surveyed for the review

Source: HTTP://WWW.LIB.UTEXAS.EDU/MAPS/MIDDLE_EAST_AND_ASIA/BANGLADESH_POL96.JPG

Rangpur and Dinajpur – these two districts are located in the northwest region of Bangladesh. Aquaculture in these two districts is generally poorly developed, mainly due to the seasonal nature of the ponds. However, semi-intensive carp polyculture is rapidly developing in the area.

Bogra – is located in the northwest region of Bangladesh. This district is particularly well known for the pangas hatcheries that supply juveniles for grow-out to farmers throughout the country.

Mymensingh, Narshingdi and Comilla – located in the northeast region of Bangladesh, these districts have well-developed semi-intensive carp polyculture and rapidly growing intensive pond based pangas nursery and grow-out. Substantial quantities of industrial and farm-made feeds are used in these districts and there are several fish feed mills.

Noakhali and Laxmipur – located in the southeast region of Bangladesh. Semi-intensive carp polyculture is well developed here and there are several new prawn hatcheries and a number of feed mills. Prawn based semi-intensive carp polyculture in ponds and in seasonal lowland rice fields is developing rapidly in these districts. The potential for aquaculture expansion in these districts is high and prawns from where are now being exported.

Cox's bazaar – coastal district located in southeast Bangladesh. It has well developed shrimp hatcheries that supply post larval shrimp to other areas in the country for

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[3] Shrimp primarily refers to the black tiger shrimp, *Penaeus monodon* and includes other marine or brackish-water shrimp species. Prawn primarily refers to giant freshwater prawn, *Macrobrachium rosenbergii* and other freshwater prawn species.

grow-out. Shrimp farming is practised using extensive technologies in large ponds and 'ghers[4]'. There are several aquafeed mills in the district.

Sathkhira District – coastal district located in northwest Bangladesh with well-developed shrimp grow-out farms. Improved-extensive and semi-intensive technologies using industrial and farm-made feeds are employed. The culture of shrimp is carried out in 'and fish feed mills ghers' as an alternate to crop production.

3. AQUACULTURE PRACTICES AND FARMING SYSTEMS

Aquaculture in Bangladesh developed primarily with Indian major carps (*Labeo rohita*, *Catla catla* and *Cirrhinus cirrhosus)* using seed collected from the wild. The sector expanded rapidly with the development of hatchery technologies for Indian major carps and the introduction of exotic carps from China and Europe. Production systems were largely extensive, with limited use of pond inputs. Significant advances in pond management have been made in the last few decades, such that the current array of systems can be classified into three distinct categories, viz. improved-extensive, semi-intensive and intensive systems based on increasing pond inputs, levels of intensification and management (Table 4).

3.1 Semi-intensive polyculture of carps[5]

Semi-intensive systems are the most commonly used aquaculture production systems in the country. The improved availability of seed of various species as well as improved trading networks have enabled these systems to become successful over the last decade.

Overall, the use of feeds and fertilizers in ponds have increased. However, there is considerable variation among farmers with respect to the quantities used and the mode of application. One of the principal objectives of this review was to obtain a better understanding of these variations to develop appropriate strategies for the development of the sector. In particular, cognisance was taken of the high local demand for lower priced fish by poor rural communities. Both poor and marginal farmers practice semi-intensive aquaculture using small ponds or seasonal water bodies. Carp polyculture systems are largely dependent on primary and secondary production through the application of organic and inorganic fertilizers, though fish production can be improved through the application of effective fertilization strategies and supplementary feeding.

3.2 Semi-intensive prawn based carp polyculture

Prawn/carp polyculture has developed rapidly in different areas of the country. In particular this has been facilitated by the improved supply of post-larvae (PL) from newly established hatcheries. Until recently, the major source of prawn seed was from natural waters (Muir, 2003). Hatchery produced PLs fed with formulated industrial feeds in ponds provide healthy juveniles with higher survival rates, improved production and higher profit margins. Recently many low-lying areas have been converted into ponds for prawn and fish culture, particularly in Jessore, Noakhali and Laxmipur Districts. Due to the high price of prawns, their introduction into the carp pond production systems acts as an incentive to use supplementary feed as well as

[4] Ghers are specially designed ponds used mainly for the culture of shrimp and prawns. These have largely developed in the coastal areas of southwestern Bangladesh.

[5] 'Carps' as used in this review includes the Indian major carps (rohu, *Labeo rohita*; catla, *Catla catla*; mrigal *Cirrhinus cirrhosus*; orange-fin labeo, *Labeo calbasu*) and Chinese carps (silver carp, *Hypophthalmichtys molitrix*; grass carp, *Ctenopharyngodon idella*; bighead carp, *Aristichthys nobilis*). Carp polyculutre also includes species such as Java barb (*Barbonymus gonionotus*), common carp (*Cyprinus carpio*), mirror carp (*Cyprinus carpio var. specularis*), Nile tilapia (*Oreochromis niloticus*) and sutchi catfish (*Pangasius hypophthalmus*).

inorganic and organic fertilizers on a regular basis (DoF, 2005; Muir, 2003; Demaine, 2005; Field Survey, 2005).

3.3 Intensive culture of sutchi catfish (local name: Thai pangas), mono-sex Nile tilapia and Thai strain of climbing perch in ponds

The intensive culture of sutchi catfish (*Pangasius hypophthalmus*) (local name: Thai pangas) and more recently, the production of monosex Nile tilapia (*Oreochromis niloticus*) and the Thai strain of climbing perch (*Anabas testudineus*) have developed rapidly, particularly in peri-urban areas in Mymensigh, Narshindi District close to the capital city Dhaka and in the Bogra District. As elsewhere, intensive finfish farming is dependent on a reliable and adequate source of appropriate feeds. Farmers use formulated pellets, manufactured in their own or local cooperative feed mills or purchased from the commercial aquafeed industry. The market price of Thai pangas is lower than Nile tilapia or climbing perch and hence is an affordable protein source for marginal and poor urban people. However, as large amounts of relatively expensive feeds are used the profit margins are lower. This has resulted in a shift towards the production of high-value fish such as mono-sex Nile tilapia, Thai strain of climbing perch and walking catfish (*Clarias batrachus*) (Muir, 2003, Field Survey, 2005).

3.4 Extensive and improved-extensive shrimp culture

The major shrimp culture activities are located in the southeast and northwest regions of Bangladesh (Cox's bazaar, Sathkhira, Bagerhat, and Khulna) and PLs are obtained mainly from hatcheries. Shrimp farming systems in Bangladesh can be generally classified as extensive, in which the shrimp are reared under low-level input conditions and farmers rely mainly on natural pond productivity. The level of production is consequently very low. In recent years there has been a shift towards the greater use of fertilizers and industrial feeds in smaller ghers and these systems are now described as "improved-extensive systems" (Table 5).

The reliable production of PLs in hatcheries now ensures a consistent and adequate supply of seed for the entire production period of around 8 to 9 months. Farmers use

TABLE 4
Characteristics of the different farming systems for carp, prawn and pangas, 2005

Descriptions	Carp polyculture		Prawn culture	Pangas culture
System	Improved-extensive and semi-intensive		Semi-intensive	Intensive
Species	Indian major carps, Chinese carps and common carp	Indian major carps, Chinese carps, common carp, Java barb, tilapia and Thai pangas	Indian major carps, Chinese carps and prawn	Thai pangas, carps and Nile tilapia
Average farm size (ha)	0.05–2.0	0.05–2.0	0.12–0.58	0.97–2.02
Culture period (months)	5–12	5–12	5–8	6–10
Yield (tonnes/ha)	2.0–2.5	2.0–3.0	2.8–3.0	12.0–15.0
Stocking density (per ha)	12 000–15 000	15 000–20 000	10 000–12 000	25 000–30 000
Species ratio	Major carps - 40% Chinese and common carp - 60%	Major carps - 30% Chinese carp, common carp, Java barb - 40% tilapia - 10% pangas - 20%	Major carps - 30% Chinese carps - 40% prawn - 30%	Pangas - 90% tilapia - 10%
Types of feed used with major ingredients	Mixed feed (RB, MOC, WB)	Mixed and pellet feeds (RB, MOC, WB)	Mixed and pellet feeds (RB, MOC, WB, FM, BM)	Pellet feed (RB, MOC, WB, FM, BM vitamins, minerals)
Types of fertilizers used	Cow dung, urea, TSP and lime	Cow dung, urea, TSP and lime	Cow dung, urea, TSP and lime	Lime

Note: RB – rice bran, MOC – mustard oilcake, WB – wheat bran, FM – fishmeal and BM – bone meal

Source: Field Survey (2005)

TABLE 5
Characteristics of the different types of shrimp culture systems, 2002

Description	Extensive	Improved-extensive	Semi Intensive
Potential area (ha)	100 000	55 000	15 000
Shrimp yield (kg/ha/year)	200–400	400–800	1500–3000
Farm size (ha)	>5.0	1.0–5.0	0.5–1.0
Stocking density (PL/m^2)	2–4	5–8	8–15
Culture period (days)	100–120	100–120	100–120
Survival rate (percent)	40–50	50–60	60–70
Average harvest size (g)	35	30	25
Average price (BDT/kg)	350	350	300
Water exchange (time/year)	1	2	3
Expenses (BDT/ha/year)			
Land rent	15 000	20 000	30 000
Pond preparation	5 000	8 000	20 000
Fry	15 000	32 500	57 500
Lime	3 000	5 000	10 000
Fertilizer	100	200	400

US$1.00 = BDT 57.00 [6] (2003 average exchange rate)

Source: Muir (2003)

multiple stocking strategies, under which PLs are stocked at 15–30 day intervals. A recent study by Muir (2003) suggests that improved organic and inorganic fertilization strategies in these smaller systems can lead to a reduction in the use of pelleted feeds.

Farmers have developed several strategies to reduce risk. The most important of these include the practices of multiple stocking and harvesting, stocking of larger juveniles after extensive nursing of PLs and the combined production of shrimp with prawns and carp at low salinity levels. The reduction in risk exposure has encouraged intensification using feeds and fertilizers and has led to an improvement in overall production.

4. FEEDS AND FERTILIZERS USE IN AQUACULTURE

4.1 Organic fertilizers

Cattle and buffalo manure is commonly used as a source of nutrients for fishponds in rural areas of Bangladesh, though the bulk is used for crop farming. The 8.44 million households in the country have a combined total of some 22.29 million cattle and buffalo (BCA, 1996 cited in BBS, 2004). Rural households also rear goats, sheep, chickens and ducks, though the collection of manure from these animals for use as fertilizer is not a viable proposition. On a limited scale, the recent establishment of industrial scale chicken farming provides an opportunity for commercial farmers to purchase and use chicken manure in ponds. The use of biogas as a source of household energy by better-off households with relatively large numbers of livestock is also increasing. The slurry from these biogas plants may also be a good nutrient source for fishponds. A limited number of farmers use compost in fishponds, which is made using crop by-products such as water hyacinth, rice straw, urea (5–10 percent of total compost amount) and lime (2–5 percent). There is considerable potential to increase the production and use of compost in fishponds, though this would require training and raising the level of awareness of the value of compost for pond fertilization.

A recent survey in Mymensingh District revealed that 63 percent of farmers use cow dung, and only 20 percent use compost as pond nutrient inputs. The average application rate was 6.7±6.5 tonnes per ha per year (Karim, 2006). It is well known that the nutrient content of cow and buffalo dung is lower than that of poultry manure and compost (Table 6). However, bovine manure is cheaper and more readily available

[6] Conversion rate of US$ and BDT was for the time when the data were collected. The present conversion rate is US$1.00 = BDT 68.00)

TABLE 6
Nutrient content of different organic manures and their price (BDT/kg, 2005)

Manure	Nutrient content (%)					Price
	Moisture	Nitrogen	Phosphorus	Potassium	Sulphur	
Cow dung (fresh)	60.0	0.50	0.15	0.50	-	0.50
Cow dung (decomposed)	35.0	1.20	1.00	1.60	0.13	0.60
Poultry manure	55.0	1.90	0.56	0.75	1.10	2.00
Compost	40.0	0.75	0.60	1.00	-	2.50

US$1.00 = BDT 65.00

Source: BARC (2005) and Field Survey (2005)

to farmers than chicken litter or compost. For this reason, the promotion of the use of cow and buffalo dung for semi-intensive aquaculture throughout the country has a greater prospect for adoption.

Several different techniques are used to enhance natural productivity in nursery ponds. Farmers who do not have access to adequate quantities of animal manure rely on the decomposition of natural and / or supplementary vegetation in newly inundated ponds to provide organic nutrients for plankton production. Some nursery owners apply mustard oilseed cake to the ponds a few days before stocking to achieve the same effect. The application of manure and slaughterhouse waste to enhance natural productivity of nursery ponds (Field Survey, 2005) is strongly promoted. Mustard oilseed cake and rice or wheat bran are commonly used feeds for fish fry. The non-ingested proportion of the feed also serves as a nutrient source for primary and secondary production.

4.2 Non-conventional organic nutrient sources

a) Solid biodegradable organic waste from urban areas

This includes unused parts of vegetables, fruits, fish, meat, kitchen waste from households, markets, hospitals, restaurants, canteens, food processing plants (both in small towns and in large cities). In most instances this valuable and nutrient rich material is dumped, hence creates unhygienic conditions. Some of this waste could be used effectively and profitably for fish production in peri-urban areas as a source of nutrients as well as supplementary feed. Regular collection and "disposal" of waste in fish ponds would contribute towards maintaining sanitary conditions in urban areas. In order for this to be effectively implemented the awareness would need to be raised among fish farmers, local authorities and the appropriate central government departments.

b) Sewerage waste from urban areas

Urban and peri-urban aquaculture is rapidly developing in many countries and has been stimulated principally by the proximity to markets, access to information and the availability of wastes (Little and Bunting, 2005). Large volumes of sewerage are disposed via drainage canals or accumulate in low land ditches, creating substantial health problems for urban dwellers during the monsoon season when it mixes with run-off water and enters into urban dwellings with floodwater. The problem is severe in large cities and is becoming more and more of a crisis in smaller cities throughout the country. Human waste from urban areas is disposed mainly into rivers and canals via sewerage canals, resulting in the pollution of natural waterways. This neither is a solution to the problem nor is it an acceptable environmental practise. The potential exists to 'harvest' this rich nutrient source for use in crop production and after initial treatment, for fish production (Bunting, Kundu and Mukherjee, 2005; Costa-Pierce *et al.*, 2005). There are some examples of sewerage fed water bodies in urban areas used for the culture of tilapia in Bangladesh. However, these are unplanned and may pose health hazards to workers and consumers (Barman, Little and Janssen, 2003). There is a need for scientific bodies and appropriate government departments to assess the potential of sewerage fed aquaculture and, if feasible, to draw up guidelines for the safe use of human waste in aquaculture.

4.3 Inorganic fertilizers

Nitrogen and phosphorous in the form of inorganic fertilizer are applied to fishponds to stimulate algal growth to increase zooplankton production. Farmers are aware of the benefits of using inorganic fertilizers such as urea, TSP and others. However, despite government subsidies, the use of inorganic fertilizers in aquaculture is limited by its price (Barman, Little and Edwards, 2002; Thompson, Sultana and Firoz Khan, 2005).

The national demand for inorganic fertilizers is estimated by the requirements for crop production. The estimated amount of urea and TSP used by aquaculture is less than 5 percent of national use and hence the requirement of the sector is not considered (Table 7).

Farmers who are intensifying their aquaculture operations are encouraged to use inorganic fertilizers in combination with organic manures and supplementary feeds regularly. However, with experience, further intensification does not necessarily require additional inorganic fertilization. Instead, production can be increased through the application of pig manure as in Viet Nam (Barman, 2005) or through integration with ducks and pigs as in NE Thailand (Edwards and Alan, 2001).

Lime is used to improve water quality and to increase productivity. The present field survey showed that farmers use lime during pond preparation and as a disinfectant prior to the winter months to prevent disease. Farmers who practise intensive pangas aquaculture apply small quantities of lime to their ponds on a monthly basis to improve water quality. Similarly, prawn farmers lime ponds prior to stocking, and at regular intervals thereafter, to facilitate moulting (DoF, 2005, Field Survey, 2005). Several types of lime are available in the market for use in aquaculture and are affordable to the farmers.

Despite the excellent nutrient composition of poultry manure, Banerjee *et al.* (1979) and Knud-Hansen (1998) showed that 1 kg of urea and 1 kg of TSP together contain an amount of available nitrogen and phosphorus equivalent to about 100 kg of chicken manure. In addition, it is a more cost effective source of nutrients (Knud-Hansen and Pautong, 1993). Nevertheless, it remains extremely difficult to convince farmers of the benefits of using inorganic fertilizers.

The increased and improved use of different nutrient inputs in semi-intensive aquaculture systems has almost doubled fish production compared with conventional (improved-extensive) carp polyculture systems (Table 8).

Fish production under semi-intensive culture practices can be improved further by (a) increasing awareness of the effective use of on-farm organic nutrients instead of more expensive off-farm nutrients and feeds; (b) improving the methods of manure and inorganic fertilizer application; (c) increasing the efficiency of the nutrients through improvements of the culture environment and (d) developing strategies and systems to harvest and use nutrients from non-conventional sources such as ‘urban organic solid waste’ and ‘sewerage waste’, in a planned manner, for sustainable development of aquaculture.

TABLE 7
Current use, domestic production and inorganic fertilizers imports in 2005–06 (thousand tonnes)

Fertilizer	Use	Domestic production	Imports
Urea	2 875	2 000	875
Triple super phosphate	585	200	385
Single super phosphate	125		125
Di-ammonium phosphate	550	250	300
Gypsum	150		150
NPKS*	117		117
Zinc	30		30

*Mixed fertilizer containing nitrogen, phosphorus, potassium and sulfur

Source: Tofazzal Mia, Deputy Director, pers. comm., DAE[7], Dhaka, Bangladesh

[7] Department of Agricultural Extension, Ministry of Agriculture, Government of Bangladesh

TABLE 8
Use of inputs (tonnes/ha/year) and comparative fish production data in two different culture systems in Mymensigh district, 2005

Production systems	Feed			Organic fertilizer		Inorganic fertilizer			Fish production (tonnes/ha/year)
	Rice bran	Wheat bran	Mustard oil cake	Cow dung	Poultry litter	Lime	TSP	Urea	
Improved-extensive (n=24)	6.83 (5.41)	0.12 (0.37)	0.99 (1.41)	6.55 (5.94)	0.64 (1.21)	0.08 (0.12)	0.04 (0.09)	0.03 (0.03)	2.99 (1.47)
Semi-intensive (n=23)	9.36 (5.29)	0.30 (0.73)	3.2 (1.86)	6.37 (6.58)	1.26 (2.35)	0.14 (0.16)	0.27 (0.25)	0.62 (0.30)	5.83 (1.91)

n= number of farmers; figures in parentheses are standard deviations

Source: Karim (2006)

In the context of the limited availability of feeds, the use of inorganic and organic fertilizers together with supplementary feeding offers the best opportunity to increase total fish production by the large number of small-scale farmers practising semi-intensive carp polyculture. It is, therefore, important for institutions to focus on the improvement of semi-intensive fish culture systems in Bangladesh.

5. FEED INGREDIENTS AND FEEDS

5.1 Cereal products and by-products

A variety of cereals and cereal by-products are either used, singly or mixed, for the feeding of fish in ponds. The most commonly used feed in Bangladesh is rice bran, a by-product of the principal cereal crop of the country. Three common types of rice are grown in Bangladesh, viz. "Boro", "Aus" and "Amon". Boro-irrigated rice is grown in the dry season and harvested before the monsoon (February to April). Aus is grown in the dry season from May to August, while Amon rice is grown during the monsoon season from September to January. Production of Aus is limited compared to other two types. The three types of rice provide a year round supply of bran. National rice production figures from 1997 and 2001 are given in Table 9.

Rice bran comprises five percent of the total rice yield. It is used mainly as feed for cattle and buffalo and is an important ingredient in fish feeds. The nutrient quality and price of rice bran varies depending on its fineness. The bran produced in automated rice mills is finer and has a higher available nutrient content in comparison with bran produced in rural husking mills. Coarse brans are about a quarter of the price of the finer bran. The quality of the bran depends on freshness, storage conditions and duration of storage and because it is a by-product millers normally take less care during collection and storage.

The proximal composition of rice bran varies greatly and depends on the milling process and original quality. Crude protein levels range from 9.8 to 17.2 percent, crude lipid (7.7–22.4 percent), crude fibre (5.7–20.9 percent), ash (7.1–20.6 percent) and nitrogen free extract (40–41 percent). Rice bran is a good supplementary feed and its high calorific value has a protein sparing effect (Xin, 1989). Fish fed on rice bran usually have a high fat content, which is desirable from a human nutrition perspective, as rural, rice-based diets in Asia are typically low in fat (Xin, 1989).

TABLE 9
Production of different types of rice by year in Bangladesh (thousand tonnes), 1997–2001

Year	*Amon* rice	*Aus* rice	*Boro* rice	Total production
1997–1998	8 850	1 875	8 137	18 861
1998–1999	7 736	1 617	10 552	19 905
1999–2000	10 306	1 734	11 027	23 067
2000–2001	11 249	1 916	11 921	25 086

Source: BBS (2004)

Considering the importance of rice bran in animal feeds, or as a single feed, it is important to maintain its quality during production, transportation and storage. Broken rice is also produced as a by-product in rice mills and is used mainly as feed for poultry but also as an ingredient in fish feed.

In recent years the production of maize has increased several fold from 3 000 tonnes in 1997–98 to 64 000 tonnes in 2001–2002 (BBS, 2004). In comparison to rice and wheat, the demand for maize for direct human consumption is low. As a result, there is more scope to use maize for animal feeds, particularly for poultry. The use of maize as an ingredient in fish feed has increased in recent times especially for feeding carp broodfish and during grow-out. It is also used as an ingredient for the manufacture of pelleted feeds for pangas, at inclusion rate varying between 10 to 15 percent by weight. To reduce the cost of fish feeds farmers are inclined to mill their own maize flour for inclusion into feeds rather than purchasing it (Field Survey, 2005).

The production of wheat in 2000–2001 was 1.673 million tonnes. Wheat flour is used mainly for human consumption, though some portion (normally of inferior quality) is used as an ingredient in pelleted fish feed. Wheat flour in small proportions is also used as a feed for fish fry shortly after they are stocked into nursery ponds. The granular form of wheat flour (*suzi*) is used as a feed for prawn PLs a few days after stocking into nursery ponds. Wheat bran is also used a fish feed ingredient.

5.2 Oilseed by-products

Oilseed cakes are important ingredients in fish feeds. Some 376 000 tonnes of various oilseed cakes were produced in 2001–02. The most important seed cakes used in fish feeds are rape and mustard oilseed cake, while groundnut, sesame and coconut seedcake are less commonly used. Rape and mustard accounted for 62 percent, while coconut comprised 23 percent, groundnut 8 percent, sesame sux percent and linseed less than one percent to total fish feed production in Bangladesh. The nutritive composition of the different types of oilseed cake is presented in Table 10.

The results of the field survey suggest that there is a reduction in the use of oilseed cake as a single feed by fish farmers. More often, farmers are now using a combination of ingredients (mustard oilcake, rice bran, wheat bran, maize bran and powder, bone meal, fishmeal, minerals, snail shell powder, vitamins). Pangas and prawn farmers are achieving higher yields using mixed feeds (Field Survey, 2005; Muir, 2003). However, with the expansion of aquaculture activities and the rapid development of intensive culture systems for pangas, tilapia and climbing perch, the overall demand for oilseed cake in Bangladesh is increasing. Maintenance of oilseed cake quality during production and storage is also important for its effective use.

5.3 Pulse powder and by-products as fish feed

Other than for direct use in human nutrition, powdered pulses and by-products (bran) are largely used as livestock feed. Use of pulse powder (*basan*) in small proportions in formulated pellets for Pangas has been reported. However, the scope for the use of pulses is limited as the traditional production areas are now used for the cultivation of rice and other crops.

5.4 Weeds/grasses and plant by-products as fish feed

Duckweed is commonly used as feed for Java barb and grass carp, which grows prolifically in low land rice fields, mainly during the monsoon season, coinciding with the fish production period. The collection of duckweed is labour-intensive. In Jessore, poor people collect duckweed for sale to fish farmers (Field Survey, 2005). Generally, it grows faster in ditches or small derelict water bodies that are connected to household drainage systems where there is a good supply of nutrients.

Grasses in wetland areas are used as a source of feed for grass carp, as are banana leaves (BBS, 2004). Water hyacinth is a common aquatic weed but its use as a fish feed is limited, due to its poor palatability. By-products of vegetables such as unused leaves of cabbage and radish could be used as fish feed but the production of these vegetables largely takes place during winter months when fish require less feed. However, the development of early variety of cabbage has the potential to be used as an input in fish feed due to its high production volumes, extended seasonal availability and low price.

5.5 Fish feed from animal sources

5.5.1 Fishmeal

Fishmeal in Bangladesh is made from trash fish and other marine aquatic animals. However, it is important for the authorities to recognise the importance of this fish for direct human consumption, instead of reducing it for the production of animal feeds.

Fish feed millers generally use industrial fishmeal, though some purchase trash fish and other by-catch species for the manufacture of their own fishmeal. The Bangladesh Fisheries Development Corporation (BFDC) has four fishmeal production plants with a capacity to produce eight tonnes/day (Murtuza, 1998). Industrial fishmeal contains around 56 percent protein, 20 percent lipid and 2 percent crude fibre (Table 8). The amount of trash fish used in aquaculture in Bangladesh ranges between 5 000 and 70 000 tonnes/year (NACA/FAO, 2004).

Dried fish is more readily available at the coast than in inland areas. A more equitable distribution of fishmeal to facilitate the manufacture of animal and fish feeds was addressed by a Danida (Danish International Development Assistance) supported project. The project provided transportation facilities for the movement of dried fish, which due to its smell is normally not permitted on public transport. This created a win-win situation whereby the feed producers had access to good quality dried fish, while the producer received a better price by selling their dried product directly to the users instead of an intermediary. By linking the local feed factories directly with the producers of dry fish enabled the factory to provide quality feeds at a competitive and affordable price for the farmers (Harvey, 2005).

5.5.2 Bone and meat meal

The use of bone and meat meals in fish feed has recently increased as an alternative to fishmeal. Large, though unspecified, quantities of bone and meat meal are now imported from several countries such as Croatia, Denmark and Belgium. The protein content of meat meal and bone meal ranged from 40–55 percent (Field Survey, 2006).

5.5.3 Other sources of animal protein as feed ingredients

Alternative animal sources include shrimp meal, blood meal and silkworm pupae. However, the availability of these resources is limited such that their possible use in fish feeds is at best marginal. For example, shrimp heads are used directly for human consumption.

6. FEEDING PRACTICES IN RELATION TO FARMING SYSTEMS AND SPECIES, FARM-MADE FEEDS AND NUTRIENT MANAGEMENT STRATEGIES

6.1 Carps

Broodstock feeds

Two to three months prior to breeding, carp broodstock are fed a mixed, high protein feed. The composition of the feed is variable but normally consists of mustard oilcake (40 percent), rice bran/rice polish (20 percent), wheat bran (30 percent), fishmeal (9 percent) and vitamin premix 1 percent at 2 percent body weight per day. Other ingredients that may be incorporated into the broodstock maturation diet include molasses, corn flour, meat and bone meal, and fishmeal (Field Survey, 2005). Feed is delivered as 'wet balls' placed in one or two specific places within the pond. To increase the availability of natural feed cow dung at 250 kg/ha, urea at 50 kg/ha and TSP at 25 kg/ha are applied after mixing with water.

Larval feeds

Feeding of carp larvae starts after yolk sac absorption (32–48 hours after hatching depending on temperature). The larvae are commonly fed on hardboiled chicken or duck egg yolk. Two egg yolks suffice for 0.4–0.5 million larvae. The egg yolk is mixed with water, spread over the rearing tanks, and applied four times daily at six hourly intervals until 4–5 days after hatching, after which they are offered for sale. Zooplankton (rotifers and cladocerans) are the main natural food items of the larvae in nursery ponds. To enhance zooplankton production farmers fertilise their ponds in various ways. The most commonly applied fertilizers are cow dung, urea and TSP at variable rates (Saha *et al.*, 1989, Miah *et al.*, 1996), depending on availability. Goat litter and fermented / decomposed mustard oilseed cake can also be applied prior to stocking. It is generally recommended that the litter of one goat is adequate for 40m^2 pond surface area or 85 kg/ha of decomposed oilseed cake.

TABLE 10
Chemical composition (percent dry matter) of major feed ingredients in Bangladesh

Ingredients	Dry matter	Crude protein	Crude lipid	Ash	Crude fibre	NFE[1]	Gross energy (kcal/kg)
Feed ingredients of animal origin							
Fishmeal	91.8	56.4	19.7	19.5	2.2	2.2	4 365
Fish silage	90.1	56.8	7.5	12.2	6.5	17.0	5 432
Blood meal	90.8	92.9	0.3	6.3	0.5	-	4 250
Silkworm pupae meal	91.2	61.1	24.8	6.7	4.3	3.2	5 939
Poultry offal meal	89.8	75.5	16.3	7.3	1.0	-	
Bone meal	92.5	17.5	5.2	65.7	3.5	8.1	1 988
Meat and bone meal[2]	90.9	55.6	12.34	29.7	NA[3]	-	
Protein concentrate[4]	91.6	61.0	11.5	18.1	NA	-	
Feed ingredients of plant origin							
Soybean meal	91.4	45.2	20.5	6.2	5.0	23.1	
Sesame meal	92.0	33.3	8.4	14.9	24.0	19.5	4 743
Mustard oil cake	93.0	36.5	11.2	9.2	11.6	31.5	4 978
Linseed meal	90.9	39.0	6.7	12.8	9.1	32.5	4 386
Coconut oil cake	95.5	18.2	10.2	6.5	11.7	53.5	4 723
Cotton seed meal	87.6	35.7	17.1	6.1	18.3	22.8	
Cotton seed oil cake	90.9	22.7	6.2	11.7	29.9	29.5	
Rice	87.4	8.4	2.1	1.0	1.6	86.9	
Rejected broken rice	86.6	10.6	2.1	2.2	3.1	82.1	
Rice bran	90.0	12.6	16.5	13.6	16.3	40.9	4 235
Wheat bran	88.5	18.2	4.4	4.8	14.0	58.6	4 488
Wheat flour	93.2	12.5	1.3	2.1	2.1	75.6	4 488
Broken maize	87.9	11.3	5.0	2.5	2.8	78.4	
Lentil bran	84.3	19.5	0.5	7.3	25.9	46.9	4 286
Black gram bean meal	12.9	18.8	0.6	7.5	22.8	50.5	4 252
Mung bean bran (green gram)	87.9	8.1	2.9	10.6	37.5	41.0	
Grass pea bran	87.5	11.0	1.8	8.1	38.8	40.4	
Black gram bran	87.5	17.9	2.4	7.4	24.3	48.0	
Field pea bran	89.2	11.4	1.0	5.8	39.6	42.3	
Leucaena meal (unsoaked)	90.0	27.2	6.3	6.6	19.4	40.5	
Leucaena meal (soaked)[5]	90.2	29.6	5.3	4.4	18.8	41.9	
Water hyacinth leaf meal	94.3	25.6	1.1	11.7	17.2	44.4	4 031
Duck weed meal	94.9	17.6	1.4	38.1	8.1	34.8	3 969
Molasses	31.7	4.5	0	11.9	0	83.6	3 624

[1]NFE = Nitrogen free extract; [2]imported, country of origin Australia; [3]NA = not analyzed; [4]imported, country of orgin USA;
[5]leucaena leaves were soaked in water at ambient temperature (25–28^{0}C) for 48 hours to reduce the mimosine content of the leaf

Source: Hasan, Alam and Islam (1989); Zaher and Mazid (1994); Hasan, Roy and Akand (1994); Hossain (1996); Faruque (2006)

TABLE 11
Feeds used in carp nursery ponds, 2005

Type of feed	Duration (days)	Amount of feed (x weight of hatchlings stocked)	Frequency of feed use (no./day)
Wheat flour	3	3*	3
Wheat flour and mustard oilcake**	4	4	2
Mustard oilcake and rice bran	7	5–7	2
Mustard oilcake, rice bran/wheat bran	7	8–10	2

*Amount of feed used = 3 times the weight of the hatchlings stocked, **Ratio of ingredients in all feed mixtures are usually 1:1.

Source: Field Survey (2005)

Nursery management

To improve survival and growth, carp nursery ponds are limed (250 kg/ha) and fertilised (cow dung 5 – 7 tonnes/ha, urea 50 kg/ha and TSP 25 kg/ha) prior to the introduction of early juvenile fish. An insecticide (sumithion or dipterex) is also applied 16–24 hours before stocking to remove insects and larger zooplankton that may predate on the larvae. After stocking, the larvae are fed at regular intervals for 3 weeks until the late juvenile stage (Field Survey, 2005) (Table 11).

At the end of the three-week nursery period, the fry are transferred to separate ponds at a lower density (thinning out) and grown to fingerlings for sale. During this period, they are normally fed a diet consisting of mustard oilcake (50 percent) and rice bran/wheat bran (50 percent) at a rate of 10–12 percent of body weight per day and fed twice daily. In addition, inorganic and organic fertilizers such as cow dung 275–500 kg/ha, urea 8.5 kg/ha and TSP 5.0–6.2 kg/ha are applied at weekly intervals. Before application, cow dung and TSP are soaked in water overnight. Urea is then added and the mixture is applied to the pond before noon.

Carp grow-out systems

Carp grow-out is practised either under “improved-extensive” (in flooded rice fields or oxbow lakes) or under semi-intensive culture conditions in ponds. In the semi-intensive systems, feeds are used to supplement natural food to achieve higher yields. Generally, several carp species are farmed under polyculture conditions and this has been strongly promoted throughout the country. Semi-intensive polyculture of carp has yielded good results in communal ponds where the water is used for various purposes, particularly in rural areas of Bangladesh (ADB, 2005). Studies in the districts of Kapasia and Sreepur revealed that the average level of pond inputs were similar to those recommended by the extension services with the exception of lime, which many did not apply before stocking. The majority of pond owners use cow dung from their own sources and about 50 percent of farmers used urea. Rice bran is used as a supplementary feed by most farmers and is purchased from the local market. Where affordable, farmers also use mustard oilseed cake (Thompson, Sultana and Firoz Khan 2005).

Several feeding methods are used by farmers in rural areas. Farmers will either feed their fish on a daily basis by spreading the feed over the surface, while others fill perforated bags with a mixture of mustard oilseed cake, wheat bran and auto rice bran[8]. These are suspended in the water using bamboo poles for 7–10 days rather than applying feed on a daily basis. Alternatively, ingredients such as mustard oilseed cake (50 percent) and rice/wheat bran (50 percent) are mixed and kneaded into wet dough and fed to the fish every 3 to 4 days at a rate of 2–3 percent of body mass twice per day, in the morning and evening. Most of the more entrepreneurial farmers use semi-

[8] Rice bran produced from automatic rice mill. These rice brans are finely milled and have a better nutrient content.

TABLE 12
Feed and fertilizer use, production and income of entrepreneurial carp polyculture farmers in different areas in Bangladesh, 2005

Categories/types	Specifications
Pond area (ha) (mean± SD)	2.1±2.0
Species (polyculture)	Indian major carps, Chinese carps, Java barb, common carp and pangas.
Fertilizers	Lime, cow dung, urea, TSP
Feed ingredients (proportion in the feed)	Rice bran 20–50%, oilcake 25–70%, maize 10–50% and wheat bran 10–50%
Feed ingredients used (% of respondent)	Rice bran 60%, oilcake 100%, maize 65%, wheat bran 20%
Feeding frequency (times per day)	Once (most common) Once every alternative day (rarely)
Amount of feed used per farmer (kg/day)	10–35
Culture period (months)	5–12
Total feed use (tonnes) (mean ± SD)	3.2±2.1
Total expenditure for feed (BDT) (mean ± SD)	35 000±17 000
Price of feed (BDT/kg)	7.00–10.00
Total fish production (tonnes) (mean ± SD)	6.2±5.8
Yield of fish (tonnes/ha) (mean ± SD)	3.6±1.1
Price of fish (BDT/kg)	38.00–55.00
Total income per farmer (BDT/year)	90 000–1 200 000

SD = standard deviation; US$1.00 = BDT 65.00
Source: Field Survey (2005).

intensive systems of production with higher levels of organic and inorganic fertilization and supplementary feeding. Their yield and income is significantly higher than that of the average farmer (cf. Tables 4 and 12).

6.2 Pangas

Hatchery and nursery

Pangas hatcheries are located mainly in the Bogra District in northern Bangladesh. Pangas fry and fingerling production has developed into a major activity in this area at the expense of carp hatcheries. This change has been brought about mainly by the higher price for pangas seed and improved transport and communication infrastructure. Pond area of pangas hatcheries ranges from 0.2–6.2 ha, while the total amount of feeds used for the management of broodfish varies from 5–40 tonnes per annum per farm. Feed expenditure amounts to between 60 and 70 percent of total hatchery expenditure. The hatcheries produce up to 20 million pangas hatchlings per season. Some of the hatcheries also produce hybrid catfish seed. There have also been substantial advances in pangas broodstock management. Instead of only using mustard oilseed cake and bran, farmers now use mixed feeds containing up to 11 different ingredients (Table 13). This has resulted in improved seed quality and survival (Field Survey, 2005).

TABLE 13
Composition of pangas broodstock feed in Bogra District, 2005

Ingredients	Proportion in feed mixture (%)		Price (BDT/kg)
	Minimum	Maximum	
Rice bran	30	91	11.0
Mustard oilcake	1	10	12.0
Corn flour	3	10	11.0
Broken rice	0	10	7.5
Pulse flour	0	5	40.0
Wheat bran	4	10	12.0
Fishmeal	2	10	32.0
Bone meal	2	5	10.0
Salt	0	3	10.0

US$1.00=BDT 65.00
Source: Field Survey (2005)

Pangas larvae and early juveniles are reared in aluminium trays on mixed feeds using ingredients such as egg yolk, wheat flour, pulse powder, refined dried fish powder and vitamin premix. Some hatcheries also feed the larvae on a paste consisting of rotifers, egg yolk and fresh fish, at two hour intervals (Field Survey, 2005). For the first 15 days after stocking the early juveniles are fed on wheat flour mixed with eggs and then on mixed feeds (rice bran, boiled broken rice, corn flour, wheat flour, mustard oilcake and vitamin premix). Only some farmers use commercial pelleted feeds for fry nursing. Pangas fingerlings in the Bogra district are sold when they are 2 to 3 cm in length. Farmers purchase seed directly from the hatcheries, generally in large numbers of at least 0.2–0.3 million at a time and stock them in their own nursery ponds before transferring them to grow-out ponds. Purchasing seed of this size reduces transport stress and mortality. In the (secondary) nursery ponds they are fed either on commercial pelleted feeds or farm-made, mixed, non-pelleted feed.

Pangas grow-out systems

The grow-out of pangas is mainly pond based. Fingerlings are stocked at between 25 000 and 75 000 fingerlings/ha. Grow-out periods range from 5–6 months to 8–10 months. For optimum feed utilization the fish are grown in polyculture with several carp species and Nile tilapia. This practise also increases production and income. Pangas production largely depends on the use of formulated pelleted feeds, though farm-made feeds are also used. Consequently, there are numerous local feed mills in the pangas farming areas. The reported annual yield in Mymensingh and Comilla districts is in the region of 27 tonnes of pangas, four tonnes of tilapia and one tonne of carps per ha/year. The ingredients used for pangas pelleted feeds vary widely between farmers and amongst industrial pellet manufacturers. Normally 7– 8 types of ingredients are used. Fine rice bran from industrial rice mills, mustard oilseed cake, wheat bran, fish, squid or crustacean meal and wheat flour are the major ingredients. In addition, maize flour, snail or mussels shell powder, bone or meat meal, vitamin and mineral premix are also used (Field Survey, 2005). Ration size, the types of feed, price, feeding frequency and food conversion ratio's are illustrated in Tables 14 and 15.

The market has responded positively in supplying the increasing demand for fish feed ingredients and compound feeds. Farmers are able to obtain several different ingredients directly from local markets or from feed millers. Some farmers use their own pellet making machines, while others, who do not own the necessary machinery, supply the ingredients to millers who prepare the feeds to their specifications (Figure 3). Farm-made feeds and feeds produced by local millers are cheaper than the industrially available feeds (Figure 4). However, many

TABLE 14

Pangas rations during the grow-out cycle in ponds in Trishal, Mymensingh, 2002

Size of fish (g/fish)	Ration (% body weight)
<100	15–20
100–150	10
151–500	5
>500	3

Source: Muir (2003)

TABLE 15

Feeds used in pangas grow-out in Mymensingh, Narshindi, Comilla and Dinajpur districts, 2005

Type of feed	Source	Price (BDT/kg)	Feeding frequency (no./day)	FCR
Commercial pellet feed	Commercial aquafeed industry	16–22	2	1.8–2.0
Commercial Pellet feed	Small local feed manufacturers	14.00	2	2.0–2.2
Pellet feed	Farm-made or made in rice mill facilities	12.00	2	2.0–2.5
Mixed non-pelleted feeds	Farm-made	5–10	2	-

US$1.00 = BDT 65.00

Source: Field Survey (2005)

FIGURE 3
Ground mixed feed ingredients ready for pelleting in a small pellet machine

COURTESY OF BIBHU BHUSAN MOJUMDAR

FIGURE 4
On-farm pelleted feeds ready to be applied to pangas ponds

COURTESY OF BIBHU BHUSAN MOJUMDAR

farmers are aware of the nutritional requirements of the fish such that fish production using farm-made feeds is often inferior to that achieved using industrial pellets. Semi-intensive pangas culture has also developed in areas outside of the traditional clustered pangas farming areas as in Mymensingh, Narshingdi, Tangail, Kishorgonj and Bogra districts. Farmers in these areas, e.g. Dinajpur and Comilla Districts use mainly farm-made feeds composed of various combinations of rice bran, maize powder, oilcake, boiled broken rice, biogas slurry and occasionally dry fish powder, vitamins and mineral premix. The price of feed varies between BDT 5.00–8.00/kg. Similar to their counterparts elsewhere, farmers in the more isolated pangas growing regions also use lime during pond preparation as well as urea and TSP at regular intervals. Production costs are lower in the more isolated areas than in the clustered areas, though production per unit area is lower at approximately 5 to 8 tonnes/ha/year.

6.3 Shrimp

Shrimp hatcheries and nurseries

The production of shrimp post-larvae (PL) in hatcheries is very successful and supply reportedly exceeds demand. It is important to note that most of the high cost feeds used for larval rearing is imported. Almost all hatcheries purchase brood shrimp from trawlers, varying in size from 60–150g and price from BDT 1500 to 2500 per piece. After capture, they are kept in broodstock rearing tanks for 5–7 days until the gonad maturation process is completed. During this period they are fed on mixed feeds consisting of crab muscle, cow liver, squid muscle and mussel meat as well as formulated feeds. Most of the hatcheries use algae, produced in their own facilities, to feed the larvae as well as other types of plankton purchased on the market. Various imported feeds, including *Artemia*, (Table 16) are used for PL rearing. Annual production of PLs varies from 100–300 million per hatchery.

TABLE 16
Feed used for final maturation of shrimp broodstock, larval and post-larval rearing in hatcheries at Cox's bazaar, 2005

Shrimp	Type of feeds	Price of feed (BDT/kg)	Amount and feeding frequency
Broodstock	Crab muscle, cow liver, squid muscle, mussel meat	Crab 40–45, Cow liver 120, squid 70–90 and mussel meat 40–45	10% of body weight of shrimp, applied 4 times/day
Larvae	Algae (diatom) and other commercial feeds	Algae from own source and *Spirulina* powder 3 000	6 times/day until post-larval stage
Post-larvae	*Artemia* nauplii 40%, brine shrimp flake and mixed feed 60 %	*Artemia* 3 500, brine shrimp flake 1 500 and mixed feed 400	15–16 days after reaching post-larval stage in nursing tanks

Source: Field Survey (2005)

There are no facilities dedicated solely to PL nursing. Nursing is carried out in small sections of the gher for a short period (PL $_{11–15}$). These are called pocket nurseries. PLs are stocked in the pocket nurseries for 4–7 days whereafter the outlet is opened and PLs are allowed to enter into the gher. The process of stocking PLs in the pocket nurseries and then transferring them to grow-out facilities is normally repeated at 15 day intervals and continued throughout the production season from February to September. Before stocking PLs into the pocket nurseries (≈ 0.04 ha), 500g bleaching powder, 4 kg lime, 2 kg urea and 1.5 kg TSP are applied. Within 5–6 days of urea and TSP application, the colour of the water becomes light green and is then ready for stocking of PLs. In the pocket nurseries formulated granular powdered feeds are used (e.g. Tiger brand feed of CP Feed Ltd.). The feed contains 42 percent protein, 8 percent lipid and 10 percent moisture. The amount of feed used is 200g for every 0.1 million PLs twice per day at 07.00 and 19.00 hours. The price of granular feed is around BDT 75.00/kg. The feed is moistened before use and applied by spreading it along the shallow ends of the nursery pond. Wheat flour was used previously even though mortalities often reached 50 percent. The use of formulated granular feed has significantly increased the survival rate of PLs.

Shrimp grow-out systems

Shrimp grow-out in large gher systems in both Cox's bazaar and Sathkira is an extensive operation and production depends almost entirely on fertilization and natural food, with a limited measure of supplementary feeding. Shrimp production in large gher's rarely exceeds 150 kg/ha. Previous studies on shrimp grow-out (Muir, 2003) also reported low levels of pond inputs. Sixty four percent of farmers applied small quantities of pre-stocking inputs and only 41 percent applied some form of post-stocking inputs, such as lime, urea, cow dung, rice/wheat bran, fishmeal and oil cake (Muir, 2003). The recent field survey confirmed these findings. Farmers who use small to medium size ghers have adapted their technologies to a semi-intensive scale of operation. The size of large ghers located in Cox's Bazaar and Sathkhira Districts vary between 32 and 138 ha. In this area shrimp culture is alternated with salt production and the culture period is 6–7 months. In Sathkhira, the ghers are used only for shrimp production. PL stocking densities vary from 0.7–3.1/m^2. The first harvest occurs 3 months after stocking, when the shrimp range in size form 100 to 65g (10–15 shrimp/kg). At such a size the price varies from BDT 400–600/kg and production varies from 63–150 kg/ha. Large ghers are generally prepared using lime at 31 kg/ha and cow dung at 250 kg/ha. Inorganic fertilizers such as urea (@ 2.5–5.0 kg/ha) and TSP (2.5 kg/ha) are diluted and spread throughout the gher area by boat and applied at one month intervals. Rice bran or wheat bran at 5–6 kg/ha is used as supplementary feed. The bran is soaked in water for 12 hours before it is applied in the evenings at 8 – 15 day intervals.

Small and medium ghers vary in size between 0.67 and 2.67 ha. They are used for monoculture of *P. monodon* or polyculture of shrimp in combination with *M. rosenbergii* and several carp species. Production is higher than in the large ghers and ranges from 500 to 1000 kg/ha under monoculture and polyculture conditions, respectively. Rice and wheat bran, mustard oilseed cake and commercial pellets are used as feed, though the amount and frequency of feeding varies greatly amongst farmers. All farmers with small and medium size ghers use organic and inorganic fertilizers, including cow dung, poultry droppings, urea and TSP to increase natural productivity. Lime, urea and TSP are used as pre- and post-stocking inputs (Table 17).

TABLE 17
Use of organic and inorganic fertilizers in small and medium size ghers per grow-out cycle, 2005

Input	Pre-stocking (kg/ha)	Post-stocking (kg/ha)
Lime	63–250	15–62
Urea	6–42	6–125
TSP	0–15	30–37
Cow dung	4 000	
Poultry dropping	1 250	

Source: Field Survey (2005)

6.4 Prawns

Hatcheries

Prawn hatchery operators use formulated granular feeds produced by local feed manufacturers for the production of post-larval *M. rosenbergii*. The prawn broodstock is stocked in separate ponds four months before use in the hatchery and are fed regularly with granular feeds at a rate of 6 percent body weight, twice a day. Feeding trays are used to check and adjust the amount of feed required. A proportion of feed is also applied outside the trays to ensure feeding of all prawns in the pond. To induce the broodstock to feed more, the granular feed is alternated with farm-made feeds for 1–2 days at 15–20 day intervals. These farm-made feed generally include auto rice bran (30 percent), wheat bran (10 percent), mustard oilseed cake (25 percent), fishmeal (30 percent) and molasses (5 percent).

Twelve hours after hatching the larvae are fed *Artemia* nauplii, at a rate of 25g Artemia per 200 000 larvae for the first 10 days, whereafter the feeding rate is doubled until day 30. The Artemia is supplemented with farm-made chicken or duck egg custard. After 30 days the PLs are ready for sale. The greater proportion of prawn PLs used in Bangladesh are however still collected from the wild, so there is great potential for the development of additional prawn hatcheries. However feed costs are high and this calls for the development of alternative cheaper feeds.

Nursing of post-larvae

Laxmipur and Noakhali Districts are the major prawn nursery areas. The duration of the nursery period ranges from 1–3 months and farmers normally use small (0.02 to 0.07 ha), shallow (90 – 100cm) ponds as nurseries, which are integrated with crop farming in one way or another. PLs are stocked at a density of 25–35 PLs/m^2. All nursery operators apply lime to their ponds as a pre- and post-stocking management strategy at 150–250 kg/ha and 13–150 kg/ha, respectively. Some also use cow dung at 250–800 kg/ha, urea at 13 kg/ha and TSP 13.0 kg/ha but only as pre-stocking inputs. During the nursery period the juvenile prawns are fed on a variety of feeds, such as wheat flour (local name: *suzi*), broken rice or mixed feeds (mustard oilcake, wheat bran, wheat flour and fishmeal) as well as farm-made pelleted or commercial feeds. Higher survival rates are obtained with the use of formulated pelleted feeds.

TABLE 18

Formulation (%) and price (BDT/kg) of low cost prawn diets

	Diet 1			Diet 2			Diet 3		
Ingredient	Inclusion (%)	% protein	Price (BDT/kg)	Inclusion (%)	% protein	Price (BDT/kg)	Inclusion (%)	% protein	Price (BDT/kg)
Fishmeal (local)	15	9.34	3.75	15	9.34	3.75	10	6.23	2.50
Meat and bone meal	-	-	-	8	4.09	1.52	5	2.55	0.95
Full-fat soybean	10	4.29	1.70	-	-	-	10	4.29	1.70
Mustard oilcake	15	5.65	2.10	15	5.65	2.10	14	5.27	1.96
Maize	15	1.45	1.65	15	1.45	1.65	20	1.93	2.20
Rice bran	25	1.98	2.13	27	2.14	2.30	12	0.95	1.02
Wheat bran	10	1.72	1.10	10	1.72	1.10	19	3.28	2.09
Wheat flour	5	0.64	0.75	5	0.64	0.75	5	0.64	0.75
Molasses	4	-	0.40	4	-	0.40	4	-	0.40
Salt/shell powder	1	-	0.10	1	-	0.10	1	-	0.10
Total	**100**	**25.06**	**13.68**	**100**	**25.02**	**13.67**	**100**	**25.13**	**13.67**

US$1.00 = BDT 65.00

Source: Hossain (2006)

TABLE 19
Calculated proximate composition and gross energy (kcal/100g) content of the three low-cost prawn diets (percent dry matter basis)

Components	Diet 1	Diet 2	Diet 3
Crude protein	25.1	25.0	25.1
Crude lipid	10.8	9.8	9.6
Carbohydrate	39.2	37.9	40.2
Gross energy (kcal/100g)	396	383	390
Price (BDT/kg)	13.7	13.7	13.7

Source: Hossain (2006)

Prawn grow-out

Prawn grow-out is generally undertaken in polyculture with several carp species (rohu, catla, mrigal, grass carp and Java barb) under improved-extensive and semi-intensive conditions. Farm-made pellets are normally used and these are made using mustard oilseed cake (20 percent), fine rice bran (20 percent), wheat flour (8 percent), dry fish powder (20 percent) and molasses (2 percent). The cost of on-farm pelleted feed is cheaper than commercially produced pelleted feed. The mixed non-pelletized feeds include rice bran, wheat and mustard oilseed cake in various proportions. Farmers are of the view that it is beneficial to use both pelleted and non-pelleted feeds. Only a small proportion of farmers use factory made pelleted feeds. The Danida supported project at Noakhali and Potuakhali in northern Bangladesh suggested that farmers use one of three formulations for the preparation of farm-made feeds (Table 18). The nutrient content of these feeds are tested at the Bangladesh Agricultural University Laboratory (Table 19). This is a good example of extending the practical role of an academic institution to meet farmer needs (Masum, 2005). Average production figures range between 575 and 1050 kg/ha for prawns and from 500 to 1 760 kg/ha for mixed fish.

Some farmers also use non-conventional feeds such as snail meat. However, the rapid expansion of prawn farming makes this practise unsustainable. For example, in Bagerhat the improved farm-made feeds has resulted in a significant decrease in the use of snail meat by 34 percent from 164 192 tonnes in 1998 to 22 774 tonnes in 2000 (Islam, 2001). There is a definite move towards the intensification of prawn grow-out systems. Most of the recently established farms are smaller (0.1 to 0.6 ha of pond area) and these are used on a seasonal basis (5–6 months of the year) and alternated with crop production. Farmers with perennial ponds generally extend the grow-out period for up to 10 months.

As a pre-stocking management strategy farmers apply lime at 125–250 kg/ha, cow dung and / or compost at 2–5 tonnes/ha. Lime is also applied two to three times during the production season at 50–100 kg/ha. Lime is applied by diluting it in water and spreading the liquid mixture over the water surface of the gher. Urea at 25 kg/ha and TSP 20 kg/ha are occasionally also applied at certain intervals as post-stocking inputs.

As mentioned above, prawn farmers who previously practised carp polyculture have increasingly adopted mixed prawn and fish culture. The underlying reason for this is the added benefit of prawns, which are exported. Overall, this has resulted in better managed systems, improved production and higher profit margins.

7. DEVELOPMENT OF THE AQUAFEED INDUSTRY

The increasing demand for formulated aquafeeds has resulted in the establishment of dedicated feed companies. This development is largely linked to the intensification of aquaculture in some areas of the country. Imported feeds from Europe, the United States of America, Japan and Taiwan Province of China are mainly those used in shrimp and prawn hatcheries. Mineral and vitamin premixes are also imported.

The aquafeed industry in Bangladesh has its origins in the poultry feed industry. Presently there are some 14 aquafeed manufacturers in the country (Kader, Hossain

FIGURE 5
Workers involved in making pellets in a small-scale fish feed mill at Narshindi Sadar, Narshindi, Bangladesh

COURTESY OF BIBHU BHUSAN MOJUMDAR

FIGURE 6
Common feed ingredients used for making pellet feed

COURTESY OF BIBHU BHUSAN MOJUMDAR

and Hasan, 2005); Field Survey, 2005). Most of the manufacturers are involved in the production and supply of feeds for finfish culture and principally for pangas farming, though some are now also producing feeds for shrimp and prawns. Six types of feeds are produced for shrimp (Nursery, Starter 1, Starter 2, Starter 3, Grower and Finisher) and seven different formulations are produced for pangas farming (Pre-nursery, Nursery, Starter 1, Starter 2, Starter 3, Grower 1 and Grower 2) (Field Survey, 2005).

The industry is currently unregulated with respect to quality assurance. However, policy guidelines are presently being developed by MOFL to regulate the industry so that feed quality can be assured (DoF, 2005). The significant differences between the factory quoted proximate composition of feeds and independent laboratory tests (Kader, Hossain and Hasan, 2005) emphasises the urgent need to develop a system for quality assurance for the greater benefit of farmers.

Coupled with the development of the commercial aquafeed industry there has been a marked increase in the production of compound farm-made feeds and a proliferation of small-scale feed mills in aquaculture intensive districts throughout the country (Figure 5).

Many of the small-scale feed millers simply provide a service by making pellets with ingredients supplied by the farmer. Dry fish, oilseed cake (mainly mustard but also sesame and soybean), fine rice bran, wheat flour maize, molasses, bone meal, mussel shell powder and vitamin premix are the main ingredients (Figure 6) of locally produced aquafeeds in the small-scale, micro-enterprise mills. The most common formulation is dry fish (30 percent), oilseed cake (23 percent), fine rice bran 25 percent), wheat flour (7 percent) and others (15 percent). The current manufacturing cost (milling, mixing, pellet making and drying) is BDT 800/tonne.

7.1 Aquafeed use in Bangladesh

Although based on limited information some 50 000 tonnes of feed are produced per annum by the industrial aquafeed industry, mainly for intensive culture (hatchery, nursery and grow-out) of pangas, mono-sex Nile tilapia and Thai strain of climbing perch. Shrimp and prawn feed production amounts to around 10 000 tonnes per annum (Table 20). Other than the industrially produced aquafeeds, a substantial quantity of pelleted feed for pangas and shrimp and prawn are either farm-made or produced by small-scale feed manufacturers. Estimates of total aquafeed use and its origin are presented in Table 20. Overall, some 230 000 tonnes of aquafeeds are used per annum.

Of interest are the relative proportions of feed use by the relatively small number of intensive fish farmers in comparison with the farmers who employ improved-extensive and semi-intensive technologies. In the improved-extensive and semi-intensive farming systems (see above) production is largely reliant on fertilization and natural pond productivity, with limited supplementary feeding. It is estimated that approximately

TABLE 20
Estimated amounts of feed use for aquaculture production in Bangladesh, 2004

Production systems/species	Industrial pellets (tonnes)	On-farm pellets & mixes (tonnes)	On-farm mixed feed (tonnes)	Total (tonnes)
Pangas, tilapia and climbing perch	50 000	40 000	10 000	100 000
Shrimp and prawn	10 000	20 000		30 000
Carp polyculture for food fish	-		80 000	80 000
Carp seed production	-		20 000	20 000
Total	**60 000**	**50 000**	**100 000**	**230 000**

Source: Field Survey (2005)

89 percent of the total annual aquaculture production of >900 000 tonnes in Bangladesh is produced by the latter group of farmers. Assuming that 100kg of supplementary feed is used to produce 1 tonne of fish in the improved-extensive and semi-intensive systems equates to a total use of around of 80 000 tonnes of supplementary feeds, the bulk of which consists of bran and mustard oilseed cake. It is estimated that a further 20 000 tonnes of supplementary feeds are used for the production of seed, such that the total feed use by extensive and semi-intensive farmers is around 100 000 tonnes or 44 percent of the total aquafeed use in the country. By comparison, the semi-intensive and intensive farmers who produce mainly pangas and other high value products use 56 of the feed to produce 11 percent of total aquaculture production.

8. PROBLEMS AND CONSTRAINTS OF FEED AND FERTILIZER USE IN AQUACULTURE

- Many of the poor and marginal farmers have a limited understanding of the feed and nutrient requirements of the animals they are producing. They mainly practice extensive aquaculture with limited and irregular use of feeds and fertilizers and production levels are low.
- Semi-intensive and intensive farmers are reliant on poor quality feeds irrespective of whether the feed is made by the formal aquafeed industry or by small-scale feed mills. Similarly, this is also largely a consequence of their limited knowledge about the nutritional requirements of the culture species, the proximate composition of the ingredients and price. Manufacturers often use cheaper ingredients of inferior quality, resulting in poor feed quality and lower than expected yields. Facilities to test the composition of ingredients and composite mixed feeds are not readily available to farmers, who have to bear the consequences and the costs.
- The aquafeed industry is unregulated and feed quality is not guaranteed. Hence there is an urgent need to finalise and implement policy for aquafeed regulation and a need to build the requisite capacity and facilities to manufacture high quality aquafeeds.
- The seasonally limited availability and supply of aquafeed ingredients is problematic. Competition for these commodities by other users, e.g. the poultry feed industry is high, which result in higher prices. Many storage facilities are antiquated and inadequately resourced to store the ingredients in an appropriate and safe manner such that they are readily available throughout the year.

9. RESOURCE AVAILABILITY AND THE EXPANSION OF THE AQUACULTURE INDUSTRY

Fish production in Bangladesh can be increased through further improvements in the improved-extensive and semi-intensive culture systems for carps, prawn and shrimp, in particular by increasing farmer awareness in the use of feeds and fertilizers. Access to farm inputs by poor and marginal farmers has to be improved in order to increae rural fish production.

The rapidly growing feed manufacturing sector must be regulated with respect to feed quality, such that famers are in a position to purchase quality feeds. This would result overall in higher production levels. Moreover, there is a need for the formal aquafeed industry to become more pro-active with respect to the supply of and quality of ingredients. The demand for feed has to be estimated by the industry on a regular basis so that the demand can be met at a reasonable cost.

10. RECOMMENDATIONS

The recent advances in aquaculture production have given rise to several new constraints. These must now be addressed in order for the industry to expand in Bangladesh. The following recommendations may be useful for the sustainable development of the aquaculture sector:

- The degree of cooperation between government and university laboratories to provide support to the aquafeed industry to manufacture high quality feeds and to provide information on the nutritional requirements of fish must be improved.
- Information on appropriate storage methods and modern fishmeal manufacturing technology needs to be disseminated.
- Extension services must provide a greater degree of support to farmers such that they are able to manufacture better farm-made feeds.
- Extension services must provide appropriate information to farmers for improved fertilization schedules to enhance natural pond productivity.
- Extension services must promote the effective use of inorganic fertilizers in fish culture to increase natural pond productivity.
- Intensive producers must be educated in the judicious use of aquafeeds and expansion of their activities in a controlled manner.
- Extension services must educate poor and marginal farmers (carp farmers) throughout the country to improve their production through regular use of nutrients and feeds.

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APPENDIX

A.1. Family, common English and scientific names of major aquaculture species in Bangladesh

Major group	Family	Common English name	Scientific name
Major carps	Cyprinidae	Rohu	*Labeo rohita*
		Catla	*Catla catla*
		Mrigal	*Cirrhinus cirrhosus*
Exotic carps	Cyprinidae	Silver carp	*Hypophthalmichthys molitrix*
		Common carp	*Cyprinus carpio*
		Common/mirror carp	*Cyprinus carpio*
		Grass carp	*Ctenopharyngodon idella*
		Java barb	*Barbonymus gonionotus*
Other carps	Cyprinidae	Kuria labeo	*Labeo gonius*
		Orange-fin labeo	*Labeo calbasu*
		Olive barb	*Puntius sarana*
Snakeheads	Channidae	Snakehead murrel	*Channa striata*
		Great snakehead	*Channa marulius*
		Spotted snakehead	*Channa punctata*
Catfishes	Bagridae	Rita	*Rita rita*
		Long-whiskered catfish	*Sperata aor*
		Giant river-catfish	*Sperata seenghala*
	Siluridae	Wallago	*Wallago attu*
	Pangasiidae	Yellowtail catfish	*Pangasius pangasius*
		Sutchi catfish	*Pangasius hypophthalmus*
	Schilbeidae	Silond catfish	*Silonia silondia*
		Catfish	*Eutropiichthys vacha*
	Heteropneustidae	Stinging catfish	*Heteropneustes fossilis*
	Clariidae	Walking catfish	*Clarias batrachus*
		North African catfish	*Clarias gariepinus*
Climbing perch	Anabantidae	Climbing perch	*Anabas testudineus*
Other fishes	Notopteridae	Clown knifefish	*Notopterus chitala*
		Bronze featherback	*N. notopterus*
	Percidae	Nile tilapia	*Oreochromis niloticus*
		Mozambique tilapia	*O. mossambicus*
Shrimps & prawns	Penaeidae	Black tiger shrimp	*Penaeus monodon*
		White shrimp	*Penaeus indicus*
		Brown tiger shrimp	*Penaeus semisulcatus*
		Brown shrimp	*Penaeus brevicornis*
		Brown shrimp	*Metapenaeus monoceros*
		Shrimp	*Parapenaeopsis sculptilis*
	Palaemonidae	Giant freshwater prawn	*Macrobrachium rosenbergii*
		Monsoon river prawn	*Macrobrachium malcolmsoni*

Source: Hasan (1990); FishBase (05/2007) (http://www.fishbase.org/search.php)

B.1. Amino acid composition of feed ingredients used in Bangladesh (percent dry matter)

Amino acids	Fishmeal	Fish silage	Bonemeal	Silkworm pupae	Poultry offal	Soybean meal	Sesame meal	Mustard oilcake	Linseed meal	Cotton seed	Leucaena meal	Water hyacinth	Duckweed meal	Rice bran	Wheat bran
Threoonine	3.13	2.52	5.37	2.29	2.64	1.63	1.21	1.46	1.24	1.21	1.21	1.08	0.70	0.47	0.49
Cystine	0.48	0.44	0.88	0.73	0.69	0.28	0.32	0.70	0.37	0.39	0.17	0.10	0.12	0.14	0.18
Valine	3.16	2.53	7.90	3.01	3.85	2.10	1.27	1.47	1.75	1.56	1.49	1.19	0.76	0.59	0.62
Methionine	1.95	1.75	1.20	1.22	1.04	0.54	1.37	0.32	0.58	-	0.58	0.17	0.09	0.23	-
Isoleucine	2.65	2.13	0.85	2.66	3.47	1.82	0.92	1.34	1.41	1.15	1.12	0.95	0.50	0.37	0.42
Leucine	4.96	4.46	10.34	4.19	4.92	3.37	1.79	2.32	2.43	1.92	2.22	1.75	1.10	0.72	0.89
Tyrosine	2.23	1.92	2.43	3.49	2.42	1.29	0.56	0.73	0.64	0.64	0.87	0.68	0.39	0.19	0.29
Phenylalanine	2.54	2.16	6.84	1.89	3.13	2.22	2.11	1.38	1.53	1.51	1.57	1.19	0.71	0.47	0.61
Histidine	0.65	0.53	4.95	2.30	1.56	1.24	0.63	0.72	0.75	0.65	0.42	0.46	0.26	0.30	0.46
Lysine	4.85	4.12	7.78	4.56	3.95	3.01	1.27	1.96	1.18	1.27	1.33	0.98	0.93	0.49	0.64
Arginine	3.64	3.10	3.96	3.13	3.95	3.48	2.91	1.81	2.23	2.90	1.48	1.02	1.81	0.68	0.89

Source: Hossain (1996)