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Striped catfish (*Pangasianodon hypophthalmus*, Sauvage, 1878) aquaculture in Bangladesh: an overview

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Abstract

Farming of the striped catfish, *Pangasianodon hypophthalmus*, is a major aquaculture activity in Bangladesh, particularly in the district of Mymensingh. However, pangasius farm management practices and the socio-economic impacts of pangasius farming systems in Mymensingh have not yet been adequately described in the literature. This article provides an overview of the present status and characteristics of pangasius culture in Bangladesh based on data from a study conducted in Mymensingh district during 2009. The mean productivity of pangasius was 36.9 MT ha^{-1}, where 87.9% of the farms produced between 15 and 65 MT ha^{-1} of pangasius, with an additional 10–20% Indian major and Chinese carps and Nile tilapia. Pangasius aquaculture in Bangladesh has improved the economic and social status of a variety of stakeholders in communities where the fish is farmed.

Keywords: *Pangasianodon hypophthalmus*, pangasius catfish, Bangladesh, farming practices, socio-economics

Introduction

Bangladesh is one of the world's most densely populated countries, with an estimated population of more than 160 million, and high levels of poverty and malnutrition (World Bank 2010). Aquaculture in Bangladesh has expanded rapidly in the last three decades and it now ranks sixth among the largest aquaculture producing countries [Food and Agriculture Organization (FAO) (2009)] with a reported output of 1.06 million tonnes in 2009 [Department of Fisheries (DOF) (2010)]. However, whilst the traditional picture of fish culture in Bangladesh is one dominated by small-scale low-intensity carp production, much of this growth may be attributed to the recent expansion of entrepreneurial pellet-fed culture of striped catfish (*Pangasianodon hypophthalmus*) [*P. hypophthalmus* is formally known as 'striped catfish' in English, it is now far more commonly referred to as 'pangasius' or 'pangasius catfish'- we follow this convention in the remainder of the text.] and tilapia which, together, now account for close to 29% of total aquaculture production (Belton, Karim, Thilsted, Jahan, Collis & Phillips 2011b).

The last decade has seen dramatic growth in pangasius production throughout much of Asia. This has been most notable in Vietnam, which produces more than 1 million tonnes per annum for export purposes (Belton, Haque, Sinh & Little 2011a), but India, Myanmar, Indonesia and Bangladesh have also seen rapid expansion. Pangasius culture in these countries has attracted less international attention than that in Vietnam to date, however, because it serves mainly domestic markets. Pangasius catfish (called *pangas* or *Thai pangas* in Bangladesh) is now by far the most important intensively cultured species in Bangladesh in volume terms (Belton *et al.* 2011b).

Production first originated during the early 1990s in Mymensingh district, north of the capital city Dhaka. This region continues to dominate production. However, the culture system is spreading to an increasing number of districts and has rapidly evolved into an economically significant activity with long backward and forward linkages providing diverse livelihood opportunities for a wide range of value chain actors (Haque 2009a).This rapid growth has occurred in part because pangasius is popular among fish farmers due to the ease with which it can be cultured; possessing hardy characteristics, good survival rates, fast growth and ability to survive at high stocking densities (Sarker 2000). The fish has also proven popular among consumers due to its low market value (a function of high yields, low per unit production costs and ample supply), making it one of the most important cultured species, particularly among the poor in urban areas (Belton *et al.* 2011b).

Pangasius has become an important fish for national food security in Bangladesh due to both the volumes produced and to its accessibility to lower income bracket consumers. Market price is low compared with that of the Indian major carp which still account for the majority of aquaculture output in Bangladesh, and which retail for approximately twice as much (Ahmed, Alam & Hasan 2010; Belton *et al.* 2011b; Belton, Haque & Little 2012). The industry experiences seasonal and cyclical over and underproduction despite an overall upward trend; for instance, a pangasius glut during 2008 temporarily reduced farmgate prices to below production costs (Edwards & Hossain 2010), but the industry rebounded during 2009.

Although some concerns have been raised regarding the social and environmental sustainability of pangasius aquaculture in Vietnam these claims have proven largely unfounded in the Vietnamese context and are also inapplicable to catfish farming in Bangladesh, where fingerling and food fish marketing, feed production and distribution and associated services provide important employment opportunities for rural and peri-urban people, and environmental impacts appear limited (Belton *et al.* 2011a). The remainder of this article expands upon these themes to offer an up-to-date overview of the current characteristics, status and implications of pangasius aquaculture in Bangladesh, based on the results of research carried out in Mymensingh district during 2009.

Materials and methods

The study was carried out in Mymensingh district, located 120 km north of the capital city of Bangladesh, Dhaka. The district is divided into 12 subdistricts (*upazila*), among which three, Muktagacha, Trishal and Bhaluka, have large numbers of pangasius farms [Department of Fisheries (DOF) (2009)]. From these three *upazilas* a total of 90 grow-out farm owners (31 in Muktagacha; 30 in Trishal; 29 in Bhaluka) were surveyed during the period from March to December, 2009. A field team including one of the authors and two other enumerators first conducted discussions with key informants to determine which villages in these upazila had the highest concentration of pangasius farms and visited 3–4 of these villages in each upazila. Upon visiting a village the team made enquiries to discover which members of the community owned a pangasius farm, and would then attempt to locate as many as possible to conduct an interview. A mix of small, medium and large farms was selected in each field site, and a total of 90 farms were considered sufficient to ensure the overall representativeness of the sample.

Primary information on grow-out farming systems was collected using structured questionnaire surveys and additional key informant interviews and focus group discussions. Draft questionnaires were tested with a small number of farmers in the study area prior to preparing the final questionnaires. During the testing period questionnaires were modified based on feedback before being finalized. To obtain qualitative information with which to help clarify survey results, eighteen semi-structured interviews were conducted with key informants possessing particularly detailed knowledge of certain aspects of the industry. These included six farmers, three officers of the Department of Fisheries (DOF), two fish wholesalers, two catfish feed dealers, one feed mill owner, managers of two fish processing factories, one fingerling trader and one pangasius hatchery owner. Five focus group discussions were made with eight to ten farmers and farm operators per group to cross-check the findings obtained using a variety of participatory tools.

Data from the questionnaire surveys were entered into a customized electronic database developed using MS Access (Microsoft Corporation, Redmond, WA, USA), then exported to the software packages MS Excel (Microsoft Corporation) and Statistical Package for Social Science, SPSS (SPSS, Chicago, IL, USA) for statistical analysis. A probability of less than 5% ($P < 0.05$) was considered as significant in all instances, except where stated otherwise in the text.

Results and discussion

Overview of pangasius aquaculture

Pangasius is now produced in numerous districts of Bangladesh, of which, Mymensingh, Naogaon and Bogra are most important. The largest number of farms is found in Mymensingh (Table 1). Mymensingh has medium to high quality agricultural land, and is not usually severely affected by flooding (Shamsuddin, Alam, Hossein, Goodger, Bari, Ahmed, Hossain & Khan 2007). These suitable agro-ecological conditions have contributed to Mymensingh becoming Bangladesh's foremost location for pangasius culture (Ahmed *et al.* 2010), but other factors including the district's good transport links to Dhaka, the presence of fisheries research institutions [Bangladesh Agricultural University and Bangladesh Fisheries Research Institute] and being a historical leader in other forms of aquaculture are more fundamental reasons for the industry's development there.

In Muktagacha upazila, large numbers of relatively small owner-operated farms have developed in a densely clustered pattern following the conversion of lowland rice fields. In Trishal sub-district, farms developed in a more scattered manner on elevated areas of paddy (Ali & Haque 2011), and ownership by absentee entrepreneurial investors who appoint permanent labour for farm management is more common than in Muktagacha. In Bhaluka upazila, mainly large farms have been developed in rented low-lying wetland areas (*beel*) which were not previously under rice cultivation or which were single-cropped. A similar ownership pattern to that found in Trishal is evident there.

P. hypophthalmus, which is non-native to Bangladesh, was first imported from Thailand in 1990 by the Bangladesh Fisheries Research Institute (BFRI), which is located in Mymensingh, and adult broodfish were first successfully artificially spawned by scientists at BFRI in 1993 (Sarker 2000). The first attempt at commercial farming of pangasius by a private enterprise, Al Falah Farm located in Trishal upazila, reportedly took place shortly afterwards (Ali 2009). Striped catfish initially obtained a high price because consumers confused it with a highly prized wild native pangasiid catfish (*Pangasius pangasius*). As a result, the production cost of pangasius was very low compared with the farm gate price prior to 2000. This was an important factor in the initial expansion of Pangasius farming in the country.

Table 1 Estimated number and area of pangasius farms in three upazila of Mymensingh district (Source: key informant interviews)

Upazila	Number of farms	Mean farm size (ha)	Total farm area (ha)
Muktagacha	2480	1.50	3720
Trishal	1720	1.50	2580
Bhaluka	1300	6.00	7800
Total	5500	N/A	14 100

Production of pangasius catfish in Bangladesh has increased sharply over the last decade, although there are discrepancies in the figures reported. [Department of Fisheries (DOF) (2010)] recorded total aquaculture production at 1064 801 MT for the year 2008–2009, of which pangasius cultured in ponds was 59 477 MT, accounting for 6.5% of the country's recorded aquaculture production. This represented a substantial increase on 2007–2008 when the fish accounted for just 3.77% of reported production. However, Belton *et al.* (2011a) reported total pangasius production at 300 000 MT in the year 2008, based on the estimates of the Bangladesh Fish Farmers Association. This figure was also reported by Edwards and Hossain (2010) and Munir (2009). Belton *et al.* (2011b) arrived at a similar estimate of production in 2010, based on triangulation of a variety of sources, including the output of feed mills.

This would appear to indicate that the production of pangasius remains severely under-represented in official statistics. The trend in the cumulative growth in farm numbers in Mymensingh depicted in Figure 1 also suggests that the collection of official data lags behind the actual growth of the industry, but does indicate a temporary hiatus in production in 2007/08 consistent with that reported by Haque (2009a) and Edwards and Hossain (2010).

Farming practices

Farm characteristics

A total of 90 farm owners/operators were surveyed in the three upazila. Farm size and water surface area varied from 0.08 to 33.0 ha and 0.05–28.38 ha respectively (Table 2). Mean farm

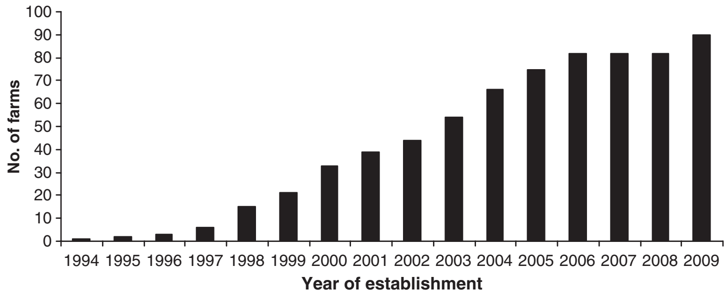


Figure 1 Cumulative growth trend of pangasius farms in the study area.

Table 2 Characteristics of pangasius farming in the study area by farm location

Items	Location (mean ± SD)			Average (mean ± SD)
	Muktagacha	Trishal	Bhaluka	
Farm size (ha)	1.63 ± 1.68	1.26 ± 1.41	7.33 ± 7.99	3.34 ± 5.42
Pond size (ha)	0.22 ± 0.20	0.36 ± 0.62	2.89 ± 3.03	1.13 ± 2.13
No of ponds farm^{-1}	7.27 ± 5.93	4.32 ± 2.75	3.82 ± 2.75	5.14 ± 4.45
Water surface area (ha)	1.21 ± 1.12	1.04 ± 1.26	6.61 ± 7.04	2.89 ± 4.82
Water depth (m)				
Rainy season	1.56 ± 0.30	1.49 ± 0.21	1.88 ± 0.54	1.64 ± 0.41
Dry season	1.05 ± 0.25	1.03 ± 0.24	1.46 ± 0.48	1.18 ± 0.39
Stocking density m^2				
Pangasius	4.66 ± 1.29	4.53 ± 1.80	3.61 ± 1.92	4.28 ± 1.75
Carps	1.59 ± 1.05	1.65 ± 1.23	2.43 ± 1.36	1.88 ± 1.26
Feed (t ha^{-1})				
Commercial pellet	80.40 ± 48.14	78.08 ± 39.68	60.40 ± 34.06	71.78 ± 40.34
Farm-made	82.16 ± 43.50	83.34 ± 47.34	56.63 ± 37.39	77.60 ± 43.56
Production (t ha^{-1})				
Pangasius	40.63 ± 24.0	39.7 ± 20.38	29.92 ± 17.43	36.86 ± 21.16
Carps and tilapia	2.72 ± 2.02	2.95 ± 2.27	4.37 ± 2.70	3.33 ± 2.43
Total	43.35 ± 24.03	42.64 ± 20.79	34.33 ± 17.89	40.20 ± 21.24
FCR				
Commercial pellet	1.93 ± 0.11	1.98 ± 0.05	2.00 ± 0.08	1.97 ± 0.08
Farm-made feed	2.12 ± 0.21	2.07 ± 0.18	1.98 ± 0.04	2.07 ± 0.18

size and water surface area were significantly different ($P < 0.05$) among the three sub-districts. Pond size ranged from 0.08 to 24.29 ha, and number of ponds per farm from 1 to 22 respectively. The average individual pond size in Bhaluka was larger than in other upazila due to the conversion of naturally occurring depressions into ponds, allowing for the construction of larger and deeper ponds at lower capital cost compared with the other two sites. Most large and medium sized farms in all three upazilas included nursery ponds.

The frequency distribution of farm size is shown in Figure 2 indicating that farm size is positively skewed (skewness = 0.93), with 21.1% of farms sized <0.51 ha, 22.2% farms sized 0.51–1 ha, 20.0% farms sized 1.01–2 ha, 22.1% farms from 2.01 to <6 ha, and only 14.4% farms of ≥ 6 ha in size. More than 40% of farms are small at <1 ha, but this requires contextualization given that the mean landholding of farm owners in Mymensingh area is 0.62 ha [Bangladesh Bureau of Statistics (BBS) (2002)] and 59% of a rural landholdings nationally are sized less than 0.2 ha (Hossian & Bayes 2009). This implies that even the owners of smaller pangasius farms are likely to be better-off than average; a fact confirmed by other data reported later in the paper.

The water depth of individual ponds ranged from 1.07 to 3.05 m and from 0.61 to 2.74 m in the rainy season and the dry season respectively (Table 2), with the great majority of farms (86.8%) with pond water depths of 1.07–2.0 m in

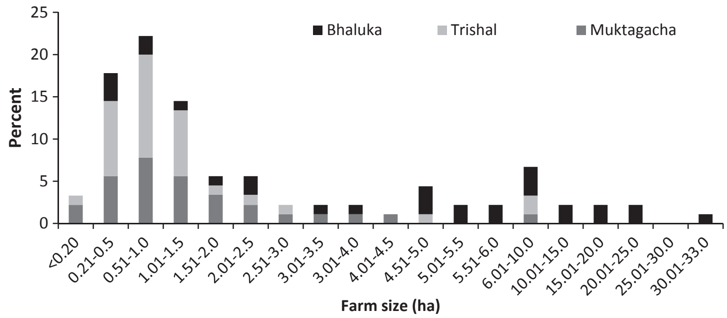


Figure 2 Frequency distribution of farm size by farm location.

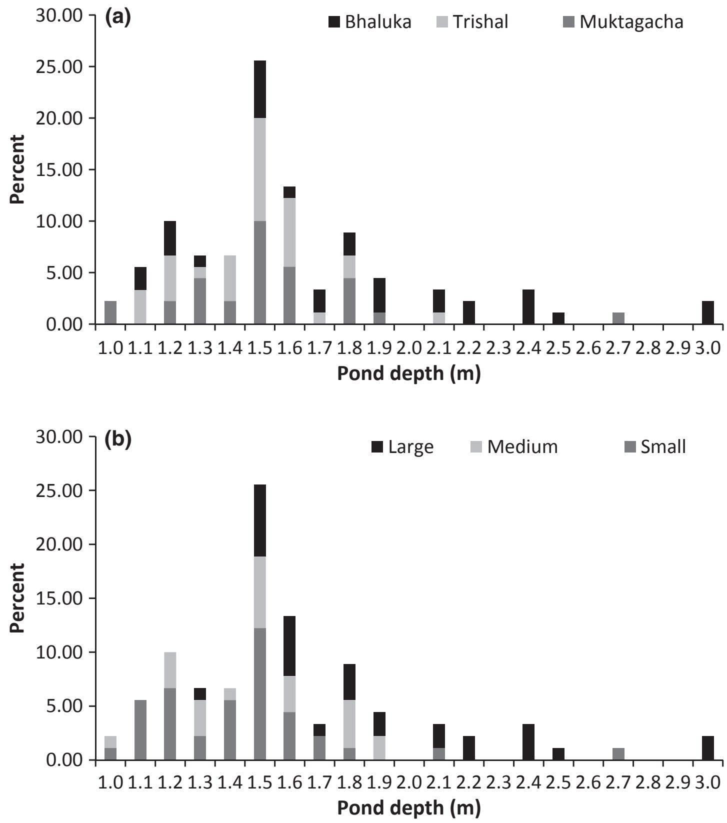


Figure 3 Frequency distribution of mean pond depth of surveyed farms by (a) farm location (b) farm size category.

the rainy season (Fig. 3). It was found that pond water depths in Bhaluka were significantly different ($P < 0.05$) to those in Muktagacha and Trishal. This is in a similar range to the average rainy and dry season water depths of catfish ponds in Bangladesh of 1.64 and 1.15 m reported by Ahmed (2007).

This shallow profile is in part a result of the method of construction which involves raising a dyke around the edge of rice paddy rather than the excavation of large volumes of soil from below ground level. Phan, Bui, Nguyen, Gooley, Ingram, Nguyen, Nguyen and De Silva (2009) reported that production of catfish in the Mekong River is positively related with pond depth. This seems to suggest that there may be potential to increase productivity in Bangladesh by digging deeper pangasius ponds. However, many farms may be prevented from adopting this strategy due to limited access to drainage facilities for discharging large volumes of water and the low lying location of some ponds.

Productivity

The productivity of pangasius ranged from 8.85 to 121.98 MT ha^{-1} (Table 2). This is significantly higher than the average annual yield of pangasius in Mymensingh of 8.34–13.95 MT ha^{-1} reported by Ahmed *et al.* (2010). Data on which the study of Ahmed *et al.* (2010) is based were collected in Bhaluka in 2006, suggesting that rapid intensification of the production system may have since taken place. Further potential for the intensification of production is indicated by the fact that 9.9% of farms produced 70 MT ha^{-1} or more. According to our key informant interviews, the farms attaining such high yields were mainly large well-financed operations with longer grow-out cycles, good quality feed and higher than average levels of water exchange. At the other end of the spectrum, unusually low levels of production were attributed to high mortalities early in the culture cycle, low stocking densities or short production periods; the latter two factors being indicative of insufficient working capital.

In addition, all pangasius farmers stocked Indian major carps (Rohu, *Labeo rohita*; Catla, *Catla catla*; Mrigal, *Cirrhinus cirrhosus*) and Chinese carps (Silver carp; *Hypophthalmichthys molitrix;* Grass carp, *Ctenopharyngodon idella*; Common carp, *Cyprinus carpio*), with yields varying from 0.33 to 8.70 MT ha^{-1}. This upper value is noteworthy because it is much higher than the average yield of carp in Bangladesh. Ten farms reported carp yields of >7 MT ha^{-1}, all of which were located in Bhaluka upazila. However, the average total productivity per hectare of farms in Bhaluka is significantly lower ($P < 0.10$) than in the other two upazila surveyed. This is likely to be because the large average size of farms in Bhaluka equated to prohibitively expensive feed costs if pangasius were stocked at higher densities, leading farmers to stock a higher ratio of carps, and less fish per unit area overall compared with Trishal and Muktagacha.

Around 40% farmers also regularly stocked monosex Nile tilapia (*Oreochromis niloticus*) as an additional crop, with productivity ranging from 0.09 to 6.0 MT ha^{-1}, and many other farmers had breeding populations of mixed-sex tilapia present in their catfish ponds. The frequency distribution of pangasius production in MT ha^{-1} is shown in Figure 4, with most farms (87.9%) producing between 15 and 65 MT ha^{-1}.

Inputs

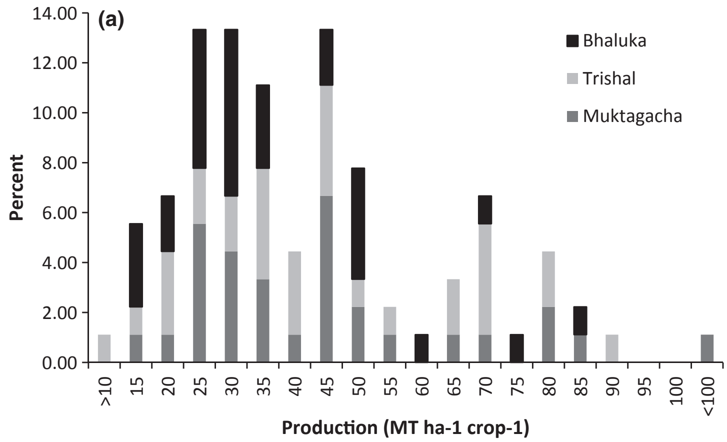
Water supply and pond preparation

Eighty-six per cent of farmers surveyed used groundwater pumped from shallow tube wells or submerged pumps for their water supply. The remainder used *beel* (wetland) water (4.4%), river water (3.3%) or depended fully on rain water (6.7%). The larger ponds in Bhaluka are almost completely rain-fed. During the months of June–September (monsoon season) most farms in other upazila are also reliant only on rainwater.

All the surveyed farms treated pond bottoms prior to filling with water and stocking, following drainage by siphoning and pumping. Most farmers (80%) removed bottom sediment every 1–4 years, and used it to repair pond dykes before treating with different soil and water treatment compounds. About 85.56% of farms preferred liming (150–250 kg ha^{-1}) to treat the pond bottom and 15.56% farms used salts (50–70 kg ha^{-1}) as part of pond bottom treatment. In addition, 10% of farms used cowdung and compost to fertilize the soil and water. After filling the pond with water, some farmers applied inorganic fertilizers to increase pond productivity prior to stocking. Normally, Urea and TSP were used at the rate of 150–200 and 100–150 kg ha^{-1} respectively. These fertilizers help to increase production of natural foods (e.g. phytoplankton) which enhance the production of carps and tilapia. In addition, lime was used (125–200 kg ha^{-1}) to disinfect the pond water and bottom sediments.

Seed

Pangasius seed production occurs mainly in Bogra, Mymensingh, Comilla, Naogaon and Jessore districts (Table 3). Hatchlings are produced in hatcheries and nursed in ponds to a size of 2–3 cm in length. Farmers either purchased these fry directly from hatcheries or through seed commission agents, generally in large numbers at a time. Commission agents work as a communication channel between farmers and hatcheries and take a percentage of the sales price. They sometimes also provide seed to farmers on credit. Farmers usually stocked seed in their own nursery ponds



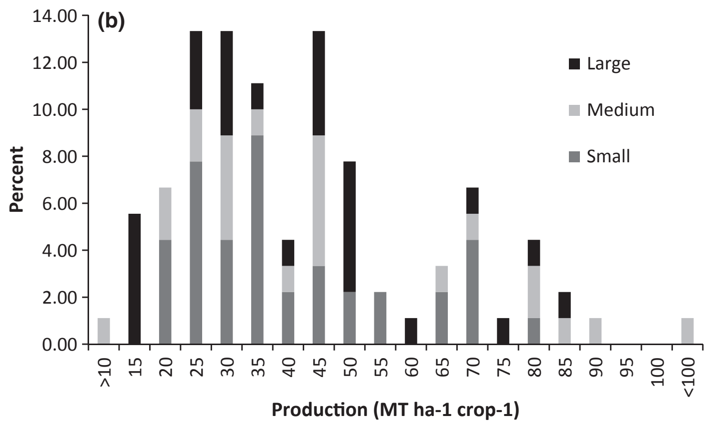


Figure 4 Frequency distribution of production in MT ha^{-1} $crop^{-1}$ of pangasius by a) farm location b) farm size category.

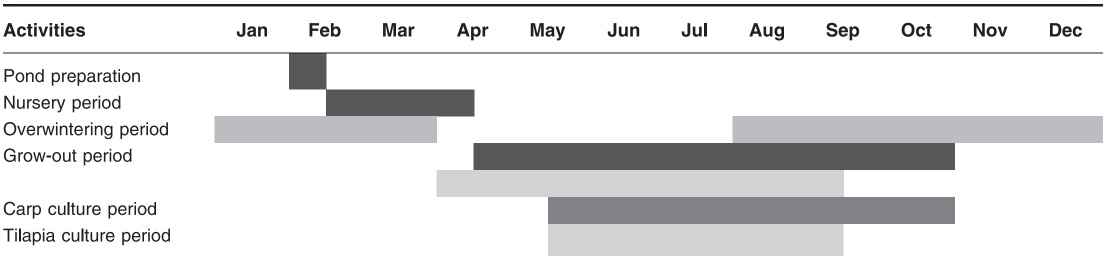
Table 3 Number of pangasius hatchery locations and output in 2009 (Source: unpublished DOF data and telephone interviews)

District	No. hatcheries producing pangasius	Kg pangasius hatchlings produced in 2009
Mymensingh	50	16 800
Jamalpur	1	150
Kishoreganj	4	350
Narshingdi	1	200
Comilla	49	4941
Brahmanbaria	6	220
Chandpur	2	10
Feni	2	95
Jessore	15	3293
Noagoan	15	3334
Dinajpur	1	130
Barisal	1	6
Bhola	2	350
Bogra	87	60 000
Total	174	89 879

before subsequently transferring them to grow-out ponds (Table 4). Most large farms (89.3%) had their own nursery pond (Table 5), whereas 69.2% of small farmers purchased fingerlings from other sources.

Most farmers began nursing seed in early March and continued until the end of April, grading and transferring to grow-out ponds on several occasions to reduce stocking densities. Farmers who did not have nursery ponds purchased fingerlings ranging from 5 to 12 cm in length (mean 7.10 cm) from nursery farmers. According to Alam (2011), in pangasius culture in Bangladesh stocking of large size (over-wintered) fingerlings is associated with high productivity. This has also been observed for tilapia culture (Haque, Little, Barman & Wahab 2010). Most farmers (72.58%) purchased carp seed from local fry traders and the remainder collected carp seed directly from hatcheries or Bangladesh Fisheries Research Institute.

Table 4 Production calendar of pangasius farming in Bangladesh



Shaded areas correspond to the duration over which each activity is commonly practiced. Farmers stocking overwintered fingerlings (indicated in light grey) begin growout one month earlier than those stocking conventionally nursed fingerlings (indicated in dark grey).

Table 5 Farm characteristics and management by size category

	Farm size		
Item	Small (<1 ha)	Medium (1–2.5 ha)	Large (>2.5 ha)
Average level of educational attainment of owner (years)	8.5 ± 4.19	9.0 ± 5.02	10.86 ± 4.34
Farms with nursery ponds for pangasius (%)	30.8	78.26	89.3
Farms purchasing pangasius fingerlings from nurseries (%)	69.2	21.74	10.7
Stocking density per m^2 (pangasius)	4.43 ± 1.44	5.12 ± 1.77	3.38 ± 1.77
Stocking density per m^2 (carps)	1.80 ± 1.25	1.75 ± 1.06	3.47 ± 2.74
Frequency of water exchange (times per cycle)	2.67 ± 2.42	2.80 ± 1.92	0.75 ± 0.97
Volume of water exchange/cycle (% pond volume)	55.79	51.73 ± 18.55	19.28 ± 18.79
Use of water testing equipment (% of farms)	2.56	4.34	0
Farms applying organic fertilization (%)	12.82	8.69	7.14
Farms applying organic fertilization (kg ha^{-1})	121.87 ± 54.87	108.65 ± 38.56	88.63 ± 25.69
Farms applying inorganic fertilization (%)	35.89	21.73	53.57
Farms applying inorganic fertilization (kg ha^{-1})	165.74 ± 41.31	125.86 ± 59.44	133.98 ± 48.19
Use of C_aCO_3 (% of farms)	76.92	82.6	60.71
Use of C_aCO_3 (kg ha^{-1})	237.79 ± 35.84	218.35 ± 39.89	128.32 ± 31.65
Use of disinfectant (% of farms)	17.94	26.08	50.0
Use of antibiotics (% of farms)	5.13	8.70	25.0
Use of pesticide (% of farms)	12.82	17.39	35.71
Use of vitamin C (% of farms)	10.25	34.78	28.57
Use of commercial feed (% of farms)	58.97	65.2	67.9
Use of commercial feed (t ha^{-1})	70.79 ± 33.66	85.16 ± 52.08	62.50 ± 37.17
Use of farm made feed (% of farms)	35.9	34.8	32.1
Use of farm made feed (t ha^{-1})	67.34 ± 38.54	89.22 ± 59.20	83.22 ± 35.79
Use of commercial and farm made feed (% of farms)	5.12	00	00
Length of growout cycle (weeks)	32–40	32–44	32–44
Pangasius production (t ha^{-1})	37.63 ± 34.38	42.70 ± 33.66	30.96 ± 22.04
Carp and tilapia production (t ha^{-1})	3.32 ± 2.44	3.15 ± 2.06	3.47 ± 2.74

Around 40% of farmers also stocked locally available monosex tilapia as an additional crop.

Pangasius grow-out is a system of co-culture with Indian and Chinese carps and tilapia. These species utilize nutrients from waste and uneaten feed which would otherwise be lost, help to maintain good water quality, and increase pond productivity and farm income. This system improves farmer resilience against any downward fluctuations of pangasius market price as the cost of carp production is minimal and the profit margin is high. This additional crop is harvested regularly and sold in local markets to generate working capital with which to purchase more feed for the main crop of catfish.

The stocking density of pangasius fingerlings varied from 0.88 to 8 m^2 (mean 4.28), depending on the size of seedstock and the financial capacity of the farmers to purchase seed (Table 2). The mean stocking density per m^2 for pangasius fingerlings in Bhaluka was significantly lower ($P < 0.05$) than in Muktagacha and Trishal. Stocking densities for carp fingerlings ranged from 0.10 to 5 m^2 (mean 1.88), and were significantly higher in Bhaluka than in the other two upazila, reflecting the different balance of polyculture practiced there In addition, more than 40% of farmers stocked tilapia at densities from 0.20 to 2.88 m^2. Barman and Karim (2007) reported similar findings for pangasius farming systems in Bangladesh.

Feeds and feed management

Pangasius culture is intensive (as defined according to feeding practice by Edwards 2009), with all farms applying large quantities of pelleted feeds. Most farmers (65.6%) used mainly commercially produced pellet feed purchased from local feed dealers or directly from feed companies, and 34.4% of farms used farm-made feed, [We define 'commercial feeds' as dry feeds produced in feed mills. 'Farm-made feeds' are uncooked and must be sundried following production. These are produced using small locally available machines which run off diesel engines.] but with little variation according to farm size. Commercially produced pelleted feeds were used by 50%, 67.7% and 79.3% farmers in Muktagacha, Trishal and Bhaluka respectively. Only a small proportion (5.12%) of small farms reported using both commercial and farm made feeds, usually when rainy or cloudy weather made it impossible to dry farm-made feeds. About 35% of commercial pellet feeds were produced by local feed mills and the remainder came from companies located outside Mymensingh district.

Farmers were able to obtain feed ingredients directly from local markets or from feed millers. Of those farmers using farm-made feeds, around 25% used their own pellet making machines, whereas others who did not own the necessary machinery supplied the ingredients to millers who prepared the feeds to their specifications. De Silva and Hasan (2007) have noted a similar trend for the intensive farming of Indian major carps in Andhra Pradesh, India.

Many national and international feed companies have established operations in Mymensingh, and the farmers surveyed used feed supplied by 19 different feed companies. There are approximately 40 large commercial fish feed manufacturers (Belton *et al.* 2011b) and many more small-scale makers of farm-made feeds producing catfish feed (Ali 2009; Haque 2009b). Belton *et al.* (2011b) reported that total production of commercially milled fish and shrimp feeds from the 40 major mills in 2010 was 668 380 MT. This would have amounted to production of around 335 000 MT of pellet-fed fish, of which approximately 60% (201 000 MT) was thought to be pangasius. When use of farm-made feeds is also considered this brings the figure for total pangasius production close to the 300 000 MT suggested by several other sources.

Normally, six or seven types of ingredients are used to prepare farm-made feed, including fine rice bran or polish from industrial rice mills, maize meal, wheat flour or wheat bran, dry fish, mustard oil cake, soybean meal and meat and bone meal (Table 6). Dried fish are collected from Cox's Bazar, Chittagong and Khulna districts, and are also imported from India. Meat and bone meal is imported from European countries where it is produced as a by-product of the animal rendering industry. Snail or mussel meat and shells, vitamins, calcium and feed binders may also be included in feeds. The nutritional quality of commercially manufactured feeds, as stated by the manufactures, is highly variable with crude protein (CP) ranging from 23% to 32% (mean: 28.05%) (see Table 7). Figures for the CP of farm-made feeds were not available at the time of writing.

The growth of pangasius depends primarily upon the supply of feeds of an adequate quality and quantity. Feeding rates ranged from 1.5% to 12% and 1–10% of body weight per day for farm-made feeds and commercial feeds respectively, with the highest feeding rates at the beginning of the production cycle when fingerlings were small. Fish were fed twice per day throughout the pro-

Table 6 Main ingredients used in farm-made feed

Ingredients	Per cent dry weight Range	Per cent dry weight Mean
Rice bran/Rice polish	30–60	40.58
Maize meal	0–15	10.22
Dry fish/Fish meal	0–15	10.27
Meat and bone meal	0–25	13.45
Mustard oilcake	0–15	9.54
Soybean meal	0–10	6.25
Wheat flour	0–12	7.86
Salt	1–5	3.42
*Feed binder	0–1	0.50
*Vitamin	0.05–0.10	0.07
*Growth promoter	0.05–0.10	0.07
*Calcium	0–5	1.89

*Ingredients aren't always included.

Table 7 Proximate composition of commercial feeds as specified on the bags used in pangasius grow-out farms in Bangladesh (Source: Field survey)

Feed name	Moisture (max) (%)	Protein (min) (%)	Fat (%)	Fibre (%)	Ash (max) (%)	Lipid (min) (%)
ACI Fish Feed	10	29	6	7	Na	Na
Aftab Feed	11	23	6	8	Na	3
AIT Feed	12	28	7	6	20	Na
Anam Fish Feed	11	32	6	7	Na	Na
CP Bangladesh	12	32	6.5	3	Na	Na
CP Thailand	12	25	3	8	Na	Na
Lucky Fish Feed	12	30	7	6	20	Na
Mega Feed	11	26	6	10	Na	Na
National Feed	13	26	7	Na	18	Na
New Hope Feed	12	28	3	Na	Na	Na
Paragon Feed	11	28	Na	6	18	4
Quality Feed	12	30	Na	6	Na	6
Rahat Fish Feed	13	25	4	8	Na	Na
Saudi Bangla Feed	12	30	6	7	10.3	1.9
SMS Feed	12	30	6	8	18	Na
Sumaia Feed	10	26	6.5	Na	6.5	Na
Sushama Feed	11	27	6		6	Na
Tamim feed	12	30	6	7	Na	2
Zam Zam Fish Feed	12	28	6	7	18	Na

Na = not available.

duction cycle and feeding rates were higher for farm-made feeds compared with commercial feeds. The feed conversion ratio (FCR) of farm-made feeds (2.07 ± 0.18) and commercial feeds (1.97 ± 0.08) were significantly different ($P < 0.05$) from each other (Table 2). Similar trends have also been reported by Phan *et al.* (2009) for pangasius catfish farming in the Mekong Delta, Vietnam, where the FCR for commercial pelleted feed and farm-made feed was 1.69 and 2.25 respectively. The difference in FCRs between commercial feeds in Vietnam and Bangladesh was probably due to the use of floating feeds (which have a higher feed conversion efficiency than sinking feeds) in Vietnam.

Phan *et al.* (2009) reported that use of farm-made feeds resulted in higher efficiency than commercial feeds in pangasius farming in Vietnam. Although no statistically significant difference was identified for Bangladesh in the average production (MT ha^{-1}) of farms using farm-made feeds (37.41 ± 20.30) and commercial feeds (36.57 ± 21.75), the farmers interviewed felt that farm-made feeds resulted in better production and noted that they were cheaper or more cost effective than commercial feed.

This would seem to be indicative of the poor quality of much commercially manufactured feed. The sales price for a tonne of commercial feed ranged from US$ 314.28–342.86 (mean: 328.57 ± 0.56 SE), whereas the cost of farm-made feeds ranged from US$ 257.14–300 (mean: 282.25 ± 0.85 SE). The production cost of a kg of pangasius using commercially milled (US$ 0.76 ± 0.03) and farm-made feed (US$ 0.70 ± 0.05) is also significantly different ($P < 0.05$). Given these findings, the use of commercial feeds by the majority of farmers is partly explained by difficulties sourcing good quality feed ingredients year round.

Management

Health management

The degree of disease occurrence over the culture period varied from farm to farm. Of the total farms surveyed ($N = 90$), most of the farms (56.67%) did not face any major health problems, whereas the remainder of farms (43.33%) reported a range of conditions. The most prevalent symptom and/or disease was epizootic ulcerative syndrome (red spot) (61.54%), followed by dropsy (12.85%), cotton wool type lesion (10.25%), pop-eye (10.25%) and white spot (5.13%). In general, farms found disease to occur during the winter season and the level of mortality did not exceed more than 2% in a single production cycle. Disease related mortality rates for catfish in Vietnam were reported as much higher at 20–30% (Mantingh & Dung 2008). However, bacillary necrosis of *Pangasius spp.* (BNP), which is not present in Bangladesh, is the most common disease in Vietnam (Braak 2007), where it is responsible for 50–90% of mortality (Dung, Crumlish, Ngoc & Thinh 2004) and is thus a highly economically significant pathogen (Crumlish, Dung, Turnbull, Ngoc & Ferguson 2002).

The economic loss due to disease problems (estimated as the difference between expected and actual production) ranged from 1% to 5% (mean: 1.5%) of the total yearly income from fish production. Similar results were also reported by Faruk (2008) for catfish farming in Bangladesh. These low mortality rates compared with Vietnam, where stocking densities are higher and use of chemotheraputants is more pervasive, suggest that the culture system in Bangladesh is generally superior in terms of animal welfare. When faced with the occurrence of disease, most farmers turned to neighbouring farmers for advice on treatment. A variety of options were employed, of which liming was the most common, followed by the application of salt, potassium permanganate, antibiotics, pesticides, insecticides, feed additives such as vitamin c, and water exchange. Some farmers may use chemotheraputants in a prophylactic manner, but as Table 8 shows, overall levels of use for most substances (whether in a proactive or reactive manner) are generally rather low. Ali (2008) reported a wide variety of chemical and biological products to be used in freshwater aquaculture in Bangladesh.

Water quality and waste management

Water quality management plays a crucial role in increasing production for intensive or semi-intensive farming systems. Only 2% of farmers in Mymensingh area monitor water quality parameters (pH, dissolved oxygen, ammonia) using test kits, with varying frequencies ranging from daily to once a month. This is done using commercially available test kits due to a lack of laboratory facilities at the farm level. Most farms (71%) exchanged pond water at infrequent intervals ranging from 1 to 10 (mean 2.11) days and the total rate of exchange varied from 5% to 70% (mean 43.40%) over the 7–9 months of the culture period. Such levels of water exchange are very minimal compared with daily water exchange in pangasius farms in Vietnam (Phan *et al.* 2009) where much higher rates of exchange are possible due to the location of ponds on the banks of rivers and canals. These high rates of water exchange also make it possible to produce fish with the white or light pink flesh colour required in some export markets (Belton *et al.* 2011a).

Most farms (80%) discharged wastewater directly into rice fields, with the reminder dis-

Table 8 Chemicals and antibiotics used pangasius farming in Bangladesh

Substances	Molecular formula	Substance category	Farmers applying substance %	Farmers applying substance N
Calcium carbonate	$CaCO_3$	Water and sediment treatment	73.33	66
Zeolite	–	Water and sediment treatment	12.22	11
Salt	NaCl	Water and sediment treatment	15.56	14
Potassium permanganate	$KMnO_4$	Disinfectant	2.22	11
n Alkyl dimethyl benzyl ammonium chloride	$R(CH3)_2CH_2C_6H_5NCl$	Disinfectant	15.56	14
Calcium hypochlorite	$Ca(ClO)_2$	Disinfectant	1.11	1
Copper sulphate	CuSo4	Disinfectant	1.11	1
Hydrogen peroxide	H_2O_2	Disinfectant	12.22	11
Oxytetracycline	$C_{22}H_{24}N_2O_9$	Antibiotic	7.78	7
Chlortetracycline	$C_{22}H_{24}Cl_2N_2O_8$	Antibiotic	3.33	3
Fanitrothion	$C_9H_{12}NO_5PS$	Pesticide	8.89	8
Rotenone	$C_{23}H_{22}O_6$	Pesticide	4.44	4
Malathion	$C_{10}H_{19}O_6PS_2$	Pesticide	7.78	7
Vitamin C	–	Feed supplement	22.22	20
Not identified	–	–	7.78	7

charged into fallow land and canals without treatment. Use of discharged wastewater from pangasius farms in rice-fields has been reported to reduce fertilizer costs by more than 30% and enhance rice field productivity by 10% (Khan 2009), although there is also a danger that excessive nutrients will result in rice continuing with vegetative growth and not setting seed or grain. Farmers are usually unaware of the possible benefits of discharging wastewater into rice fields, so there may be considerable untapped potential to reuse pangasius pond wastewater in rice cultivation to minimize fertilizer costs for paddy farmers.

The direct water consumption required per tonne of fish was estimated from farm water volume, fish production, and water exchange rates for individual farms and ranged from 0.09 to 4.15 million litres (ML) MT^{-1} (mean: 0.65 ± 0.08 SE). Phan *et al.* (2009) reported that water consumption was 6.4 ML MT^{-1} for striped catfish production in Vietnam, which indicated much lower water use in Bangladesh. The frequency distribution of water consumption per tonne of fish produced (Fig. 5) shows water consumption to be highly skewed (skewness = 2.98). This is partly accounted for by the fact that many farms are limited in their ability to exchange water due to the construction of ponds close together, and only a few are able to manage higher rates of exchange.

However, the water quality in pangasius ponds remained well within limits mandated for compliance with Pangasius Aquaculture Dialogue certification standard introduced by WWF (Abedin 2010). This is due partly to the polyculture system with carps and tilapia, which consume uneaten pangasius feed and excreta directly, and the use of groundwater and heavy rain fall in the peak production season, which contain few nutrients to begin with.

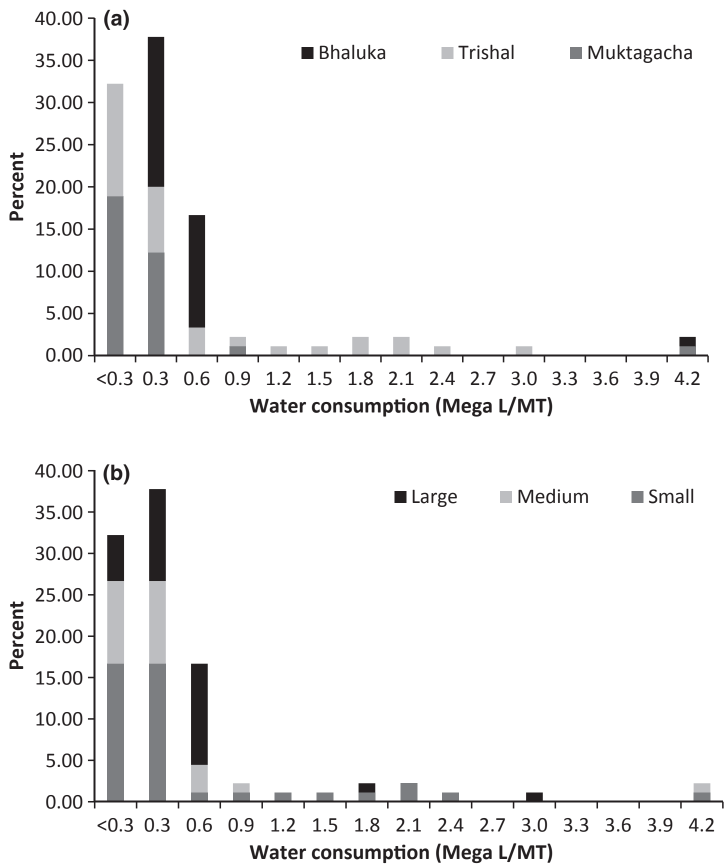


Figure 5 Frequency distribution of pangasius production in ML/MT^{-1} water consumption by (a) farm location (b) farm size category.

Farming communities

Pangasius farm owners in Bangladesh were quite young, with age varying from 25 to 65 years (mean: 40.72 ± 9.45) and most of them (60%) were under 40 years of age. The family size of farm households varied from 2 to 21 (mean: 6.45 ± 3.41) and did not differ significantly ($P > 0.05$) between the three sub-districts. More than 24% of farm owners had completed primary education, 30% secondary school certificate, 14.4% higher secondary certificate and 23.3% a bachelor's degree, with only 7.8% having received no formal schooling. However, the education level of farmers did not differ to a statistically significant degree between small, medium and large farms and there was no relationship ($r^2 = 0$) between educational level and farm productivity. These levels of educational attainment are considerably higher than the national average (World Bank 2010), indicating the relatively high socio-economic status of most pangasius farmers prior to their entry into pangasius farming. This is confirmed by Figure 6, derived from data collected during a PRA exercise in a village in Trishal, which shows farm ownership being beyond the reach of the poor and heavily skewed towards the better-off.

Almost all farm owners stated that they had been motivated to start pangasius farming because it was a profitable business. Only 5% of farmers cited training as an important influence on their decision to begin pangasius farming, although 23% of farm owners had received some formal training on pangasius culture. The remainder of farmers had gained knowledge through farming experience and from neighbouring farmers. It was found that 60% and 40% of farmers took pangasius farming as their primary and secondary occupations respectively, with 15.56% of farm owners having no secondary occupation, meaning that pangasius farming was their only source of household income.

Pangasius farming alone contributed 53.69% ± 23.52 household incomes, ranging from 10.84% to 100%. Most farming households engaged in a variety of businesses – many of which were also related to pangasius aquaculture (e.g. feed manufacturing) – with relatively small numbers involved in other types of agriculture (Fig. 7). This suggests an entrepreneurial orientation on the part of those practicing catfish grow-out. Farm owners

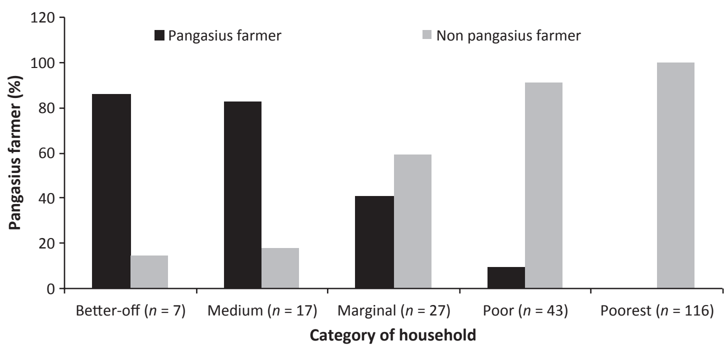


Figure 6 Income category of pangasius and non-pangasius farming households in a Trishal village.

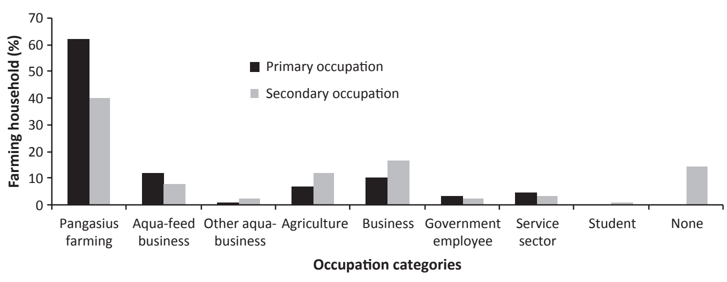


Figure 7 Primary and secondary occupations of pangasius farmers in the study area.

reported having a better standard of living since taking up pangasius culture as a result of improvements in drinking water, housing, health facilities, sanitary facilities and economic security. Almost all farmers had improved their social and economic conditions and some noted that they were able to eat better quality food than in the past.

Visible changes in standards of living and levels of economic activity can be observed in areas where there are clusters of pangasius farms. This is mainly a result of the long chains of backward and forward employment linkages associated with the activity. Seventy-six per cent of farms employed permanent labourers, although 14% of smaller farms were managed by household members. The number of permanent workers (fulltime or salaried seasonal labourers) per farm varied from 1 to 22 (mean: 4.15), of which the majority (80%) were aged 25–35. Monthly wages ranged from US$ 28.17–84.50 (mean: $43.73) per labour per month. Almost all farms employed some temporary day labour for purposes such as fish harvesting and pond repair, ranging from 4 to 1000 man days per year (mean: 145.90 ± 209.71).

Farms can thus generate employment opportunities for the rural poor in nearby communities, which are particularly important because they provide consistent year-round (rather than just seasonal) income. Farm workers also reported receiving free fish and growing vegetables on the farm site for home consumption, and obtaining credit assistance for social activities and financial assistance for their health treatments from farm owners.

Participants in focus group discussions reported improvements in the living standards of large numbers of fishers, fry traders, fish traders, marketing intermediaries, transporters and workers in water loading stations who gained employment opportunities through service provision to catfish farms and in downstream value chains. Substantial employment opportunities are also generated in the commercial fish feed and input supply industries, fish hatcheries, fish markets and particularly in the transport sector: from rickshaw/trishaw pullers to large trucks which carry pangasius to both local and more distant markets

Some large entrepreneurial famers based in Mymensingh led the formation of a producer's association in 2007, named the Bangladesh Fish Farmers Association (locally *Bangladesh Motshay Chashi Samity*), with the intent of strengthening their legal rights. The association has urged the government to centrally monitor market price of pangasius, to reduce land tax for pangasius farms, and to reduce electricity charges for fish farming. It has also highlighted the issue of poor quality fish feed ingredients and feeds. This issue has been taken up by the Ministry of Fisheries and Livestock, resulting in implementation of the 'Fish and Animal Feed Law 2010' which has been passed with the intention of safeguarding aquatic animal and human health. This institutional development is indicative of the strength and long term sustainability of pangasius farming industry in Bangladesh.

However, in some villages in Muktagacha the indiscriminate construction of large numbers of ponds has led to some water logging in nearby rice-fields and created obstacles for the movement of inhabitants. However, these consequences appear minor when compared with the broader benefits. Therefore, the introduction of pangasius into farming systems in Mymensingh seems to have had significant positive social benefits overall.

Conclusion

Pangasius aquaculture was initiated in Mymensingh district in 1993, following which production has grown rapidly to reach an estimated 300 000 MT and become an economically important form of aquaculture which is radically different to the low-intensity carp culture for which Bangladesh is better know. This growth has occurred at the same time as major expansion in the culture of pangasiid catfish species in a number of other Asian countries. As a result of several factors – including the rapid growth in output, the high management intensity of the culture system, a dependence on the supply of large quantities of inputs and the need to distribute large volumes of product (catfish and the additional 'free' crop of carps and tilapia) – the industry's establishment has had important livelihood impacts in communities where there are large concentrations of farms, particularly in Mymensingh, but increasingly also in other regions of the country, and now makes an important contribution to national food security.

Production is already highly intensive compared with other common systems of fish culture in Bangladesh, but the example of Vietnam indicates that there remains significant potential to increase per unit area productivity, and perhaps also to increase export volumes as a means of earning foreign exchange. However, practical reasons, including difficulties with drainage and water exchange may limit the extent of intensification possible, certainly in Mymensingh, although perhaps not in provinces in some areas in the South of the country.

In addition, further intensification might not be the most desirable outcome in either environmental or social terms, with a shift towards monoculture in larger and more technically efficient farms utilising greater volumes of inputs being both more resource and capital intensive and yielding slimmer margins. Such systems would likely prove more vulnerable to financial and biological shocks than the present system (the unique polyculture configuration of which lends it some economic and environmental sustainability), and would provide less jobs per unit production and fewer opportunities for farm operators at the smaller end of the spectrum. Entry into export markets could also expose producers to greater regulatory and trade related pressures, and might divert this important low cost food source way from the important domestic markets it currently serves.

Finally, there appears to be potential for further enhancing the sustainability of existing culture systems through more integrated reuse of nutrients, whether in pond soil or discharged water, for use in terrestrial agriculture. The incentives to do so may increase in future as rising resource costs constrain the use of inorganic fertilizer

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