RESEARCH PROGRAM ON Fish

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The relation between farming practices and tilapia production in small-scale fish farms in Bangladesh

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In partnership with Wageningen University & Research

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Authors

Kim Tran[1], Marc Verdegem[1], Bas Wolkenfelt[1], Chadag Mohan[2] and Johan Verreth[1]

Authors' Affiliations

[1] Aquaculture and Fisheries Group, Wageningen University & Research, Wageningen, the Netherland
[2] WorldFish, Penang, Malaysia

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Contact

WorldFish Communications and Marketing Department, Jalan Batu Maung, Batu Maung, 11960 Bayan Lepas, Penang, Malaysia. Email: fish@cgiar.org

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1. Introduction

Because of its climate and vast water resources, Bangladesh is highly suitable for fisheries (Shamsuzzaman et al. 2017). Unsurprisingly, fisheries supply the majority of animal protein (60%) in Bangladeshi diets and provide employment to over 17 million people (DOF 2016; Shamsuzzaman et al. 2017). The country's fisheries sector can roughly be divided into three parts: inland capture fisheries, inland aquaculture and marine fisheries (DOF 2016; Shamsuzzaman et al. 2017). In 2014 and 2015, aquaculture comprised 55.9% of fish production in Bangladesh, and with an annual production of 2,060,408 t, the country's aquaculture sector ranked fifth in the world (BanDuDeltAS 2015; DOF 2016). Between 2006 and 2016, fish production in Bangladesh increased 5.4% annually, mainly because of aquaculture, which grew 8.2% per year (DOF 2016).

Aquaculture is considered the key supplier of animal protein for the future in Bangladesh. However, even though aquaculture production is increasing, the knowledge of farmers on culture practices is often limited. To improve and increase aquaculture production in Bangladesh, targets have been set in the government's Seventh Five Year Plan to further develop the fisheries sector, ensure food security and produce a surplus production for export (DOF 2016).

This study was developed as part of the CGIAR Research Program on Fish-Agri-Food Systems (FISH), in an attempt to analyze current farming practices in order to identify risks for diseases and opportunities for higher production. In this way, the study could contribute to the development of better management practices for small-scale fish farming in Bangladesh. As Nile tilapia (*Oreochromis niloticus*) is considered one of the most promising aquaculture species, the focus in this report is on tilapia farmers. Various farming practices were investigated by conducting interviews with tilapia farmers in different regions of the country. The collected data and the observations on the farms were used to identify practices that could improve and increase tilapia production in Bangladesh by comparing practices and production outputs among the assessed farms.

2. Nile tilapia culture in Bangladesh

Of the total fish production for direct human consumption in Bangladesh, aquaculture provides over 50%, and this will increase even further in the future (Shamsuzzaman et al. 2017). The main finfish species cultured are different pangasius catfish, tilapia and several types of carp (FRSS 2016).

Since tilapia has high growth rates and can be cultured in a wide range of environmental conditions, it is an attractive fish to culture, and because of its generally low market prices it is often referred to as the "fish for the poor" (Ferdous, Masum and Ali 2014; Yosef 2009). For these reasons, tilapia is rapidly gaining popularity in poor countries, such as Bangladesh.

Although tilapia was first introduced in Bangladesh back in 1954, it has started to gain interest in recent years (Ahmed and Ahmed 2009). The main drivers behind this are the success of the species in several other countries and the growing international and domestic markets for tilapia. The genetic improvement of tilapia strains and the ability to produce monosex tilapia have also led to an increase in production (Ahmed and Ahmed 2009; WorldFish 2015).

Tilapia culture in Bangladesh takes place in earthen ponds, usually in polyculture with catfish species, such as pabda (*Ompok pabda*) and shing (*Gagata youssoufi*), or carp species, such as rohu (*Labeo rohita*), silver carp (*Hypophthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idella*). Tilapia fry are purchased either directly from hatcheries or via local agents who buy large quantities of fry from hatcheries and supply farmers in the region. Farmers usually assume they purchase monosex tilapia. However, this is not always the case. Throughout Bangladesh, different methods are used for tilapia culture, and these vary in stocking densities, the type of feed and the salinity of the water. Geography, too, plays a role, as it differs between the regions, which causes a variety of problems.

Tilapia broodstock.

3. Methodology

3.1 Field survey

The aim of this study was to analyze current farming practices and their impact on production and disease risks in the tilapia farming sector in Bangladesh. The hope is that it will enable better management practices. The study is based on interviews with local tilapia farmers. First, a questionnaire (Appendix 1) was designed to gain knowledge on the practices of the tilapia farmers. The questionnaire was divided into the following five sections, covering the most important aspects of the farm:

1. farmer's background
2. farm description
3. feeding practices
4. pond and water management
5. biosecurity and diseases.

To carry out the field surveys, a team was composed of five data collectors and one supervisor. The data collectors were responsible for carrying out farm visits and conducting random interviews, while the supervisor was responsible for locating farmers, data quality assurance, and communicating with the WorldFish office in Khulna as well as local fisheries officers and other external parties. The team received 3 days of training, consisting of a task description, an introduction to conducting interviews, clarifying the questionnaire, and practical training.

In 2017, the field surveys were carried out over four weeks (October–November) in which the team traveled through the survey areas. Prior to each day, the supervisor communicated with local fisheries offices to locate tilapia farmers in the region and then divided them among the data collectors.

In total, 429 tilapia farmers from four different regions were interviewed. The information from these questionnaires was entered into a database. Incomplete questionnaires, questionnaires with obvious erroneous answers and the interviews of one data collector who proved to be insufficiently skilled, were all removed from the database. That left data for 387 tilapia farmers, which was used for further analysis.

Farmer interview.

3.2 Site selection

Survey districts were selected based on the number of tilapia farmers in the area. Because the data collectors had to travel from farm to farm using local transport, a certain density of tilapia farms in a region was required to avoid unnecessary long traveling times and to achieve the targeted number of questionnaires per day. Figure 1 shows the selected districts while Table 1 lists their characteristics.

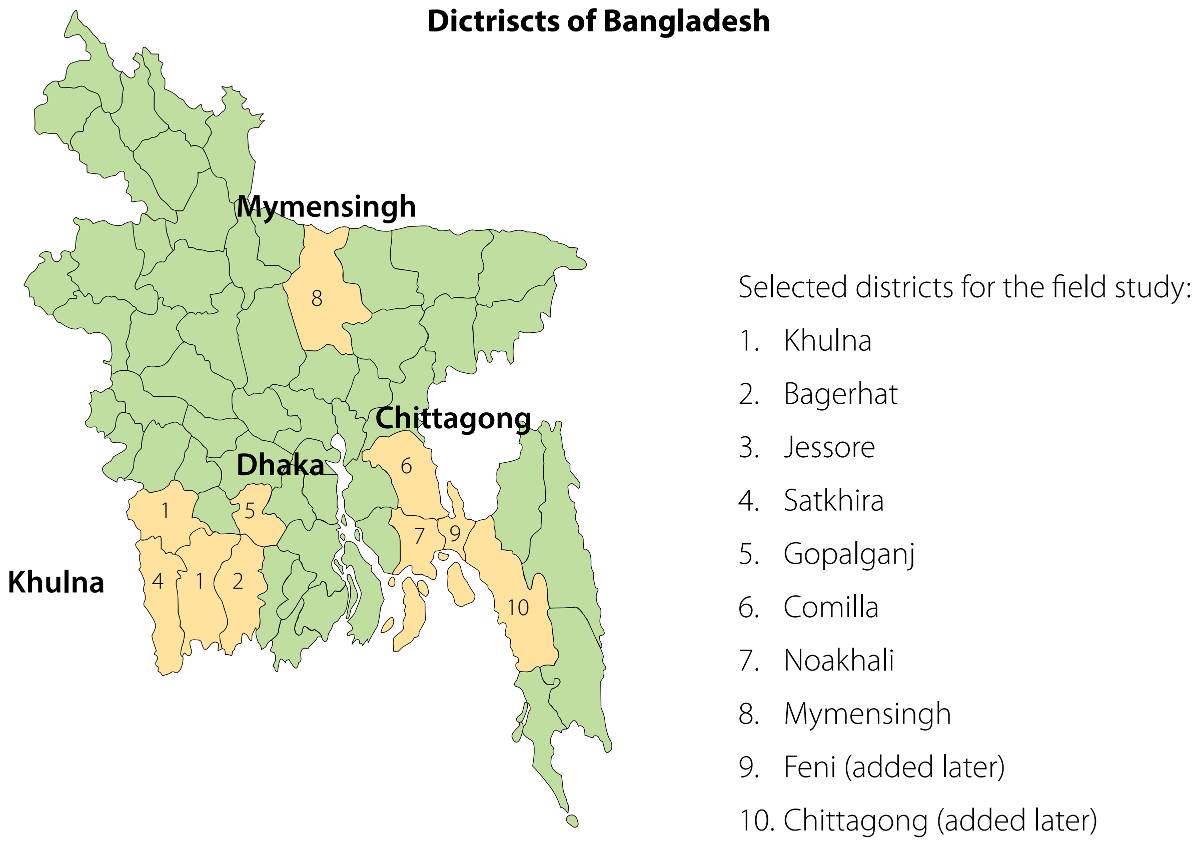

Figure 1. Selected districts for the field survey.

District	Salinity	Perceived farming type	Average production (kg/ha)	Location
Khulna	Saline/fresh	Commercial	11,325	Southwest
Bagerhat	Saline	Commercial	10,300	Southwest
Satkhira	Saline	Commercial	13,001	Southwest
Jessore	Fresh	Commercial/extra with pachani*(36%)	13,814	Southwest
Gopalganj	Fresh	Commercial	8,901	Southwest
Comilla	Fresh	Commercial	8,709	Mid Part
Noakhali, Chittagong and Feni	Fresh	Commercial	13,390	South East
Mymensingh	Fresh	Commercial	10,531	Mid Part

** Pachani is a homemade feed made up of cow dung, fertilizers such as TSP and urea, and other ingredients such as maize, wheat bran, rice bran and mustard cake oil. This mix is put in a bag and thrown in the water. The bag stays there for a few days to fertilize the pond, after which the contents are emptied into the pond to feed the fish.*

Table 1. Characteristics of tilapia farming in the selected districts.

3.3 Statistical analysis

The data were analyzed using "distance-based linear modelling" (DISTLM) in the Primer + Permanova (V6) statistical package. DISTLM is a statistical routine to investigate and model possible relationships between a multivariate data cloud (in this case described by similarities between farm performance related variables) and a set of predictor variables. The multivariate data cloud included the variables "tilapia production (kg/ha/year)," together with the variables "pond water surface area (decimal[1])," "number of tilapia stocked (number/decimal)" and "weight of fry or fingerlings stocked (g/decimal)." Because pond surface area and stocking practices influence tilapia production strongly, these variables were combined in the similarities matrix and further referred to as the "tilapia performance dataset."

The predictor variables relate to farm management decisions or farm characteristics. After removing some predictor variables to reduce information overlap, the following variables were included in the analysis:

- salinity
- water overflow
- fry type
- fry quality
- fry source
- fry acclimatization
- feed type
- commercial feed type
- poultry litter
- fertilizing
- fertilizer type
- standard procedure
- water exchange
- water quality measurement
- net fencing
- pond household use.

Forward selection was applied, starting with the predictor variable that explained the highest percentage of variation in the "tilapia performance dataset". Subsequently, other predictor variables were added one at the time, each time selecting the variable that resulted in the highest improvement in the percentage of variation in the "tilapia performance dataset" that was explained by a set of selected predictor variables. The selection procedure stopped when there was no further improvement possible in the selection criterion. As selection criterion, the AIC (An Information Criterion) was used (for more information, consult Permanova + for Primer V6 manual).

Forward selection resulted in a model with the following 9 parameters, together explaining 20% of the variation in the dataset.

Variable	Selection Criterion (AIC)	Sum of Squares	Pseudo-F	P value	Proportion of variation explained	Cumulative variation explained
Disease treatment	394.7	74.74	27.09	0.001	0.0657	6.6%
Fry acclimatization	381.6	40.60	15.26	0.001	0.0357	10.1%
Salinity	369.6	36.50	14.19	0.001	0.0321	13.4%
Net fencing	364.1	18.86	7.46	0.002	0.0166	15.0%
Water quality measurement	359.4	16.49	6.62	0.001	0.0145	16.5%
Fry source	357.2	10.31	4.17	0.010	0.0091	17.4%
Commercial feed type	354.6	11.03	4.50	0.005	0.0097	18.3%
Feed type	352.1	10.67	4.39	0.007	0.0094	19.3%
Fry type	351.4	6.41	2.65	0.051	0.0056	19.8%

Table 2. The outcome of the Distance Based Linear Modelling analysis, with the 9 predictor variables and their respective selection criterion and the variation each of them explained in the model.

The effects of these parameters on tilapia production are described in detail in the next section.

The outcome of the dbRDA is plotted and visualized in Figure 2. The interviewed farmers are shown by region, which overlap strongly. This indicates that the predictor variables influenced farm performance in different regions in the same way, so pooling of farms over regions defendable. Disease treatment, fry acclimatization, salinity, net fencing and water quality measurement seem to have most impact on farm performance. The different directions of the predictor variables in Figure 2 indicate that farming practices are highly variable, with each predictor variable grouping farmers differently in the multivariate cloud.

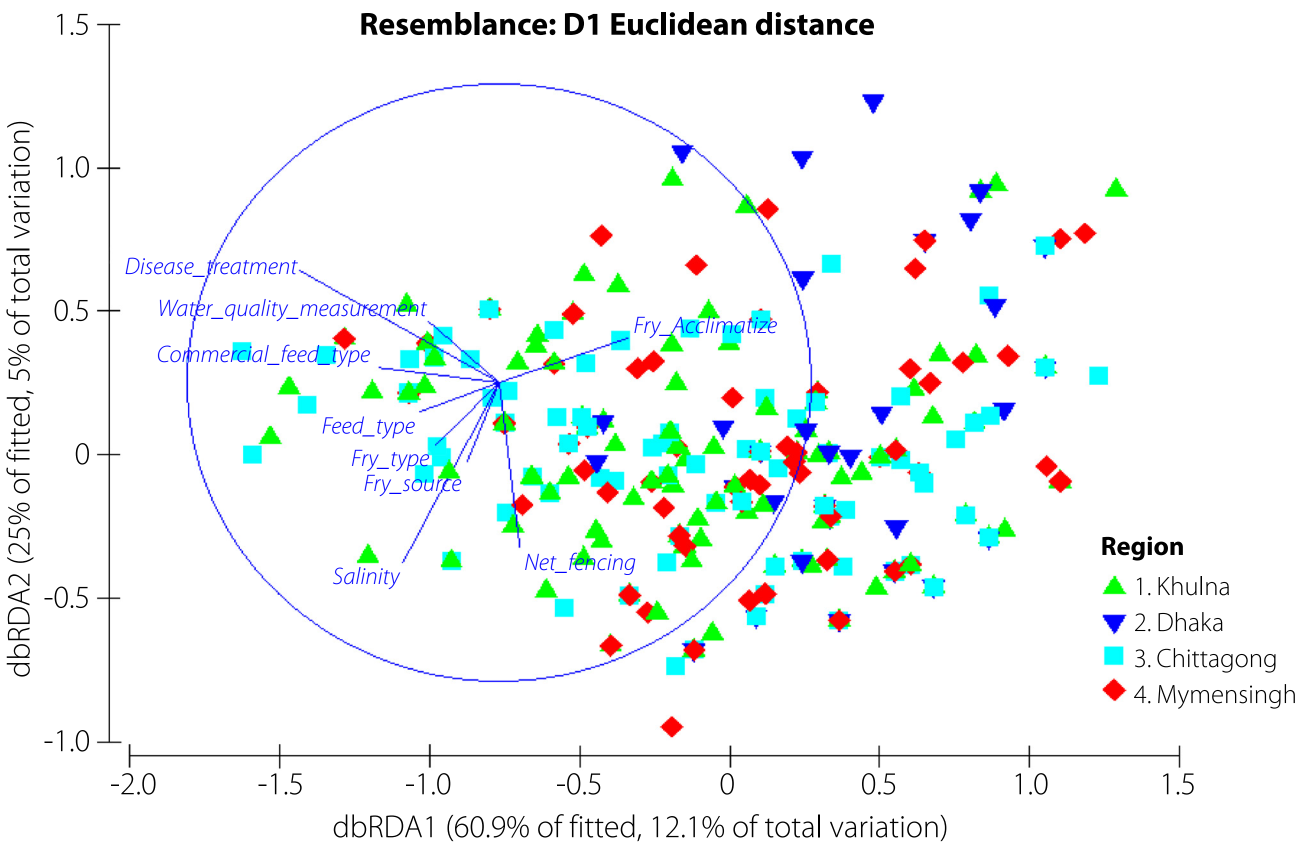

Figure 2. Two dimensional plot of the 1st and 2nd dbRDA axis. The color codes farms by region (multiple partial correlations).

4. Description of culture practices in different regions of Bangladesh

4.1 Khulna

Khulna District is located in southwest Bangladesh. In Khulna, the culture of tilapia takes place in freshwater and low saline water, which is mainly received from canals. In the past, farmers in this region use to culture pangasius (*Pangasius pangasius*), but switched to tilapia monoculture because of low market prices. In recent years, however, tilapia prices have also decreased and so monoculture has failed to generate profit, and sometimes has even resulted in losses. To make up for this, farmers have shifted to more extensive polyculture systems of tilapia with different carp species. Usually farmers produce one cycle of tilapia per year. It lasts, on average, for 240 days, whereas the carp remain in the pond for more than 300 days.

To feed their fish, farmers use commercial tilapia feed and assume that carp eat the phytoplankton in the pond. Tilapia fry are usually not directly purchased from a hatchery, but rather from local agents that buy large quantities from hatcheries and sell these to the farmers in the area. However, fry from such agents may not always be high quality. And despite being sold as monosex tilapia, fish may sometimes start reproducing during the culture cycle. Similar practices happen in all the other surveyed regions, except for Feni and Mymensingh.

In Khulna, relatively few medicines are used, and problems with diseases do not occur often. The average tilapia stocking density in the region is 233 fish per decimal (5.8/m^2). Tilapia is sold at 200–250 g for about BDT 90–100/kg (€0.90–€1.00).

4.2 Bagerhat

Aquaculture in Bagerhat takes place in freshwater ponds about 1.5 m deep, which is average for Bangladesh. The main water source in the area are canals. Rainfall also provides water, but this can cause ponds to overflow during the rainy season. In the past, farmers in Bagerhat mainly cultured prawn that were destined for the export market. But after prawns were found to be injected with gelatine to increase their weight, the demand for prawn dropped and farmers switched to tilapia culture.

Poultry shed over tilapia pond in Bagerhat.

Tilapia in Bagerhat is cultured in polyculture systems together with carp. Similar to Khulna, one production cycle is used, in which tilapia is harvested several months before carp. In Bagerhat, fish are mainly provided with commercial feed, but in some cases poultry sheds are constructed above the ponds that supply the pond with litter. This litter is assumed to function both as fish feed and pond fertilizer. Because of the high costs of commercial feed, farmers that use poultry sheds appear to make more profit than farmers using commercial feed.

Stocking densities in Bagerhat are on average the highest among all the surveyed districts (272 tilapia/decimal; 6.8 fish/m^2). Most farmers consider the fingerlings to be of poor quality. Similar to most other regions, the market size is 200–250 g, and prices vary at around BDT 90–100 (€0.90–€1.00) per kg.

4.3 Satkhira

In Shatkhira, farmers receive most of their pond water from underground wells, which contain slightly saline water. In the past, shrimp culture was popular in this region, but since market prices dropped, most farmers have switched to polyculture of tilapia and perch. With weights of over 500 g, tilapia in Satkhira have a relatively high market size. Market prices are slightly higher in this region (BDT 95–105/kg; €0.95–€1.05/kg). This is most likely caused by its target market Dhaka, which is wealthier than most other regions.

Tilapia in Satkhira is cultured in one cycle, which has the lowest average stocking density among all of the regions at 125 tilapia/decimal (approx. 3.1 fish/m^2). Usually, tilapia are stocked in April and May, and part of this is harvested and sold in September and October. The rest of the stocked tilapia remain in the pond to be sold in March, and sometimes even May or June of the following year. In those periods, no other farmers are able to supply marketable-size tilapia, so the market prices are higher: BDT 120–130 BDT/kg (€1.20–€1.30/kg) in March and BDT 130–140/kg (€1.30–€1.40/kg) in May and June.

Because dikes are generally higher in Satkhira, this region does not face the problem of escaping fish as a result of overflowing ponds. Water is sometimes added up to 40–50 times per cycle, supplying 10%–40% of the total volume per exchange.

Currently, a lot of farmers in this region face fish mortality because of diseases. In some cases, fish swim in circles close to the surface, which is assumed to be caused by the bacteria *Streptococcus*.

4.4 Jessore

Jessore District is a riverine area that often faces extreme flooding. Farmers there stock their ponds at densities of about 216 tilapia/decimal (5.4 fish/m^2), and pond water is mainly derived from freshwater wells. In Jessore, farmers start selling their fish already several days or weeks after stocking. This method is used to generate income quickly before some areas become flooded. Market sizes in this area range between 200 g and 250 g, and prices are usually in the range of BDT 80–85/kg (€0.80–€0.85/kg).

Besides farmers using commercial feed, a significant portion (36%) use a homemade feed called "pachani" that consists of cow dung, fertilizers (such as TSP and urea) and other ingredients, such as maize, wheat bran, rice bran and mustard cake oil. This mix is put in a bag and thrown in the water. The bag stays there for a few days to fertilize the pond, after which the contents are emptied into the pond to feed the fish.

4.5 Gopalganj

In the district of Gopalganj, capture fisheries from floodplains supply the majority of seafood. Recently, however, aquaculture has started to develop in this region, supplied by well water. Most tilapia farmers in the area culture their fish in combination with different species of carp. For tilapia, usually one culture cycle of 180–240 days is used, and in some exceptional cases up to 300 days.

In Gopalganj, most farmers use commercial feed, but some farmers have a poultry shed over their ponds to provide the fish with poultry litter. Stocking densities in this district average 194 tilapia per decimal (4.85 fish/m^2), and market sizes are 200–250 g, or in some cases even 500 g. Prices fluctuate in the range of BDT 80–85/kg (€0.80–€0.85/kg).

The majority of the farmers in Gopalganj face problems associated with diseases in their ponds, causing high mortality rates. The farmers consider their fry to be poor quality, and tilapia often start reproducing during the culture cycle, even if farmers expected to have bought monosex fry.

4.6 Comilla

Comilla is a freshwater region in which tilapia is mainly cultured in combination with pangasius. Previously, farmers practiced pangasius monoculture, but when pangasius prices decreased, farmers changed to polyculture with tilapia. With over 14 years of farming practice, farmers in this region are on average the most experienced in aquaculture of all the surveyed regions. Stocking densities in Comilla are relatively low (175 tilapia/decimal; 4.3 fish/m^2), but market sizes (200–250 g) and market prices (BDT 80–85/kg) are on par with other regions. Among all the regions, Comilla has the highest average pond depth, at 5.6 feet (1.7 m), compared to a mean of 4.8 feet (1.5 m) for all the regions together. The average duration of the tilapia production cycle in Comilla is 280 days, which is higher than the other regions (242 days).

Diseases occur a lot in this region, but the main species affected by this seems to be pangasius, with losses sometimes reaching over 80%. The farmers sometimes install nets or lines over their ponds to prevent thieves from stealing their fish. There are a lot of deep greenish ponds in the area, and these are likely to contain harmful levels of algae.

4.7 Noakhali, Feni and Chittagong

Stocking densities in Noakhali (240 tilapia/decimal; 6 tilapia/m^2), Feni (226 tilapia/decimal; 5.7 tilapia/m^2), and Chittagong (137 tilapia/decimal; 3.4 tilapia/m^2) vary strongly between the three different districts. Generally, the ponds in this region are quite large: 170 decimals (0.68 ha) compared to the average of 88 decimal (0.35 ha). The main source for filling the ponds is rainwater. Tilapia is cultured in combination with shing, a type of catfish. One cycle is used, but harvesting takes place three to five times annually, so market sizes differ throughout the year. Farmers provide their fish with commercial feed, and hardly any fertilizers are used. Similar to Satkhira, market prices are higher (BDT 90–110/kg; (€0.90–€1.10/kg) since their target market (Chittagong) is slightly wealthier than other regions.

Similar to Comilla, many diseases occur in this region. Even though farmers appear to be aware of the consequences of contamination, they think it would be too costly to maintain biosecurity standards. And also like to Comilla, farmers have nets and lines above their ponds to prevent their fish from being stolen.

Water color changes because of fertilization.

4.8 Mymensingh

Mymensingh is the pioneer district of Bangladesh when it comes to aquaculture. New fish species always arrive in Mymensingh first, after which they then spread across the country. Farmers in Mymensingh have about 10–12 years of experience in tilapia culture, though many of them have switched to other species in the past 2 years. The main species cultured are now pangasius, pabda, shing and gulsha (*Mystus cavasius*). These are much more profitable than tilapia. Gulsha sells for BDT 80–85/kg (€0.80–€0.85/kg) in this region.

The farmers that still culture tilapia stock their ponds on average with 270 tilapia/decimal (6.75 tilapia/m^2) in combination with catfish, which are sometimes stocked at 1000 fish/decimal. Tilapia are provided with commercial feed and are cultured in two cycles, whereas catfish are cultured for only one cycle. At the end of the first cycle, tilapia are harvested, while the catfish remain in the pond until the end of the second tilapia cycle. In Mymensingh, farmers face a lot of diseases in their ponds, mainly to catfish.

Gulsha fingerlings.

5. Data analysis

Based on the results of the collected questionnaires and the observations on the farms during the field survey, data was analyzed to select parameters that best explain the average farm performance. Eight of these parameters (predictor variables) are discussed in relation to their potential for improving the performance of tilapia production. In this way, they could be considered as suggestions for small- and medium-scale tilapia grow-out farms in Bangladesh to improve their production methods and could constitute the basis to build a better management program. However, the suggested adaptations are not always applicable to all farms, so farmers should aim to follow these guidelines only if possible and financially feasible.

5.1 Disease treatment

Of the 387 farmers interviewed, only 30% reported that they had experienced a disease problem during the past year and majority of them did not take any action to control or reduce losses. The perceived diseases did not seem to cause huge losses. On average, disease treatment increased production 1.4% above the mean production of all farmers in the survey. The data shows that farmers who applied disease treatment have larger ponds and stock more biomass and larger fish. In combination with disease treatment, this leads to slightly consistent higher production.

According to the farmers who applied disease treatment, the most common solution was to use chemicals (54%), including zeoline, lime, salt and Timesen (n-alkyldimethylbenzyl ammonium chloride and stabilized urea). Eighteen percent of the farmers used antibiotics, while 12% used probiotics, enzymes or vitamins in the feed. The remaining farmers who applied disease treatment (16%) just changed the water or stopped feeding the fish. The amount of lime, antibiotics or probiotics is based on the farmer's professional judgment. Most of the rural fish farmers do not have sufficient knowledge of disease treatment and do not recognize the signs of disease.

Data suggests that farmers with larger ponds apply disease treatment, suggesting that only larger farms can bear the cost of disease treatment.

5.2 Fry acclimatization

Sudden changes in water temperature and other water quality parameters cause stress for the fry or fingerlings and reduce the functioning of their immune system. Currently, 38% of the tilapia farmers release their fingerlings directly into their pond after arrival. If the farmers acclimatize the fry or fingerlings before stocking the ponds, they can increase production with 5.2% above the mean production of all farmers in the survey. The survey data shows that although smaller fish are stocked in smaller ponds, production increased when acclimatization is applied. Stocking larger fish and/or more biomass does not compensate for acclimatization.

In general, fish fry are 2–3 cm long and fingerlings 7–8 cm. Fry and fingerlings collected from nursery ponds were primarily stocked in hapas at a very high density and did not pass the acclimatization

Disease treatment	Response (%)	Fish performance			
		Tilapia production (kg/ha)	Tilapia number (no/decimal)	Biomass (g/decimal)	Water area (decimal)
No	70	11,004	222	194	80
Yes	30	11,480	193	370	109
MEAN	100	11,146	214	246	88

Table 3. A comparison among the surveyed tilapia farms regarding disease treatment (or not) and the associated fish performance data.

Fry acclimatization	Response (%)	Fish performance			
		Tilapia production (kg/ha)	**Tilapia number (no/decimal)**	**Biomass (g/decimal)**	**Water area (decimal)**
No	38	10,294	200	378	92
Yes	62	11,662	222	167	86
MEAN	100	11,146	214	246	88

Table 4. A comparison among the surveyed tilapia farms regarding the acclimatization of fry before stocking and the associated fish performance data.

process properly. According to the survey, 27% of the farmers in the Khulna region acclimatized their fry or fingerlings, followed by 15% in Chittagong, 13% in Mymensingh and 7% in Dhaka.

5.3 Salinity

In freshwater, farmers tend to stock bigger fish at a higher stocking density than in saline water, so tilapia production in freshwater is slightly higher. The survey shows that only 2% of the total tilapia farming area in Khulna, 4% in Dhaka, 1% in Chittagong and 3% in Mymensingh used saline water.

Tilapia production in saline water is mostly low-input and extensive. The relative area of saline water production is too low to influence mean production in the area, so salinity is not an influential factor on production levels in the surveyed areas.

5.4 Net fencing

Forty-one percent of the farmers apply net fencing, leading to an 11.3% higher production than the mean production of all farmers in the survey. Without net fencing, cattle, dogs and poultry are able to enter the pond. These animals can carry diseases or contaminate the water from a previously entered pond. Net fencing was applied most by farmers in the Khulna region (19%), followed by Chittagong and Mymensingh (9% each) and Dhaka (4%).

Fencing a pond.

In addition, 81% of the farmers suffer from overflowing ponds. If ponds are not fenced properly, this can cause large quantities of tilapia to escape. Besides having disastrous effects on the farmer's income, the escaped tilapia could also pose a threat to the native fish species in the surrounding environment, which would affect the capture fisheries.

5.5 Water quality measurement

Farmers who check water quality seem to be more successful. Those that check increased production 22% above the mean production of all farmers in the survey. Since tilapia farms in Bangladesh are quite extensive and tilapia can cope with relative poor water quality, monitoring water quality with high tech devices is not advised.

The most common parameters measured by the interviewed farmers were pH (52.7%), NH_3(17.2%) and dissolved oxygen (DO) (13.4%). Other parameters were alkalinity, Secchi disk visibility, and temperature.

Salinity	Response (%)	Fish performance			
		Tilapia production (kg/ha)	Tilapia number (no/decimal)	Biomass (g/decimal)	Water area (decimal)
Saline water (15‰)	10	10,386	142	57	115
Freshwater	90	11,234	222	268	85
MEAN	100	11,146	214	246	88

Table 5. A comparison among the surveyed tilapia farms using brackishwater or freshwater and the associated fish performance data.

Net fencing	Response (%)	Fish performance			
		Tilapia production (kg/ha)	Tilapia number (no/decimal)	Biomass (g/decimal)	Water area (decimal)
No	59	10,265	187	265	102
Yes	41	12,409	252	220	68
MEAN	100	11,146	214	246	88

Table 6. A comparison among the surveyed tilapia farms related to the use of net fences (or not) and the associated fish performance data.

Water quality measurement	Response (%)	Fish performance			
		Tilapia production (kg/ha)	Tilapia number (no/decimal)	Biomass (g/decimal)	Water area (decimal)
No	67	10,061	207	223	86
Yes	33	13,393	226	295	94
MEAN	100	11,146	214	246	88

Table 7. A comparison among the surveyed tilapia farms that monitored water quality (or not) and the associated fish performance data.

5.6 Fry source

Poor quality fry and fingerlings may cause poor growth of the fish during on-growing. Our survey indicated that in some cases fry were not directly purchased from a hatchery, but rather from local agents who buy large quantities from hatcheries and sell these to the farmers in the area. In general, well-known brand hatcheries produce fry of higher quality and with less chance of mixed sex tilapia than local dealers. Fry from agents and hatcheries were usually sold as monosex tilapia. Tilapia fry purchased from reliable sources resulted usually in higher production.

In the Khulna region, most farmers purchase fry or fingerlings from a nursery or hatchery (68%). In other areas, this practice is less prominent. For example, only 39% of the farmers in Chittagong, 35% in Mymensingh and 23% in Dhaka sourced their fry from a nursery or hatchery. In general, the marketing channel for fish fry and fingerlings starts with broodfish and continues with hatchery, nursery, fry and fingerling traders, and intermediate buyers, before reaching farmers' ponds.

Not every hatchery or agent maintains high standards for biosecurity and avoids inbreeding. To maximize production, farmers need to purchase fry from a well-known source.

5.7 Commercial feed type

If not all the feed is eaten, uneaten feed could decrease the water quality in the pond, and it also leads to high feed conversion ratios, so determining proper feeding rations is paramount for farm performance. Optimum feeding levels change with size, so knowledge on fish size is needed to feed fish effectively. Currently, 39% of the farmers determine their feeding ratio without accurate knowledge of the actual size of their fish.

Floating pellets are easily controlled and removed from the pond, which safeguards water quality and avoids overfeeding. Floating pellets were used mostly by farms in Chittagong (75%) and Khulna (62%). The combination of floating and sinking pellets was prominent among farms in both Mymensingh (32%) and Khulna (31%). In general, floating feeds offer numerous advantages over sinking feeds. Farmers can directly observe the feeding intensity of their fish and adjust feeding rates accordingly to determine whether feeding rates are too low or too high. Furthermore, it enables farmers to visually monitor the health of the reared fish as they come to the surface to feed. The drawback is that the cost of floating feed for tilapia is quite high, about BDT 7–10/kg (USD 0.09–0.128/kg) higher than sinking feed, so a significant number of farmers consider a combination of floating and sinking feed as the best compromise. Tilapia production in farms using a combination of

Fry source	Response (%)	Fish performance			
		Tilapia production (kg/ha)	Tilapia number (no/decimal)	Biomass (g/decimal)	Water area (decimal)
Own dealership	0.3	13,173	267	67	150
Hatchery	43	11,050	216	193	107
Nursery	11	10,968	190	491	94
Patilwala (fish fry hawkers)	2	3,750	107	242	54
Agent	43	11,775	224	233	69
Other farmers	0.7	5,016	120	506	108
MEAN	100	11,146	214	246	88

Table 8. A comparison among the surveyed tilapia farms according the source of the stocked fry and the associated fish performance data.

floating and sinking pellets was also 14.5% higher than the average. This is somewhat surprising, given the advantages of using floating pellets. We believe that it is entirely related with the skills of the farmers. Presumably, experienced farmers know how to monitor feed intake and dare to go for the more cost-effective combination of floating and sinking pellets. There might also be an explanation at the fish population level: smaller fish that have less access to floating pellets in competition with larger fish may still benefit from sinking pellets.

5.8 Feed type

Feeds can vary from single component feeds made on-farm, like rice bran, maize or mustard oil cake, to commercial feeds. Mixing ingredients subjected to some form of processing (simple mixing, grinding and cooking) is done in small-scale semi-intensive farms. In contrast, commercial feed ensures precise quality targets in terms of pellet size, stability and nutritional composition, so commercial feed is used usually in intensive or semi-intensive practices. Farms applying commercial feed attain on average 11.9% higher production. Khulna is the region where most farmers use commercial feed, and Chittagong is where most farmers use a combination of commercial and homemade feed. To ensure proper production levels, it is important that homemade feeds are nutritionally comparable with good quality commercial feeds. Local ingredients have often a lower digestibility than high quality ingredients used in commercial feed, so it is paramount that this information becomes available for local feed mills and farmers. (The CGIAR Research Program on Fish

Commercial feed type	Response (%)	Fish performance			
		Tilapia production (kg/ha)	Tilapia number (no/decimal)	Biomass (g/decimal)	Water area (decimal)
Floating	69	10,906	220	224	81
Floating + sinking	24	12,600	212	275	101
Sinking	6	9,741	151	425	120
Blank	1	4,415	178	119	105
MEAN	100	11,146	214	246	88

Table 9. A comparison among the surveyed tilapia farms according to the type of feed processing and the associated fish performance data.

Feed type	Response (%)	Fish performance			
		Tilapia production (kg/ha)	Tilapia number (no/decimal)	Biomass (g/decimal)	Water area (decimal)
Commercial + Home feed	16.02	5,586	199	123	91
Commercial feed	82.69	12,339	217	272	88
Home feed	0.26	312	25	6	190
No feed	1.03	4,585	201	163	79
AVERAGE	100	11,146	214	246	88

Table 10. A comparison among the surveyed tilapia farms according to the type of feed and the associated fish performance data.

Agri-Food Systems (FISH) caters to this problem.) Until that moment, local feed mills and farmers may follow the recommendations in Table 11 made by WorldFish (2009).

5.9 Fry type

Generally, it is assumed that monosex tilapia eat supplementary feed well, are able to survive adverse weather conditions and have a high resistance to disease. In general, male tilapia grow faster and use feed more efficiently than female tilapia. In addition, optimal production requires minimizal size differences in the pond, so reproduction should be avoided. Our survey indicated that applying monosex tilapia yields 5% higher production than the average. Most of the farmers therefore purchase monosex tilapia.

Mature female tilapia

5.10 General conclusions

The outcomes of the forward selection of predictor variables show that the first four are able to identify successful farmers (Table 13). Thirty percent of interviewed farmers that apply disease treatment performed 1.4% better than the average farmer. Twenty percent of the farmers combined disease treatment with fry acclimatization. Those farmers performed 5% better than the average farmers, which is still a small improvement in production. However, the number of farmers who combine disease treatment with fry acclimatization and net fencing, which represents 8% of the interviewed farmers, obtained an average production of 14,605 kg/ha. This is 31% higher than the overall mean production. When combining the first three predictor variables with water quality measurement, 4% of the farmers remained. These farmers achieved an average production of 17,459 kg/ha, which is 57% higher than the overall mean production. These farmers also implement the predictors fry source, commercial feed, feed type and fry type, so checking farmers who apply the first four predictor variables is a good way to identify potentially successful farmers. Testing these outcomes against an independent set of farmers from the same regions as presently investigated, would validate this conclusion and may then constitute a strong basis for establishing better management recommendations. A follow-up study is recommended that includes farmers

Source	Ingredient (g/kg)	35% CP	30% CP	25% CP
Plant origin	Rice bran	150	190	150
	Wheat bran	190	200	300
	Mustard oil cake	160	250	250
	Duckweed	30	0	0
Animal origin	Fish meal	150	100	0
	Dried blood	130	100	100
	Poultry viscera	100	100	100
	Shrimp-head meal	40	0	0
Supplement	Corn starch	50	60	100
Total (g)		**1,000**	**1,000**	**1,000**

Table 11.Ingredients used in the formulation of feeds of different crude protein (CP).

from other regions and also investigates the economic, household, training and education of these successful farmers.

The **percentage number in bold** shows the percentage of farmers who gave the following answers to the predictor parameters:

- Disease treatment: yes
- Fry acclimatization: yes
- Net fencing: yes
- Water quality measurement: yes
- Fry source: hatchery and agency
- Commercial feed type: floating pellets, floating and sinking pellets
- Feed type: commercial feed
- Fry type: monosex.

The *italicized number* shows the average pond production (kg/ha) obtained by the farmers answering as indicated above to the predictor variables.

Feed type	Response (%)	Fish performance			
		Tilapia production (kg/ha)	Tilapia number (no/decimal)	Biomass (g/decimal)	Water area (decimal)
Mixed sex	23	9,454	205	165	91
Monosex	77	11,651	216	271	88
MEAN	100	11,146	214	246	88

Table 12. A comparison among the surveyed tilapia farms according to the type of fry and the associated fish performance data.

Disease treatment	Fry acclimatize	Net fencing	Water quality measurement	Fry source	Commercial feed type	Feed type	Fry type
30% 11,480	**62%** 11,662	**41%** 12,409	**33%** 13,393	**86%** 11,413	**93%** 11,753	**83%** 12,339	**77%** 11,651
	20% 11,699						
		8% 14,605					
			4% 17,459				
				4% 17,549			
					4% 17,549		
						4% 17,549	
							4% 17,549

Table 13. The percentage of farmers in the survey who applied predictor parameters in a way leading to higher production performance.

6. Conclusion

Although the multivariate model explained only 20% of the variation in performance, the study was nevertheless capable to come up with some general recommendations: applying a combination of some simple management practices, such as net fencing, monitoring water quality, acclimatizing fry prior to stocking in the ponds and treating diseases when needed, seem to guarantee 50% higher production than the overall mean among the surveyed farmers.

However, some caution is warranted. The variation among the surveyed farm types was so high that differences among practices lost power. Since the model could explain only 20% of the variation in production, several sources of variation were not visible. In this regard, it is noteworthy that all farmers in this study characterized their farms as tilapia farms, while in several cases the stocking density of other species outnumbered tilapia by a factor of 4 or 5. Therefore, analyzing the data among subsets of more uniform farm types could possibly give more powerful results. Obviously, additional surveys including more regions are needed to validate the current findings.

Next, the quality of the data is highly dependent on the quality and skills of the collecting data team. In this study, one of the data collectors was removed because of insufficient quality of the work. Incidental checks indicated also that some of the farmers were inconsistent in their answers, suggesting that either the interviewer was too easy satisfied with the answer or that the farmer was guessing and trying to please the interviewer. Future studies should build a system of checks and balances into the interviews and rely on highly skilled data collectors only.

In Appendix 2, we give some general recommendations based on the current survey. But as mentioned, we emphasize that they should be used with prudence. Overall, we conclude that the coverage of the database is presently too small to come up with recommending better management practices. But the fact that groups of successful farmers can be identified with four to five simple questions is promising and deserves further exploration. By investigating the farming practices in more depth and supporting networks of successful farmers, a practical set of better management practices might be developed in the future.

Note

[1] 1 decimal = 40.46 m2

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Appendix 1. Survey questionnaire

Survey questionnaire for integrated feed and health management of tilapia culture in Bangladesh

Part 1. Farmer's background

1.1 Please provide the following information.

Farmer code							Province/Division							
Respondent name							Sex (1=Male, 2=Female)							
District							Upazila							
Union							Village							
Respondent's mobile														
Farmer's mobile (if not respondent)													Name	

1.2 How many people are in the farmer's household?

____

1.3 What is the sex of the family head?

(1=Male, 2=Female)

____

1.4 How many of farmer's household members participate in aquaculture activities?

Adult: male __________ female: __________ Child: male__________ female:__________

1.5 What is the farmer's occupation?

Major occupation (in terms of income)		Secondary occupation (in terms of income)	
Major occupation (in terms of time spent)		If the current major occupation (in terms of income) is aquaculture, what was the previous major occupation?	

1.6a Who is responsible for the pond operations?

☐ Owner ☐ Manager ☐ Other (please specify)

1.6b If not the owner, please give details.

1.6c How often does the owner visit the pond site during culture periods (number of days/months)?

1.7 How many years have you (person responsible for the pond) been involved in aquaculture?

1.8 What is your (person responsible) level of education?

(0–10, SSC=11, HSC=12, Graduate=16, Masters=17, Other=77)

1.9a Are you (person responsible) staying at the same place where your pond is located?

☐ Yes ☐ No

1.9b If not, how far away (km) do you stay from the pond?

1.10 Please provide information for the pond(s).

All ponds	**Number**	**Area (decimals)**
Total number of ponds		
Number of ponds rented		
Rent amount in BDT per year		
Target crop tilapia		
Tilapia monoculture		
Tilapia polyculture		
Other		

1.11 How big (decimals) is the area of the house where you are staying to look after the pond?

1.12 Please indicate the area (decimals) of land in your possession.

Items	Total	Rented in	Rented out	Leased in	Leased out	Mortgaged in	Mortgaged out
Homestead*							
Rice-fish plot							
Crop land							
Other							

** Excluding the area of dwelling house.*

Part 2. Practiced farming culture (selected pond)

2.1 Select one pond as a sample pond and provide details.

Do you own or rent the pond? (multiple answers)	☐ Own ☐ Rent
If you rent it, how much does it cost per year (BDT)?	
Water area (decimals)	
Dike area (decimals)	
Average designed depth (feet)	
Soil type (sand/slit/clay/loam/sandy loam/clay loam/silty loam/other)	
Salinity (1=Saline, 2=Fresh)	
How many months is the water contained in the pond?	
What is the initial source of water (pre-stock) for the pond? (multiple answers) (Groundwater=1, Rainfall=2, River/Channel=3, Other=4 specify)	
Does the initial water source usually supply enough water to allow you to practice fish culture year-round? (Yes=1, No=2)	
If not, what is the source of water (pre-stock) for the pond? (multiple answers) (Groundwater=1, Rainfall=2, River/Channel=3, Other=4 specify)	
If not, please indicate the months when the water supply is usually insufficient. (January=1…December=12)	
Is there a water overflow device/system of any kind in any of the ponds? (Yes=1, No=2)	
Please specify the method.	

2.2 Please provide the stocking density for the selected pond.

Species	Stock number	Stock quantity (kg)	Seed size (inches)	Value (BDT)
Nile tilapia (monosex)				
Nile tilapia (mixed sex)				
Carp spp.				
Catfish				
Shrimp				
Other				

2.3 Please provide harvest details.

	Tilapia	Carp	Catfish
How many times did you harvest last year?			
How many days was your last production period?			
What is the major harvest method carried out? (Seining only=1, Sein and drain=2, Drain=3, Other=4 specify)			
How many kilograms of fish did you harvest last year?			

Part 3. Feeding practices (selected pond)

3.1 How often do you apply feed? (Tick the appropriate box)

	Commercial feed	Homemade feed
One per day		
Twice per day		
Three times per day		
Other (specify)		

3.2 What feeding method(s) do you currently use? (Tick all that apply)

Homemade feeding	
Fertilizing	
Floating pellet feeding	
Sinking pellet feeding	
In association with poultry	
Other	

3.3 If homemade feeds are used, what are the ingredients? (Tick that all apply)

☐ Household leftovers ☐ Maize bran ☐ Rice bran ☐ Wheat bran ☐ Oil cake

☐ Leaves or other vegetative matter ☐ Fishmeal ☐ Other (please specify)

3.4 What quantities of feed do you apply each month?

	First month (kg)	Second month (kg)	Third month (kg)	Fourth month (kg)	After fourth month (total)	Total/year
Commercial feed						
Nursery						
Starter						
Grower						
Finisher						
Homemade feed						
Other (specify)						

3.5 What organic fertilizers do you use (if any)?

☐ Compost ☐ Non-composted vegetative matter (e.g. crop residues)

☐ Manure ☐ Poultry litter ☐ Other (please specify)

3.6 How often is organic fertilizer applied? (Tick the appropriate box)

☐ Once a week ☐ More than once a week ☐ Once every 2 weeks

☐ Once a month ☐ Once a year

3.7 What quantities (kg) are applied each time?

	Pre-stocking	Post-stocking
Compost		
Non-composted vegetable matter		
Manure		
Other		

3.8 What inorganic fertilizers do you use in the ponds?

Name

Total kg/year

3.9 What do you do with floating feed leftovers, if you have any?

☐ No action ☐ Collect the leftovers

3.10 How do you know that you provide the fish with enough feed?

3.11 How long do you store the feed maximumly?

	Days	Place for storing	Condition of storing (Ground=1, Raised=2, Both=3)
Commercial feed			
Sinking			
Floating			
Homemade feed			
Other (please specify)			

3.12 Are you (person responsible) familiar with the standard procedures (rates of feed and fertilizer application, predator control, pond maintenance, etc.) for the culture system practiced?

☐ Yes ☐ No

3.13 If not, in your opinion does this unfamiliarity explain your low fish yields?

☐ Yes ☐ No

3.14 If the respondent is familiar with the standard procedures, does he actually apply the procedures in his culture system?

☐ Yes ☐ No

3.15 If the respondent does apply the standard procedures, are there any reasons that you can observe or that the respondent gives for not attaining normal productivity?

3.16 Can you (respondent) obtain inputs from the sources of supply that you prefer?

☐ Yes ☐ No

3.17 Do you (person responsible) have customers available to sell his product to most of the time?

☐ Yes ☐ No

3.18 Do you (person responsible) think the price is satisfactory?

☐ Yes ☐ No

Part 4. Pond and water management

4.1a Do you do pond preparation after each culture cycle?

☐ Yes ☐ No

4.1b How do you prepare the ponds?

Kinds of pond preparation	How long or how often?
Pond drying	______________________
Mechanical removal of mud	______________________
Others	______________________

4.2a Do you treat the ponds with chemicals?

☐ Yes ☐ No

4.2b If yes, how do you apply chemicals in pre-stocking?

Kinds of chemical	Dose	Costs/unit (BDT)
Lime (kg)		
BKC (benzakonium chlorine) (kg)		
Chlorine (kg)		
Formalin (L)		
Zeolite (kg)		
Other (specify)		

4.2c If yes, how do you apply chemicals in post-stocking?

Chemical	**Dose**	**Costs/unit (BDT)**
Lime (kg)		
BKC (benzakonium chlorine) (kg)		
Chlorine (kg)		
Formalin (L)		
Zeolite (kg)		
Other (specify)		

4.3 Do you do water exchange during the culture period?

☐ Yes ☐ No

4.4 How often do you add/change water into the pond?

____

4.5 What percentage of the water do you change?

____

4.6 Do you measure the water quality in the fish pond?

☐ Yes ☐ No

4.7a If yes, what parameters do you measure?

Parameters	**Frequency (daily, weekly, monthly, etc.)**	**Location of the measurement**	**Person responsible**
Alkalinity			
pH			
Temperature			
Dissolved oxygen (DO)			
Secchi visibility			
Other			

4.7b If not, please explain why.

____

Part 5. Biosecurity and diseases

5.1a Do you have any net fencing surrounding the pond?

☐ Yes ☐ No

5.1b If yes, why?

____

5.2 Do you have any domestic animals entering the pond?

☐ Yes ☐ No

5.3 Do you use the pond for household purposes (bathing, washing clothes, cleaning pots, etc.)?

☐ Yes ☐ No

5.4a Do you follow any disinfection procedure for items used daily?

☐ Yes ☐ No ☐ Partly follow

5.4b If yes or partly follow, how?

5.5a Did you face any abnormal mortalities last year?

☐ Yes ☐ No

5.5b If yes, what was the nature of the mortalities?

☐ Sudden and huge ☐ Gradually increase ☐ Irregular

5.6 What types of symptoms did you observe?

____

5.7 If you observed abnormal mortalities, do you know how the fish got infected?

☐ Water quality
☐ Spread from other fish species
☐ Caused by pond conditions
☐ Feed quality
☐ Other (please specify)

5.8 Did you use any treatment to reduce the symptoms?

Chemical	**Dose**
Other	

5.9 Was the treatment effective in managing the mortalities?

☐ Yes ☐ No

5.10 How did you know about the treatment?

☐ Seller ☐ Government officer ☐ NGO officer ☐ Marketing people ☐ Mass media

☐ Other (please specify)

5.11 How do you manage the dead fish?

5.12 How do you manage the water after disease?

5.13 Do you send any fish samples to a laboratory for testing?

☐ Yes ☐ No

5.14 Please describe the condition of the fish.

How many fish were affected?

What species?

What size of fish?

5.15 When did the disease outbreak occur? (Tick appropriate box or boxes)

January	February	March	April	May	June

July	August	September	October	November	December

5.16a Have you had any management problems or difficulties in Nile tilapia culture since the operation began? (Tick appropriate box or boxes)

☐ Lack of skilled manpower ☐ Lack of knowledge ☐ Loss/damage equipment
☐ Quality of fingerlings ☐ High cost of feed ☐ Financial problems
☐ Other (please specify)

5.16b If yes, how do you prevent or overcome them? Please elaborate.

____

5.17 How many times do fishery extension workers usually visit to offer advice?

☐ Never ☐ Once a week ☐ Once a month ☐ Once in 3 months ☐ Once a year
☐ Other (please specify)

Name of Interviewer		Signature		Date	
Verified by		Signature		Date	

Appendix 2. Recommended management practices

1. **Read and follow the manuals of feed additives and chemicals carefully.**
During farm visits, instructions for additives and chemicals were not always followed. In such cases, adding these substances might not have the desired effect. To optimize the effectiveness of additives and chemicals, manuals must be studied and followed carefully.

2. **Acclimatize fingerlings to the water quality and temperature of the pond before releasing.**
To minimize stress and optimize production, fingerlings should be gradually acclimatized to the water quality and temperature after arrival. This can be done by exchanging water between the pond and a container (e.g. by using a siphon). Keeping plastic bags containing fry on the surface of ponds to equalization the water temperature is not recommended, because the temperature in the bags will increase quickly because of strong sunshine. Acclimatization should be done in the shade. If there is no shade, fry should be released in the late afternoon before sunset.

3. **Surround the pond with nets or other fencing materials.**

4. **Manage water quality (pH).**
Tilapia can survive in pH ranging from 5 to 10. The optimal pH is between 6.5 and 8. pH can be reduced by applying zeolite (SiO2) at a dose of 250 kg/ha. Exchanging water can also reduce pH. pH can be increased by adding Dolomite $CaMg(CO_3)_2$ at a dose of 100–300 kg/ha each time during the afternoon over 2–3 days.

5. **Manage water quality (NH3).**
The following table shows some of the effects of high ammonia levels:

Ammonia level	Effect on tilapia
0.08 mg/L or above	Depressed feeding
0.2 mg/L or above	Some mortality occurs
1 mg/L or above	Mortalities, particularly among fry and juveniles
2 mg/L or above	Massive mortality

High ammonia levels can be avoided by applying molasses. A good dose is to apply 20 g of molasses to trap 1 g of ammonia-nitrogen. In the short term, however, the farmer should sharply reduce the feeding rate or even stop feeding until the ammonia concentration drops below 0.05 mg/L.

6. **Manage water quality (DO).**
Although tilapia can tolerate low oxygen levels, maintaining oxygen levels above 4 mg/L is preferable. DO can be kept above this incipient level by increasing the inflow of well-oxygenated and/or cooler water and/or removing the less oxygenated water at the bottom, by using the pond outlet, and replacing it with better oxygenated water.

7. **Purchase fry from a well-known hatchery or agent.**

8. **Adapt the feeding ratios according to the size of the fish.**
Take regular fish samples to determine size ,and calculate the amount of feed based on this. If the farmer's knowledge on this is insufficient, information on feeding ratios should be requested from the feed supplier.

9. **Avoid stocking mixed sex tilapia.**

Appendix 3. Standard procedure examples for tilapia culture

Life stage	Weight (g)	Requirements (%)
Fry	0.02-1.0	40
Fingerling	1.0-10.0	35-40
Juvenile	10.0-25.0	30-35
Adult	25.0-200.0	30-32

Source: Shiau (2002).

Table 13. Protein requirements for tilapia per life stage.

Lime requirements (kg/ha of $CaCO_3$)			
Mud pH	Heavy loams or clays	Sandy loam	Sand
4.0	14,320	7,160	4,475
4-4.5	10,740	5,370	4,475
4.6-5.0	8,950	4,475	3,580
5.1-5.5	5,370	3,580	1,790
5.6-6.0	3,580	1,790	895
6.1-6.5	1,790	1,790	0

Source: Boyd (1982).

Table 14. Lime requirements per mud pH and soil type.

	Prior to stocking	After stocking
Dried poultry manure	1,500 kg/ha	50 kg/ha/day
Dried cattle manure	3,000 kg/ha	100 kg/ha/day
Dried goat manure	3,000 kg/ha	100 kg/ha/day

Source: MIDA (1985).

Table 15. Organic fertilization rates for tilapia farming.

RESEARCH PROGRAM ON Fish

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Pursuing a research agenda through a network of multistakeholder partners, the CGIAR Research Program on Fish Agri-Food Systems (FISH) enhances the contributions of fisheries and aquaculture to reducing poverty and improving food security and nutrition. FISH is led by WorldFish, together with the ARC Centre of Excellence in Coral Reef Studies at James Cook University, Australia; the International Water Management Institute (IWMI); Natural Resources Institute (NRI) at the University of Greenwich, England and Wageningen University & Research (WUR), Netherlands. In regional contexts, the program partners closely with governments, NGOs, the private sector and research organizations to influence national, regional and global policy and development practice.

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