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Health management practices and occupational health hazards in shrimp and prawn farming in South West Bangladesh

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List of abbreviations

ANEP	Agriculture and Nutrition Extension Project
AIN	Aquaculture for Income and Nutrition
BFRI	Bangladesh Fisheries Research Institute
dec.	Decimal
DFID	Department for International Development
DoF	Department of Fisheries
FGD	Focus group discussion
FAO	Food and Agriculture Organization of the United Nations
g	Gram
ha	Hectare
IFSL	Improving Food Security and Livelihood
KU	Khulna University
kg	Kilogram
KSL	Knowledge Sharing and Learning
La	Large
L	Liter
M	Medium
m	Meter
mt	Metric ton
mg	Milligram
min	Minute
NGO	Non-Governmental Organization
no.	Number
PRA	Participatory Rural Appraisal
PL	Post larvae
S	Small
SPF	Specific Pathogens Free
SD	Standard deviation
USD	United States dollar
WSD	White spot disease
WSSV	White Spot Syndrome Virus

Executive Summary

A wide range of chemical and biological products are used in aquaculture to improve the health status and to prevent or cure diseases of cultured animals. The present study aimed to identify the health issues, management practices and occupational health hazards related to shrimp (*Penaeus monodon*) and prawn (*Macrobrachium rosenbergii*) farming in the southwest region of Bangladesh. A survey was conducted in January - March, 2016 using a structured questionnaire administered to 380 grow-out farms of three production systems including only shrimp, both shrimp and prawn, and only prawn. Eight diseases and/or symptoms were identified in the production systems. White spot disease and antenna and rostrum broken symptoms were major constraints for shrimp and prawn species, respectively. In total, 35 chemical and biological products (6 water and soil treatment compounds, 9 disinfectants, 4 antibiotics, 13 pesticides, 2 feed additives and probiotics) were used to improve health, and prevent or treat disease.

None of the farmers have any specific animal health management plan, access to disease/ pathogen diagnostic services or academic aquaculture education. The farmers practice strategies to reduce the impact of diseases such as multiple stocking, multiple harvesting, and polyculture, immediate harvesting in appearance of disease symptom, dead fish collection and buried underground. Fifty four percent farmers received short aquaculture training courses from different sources such as the Department of Fisheries (DoF), the Aquaculture for Income and Nutrition (AIN) project, and the Building Trade Capacity of Small-scale Shrimp and Prawn farmers in Bangladesh-Investing in the Bottom of the Pyramid Approach (STDF) project. Very few farmers (11%) prepared medicated feed, and for those who did there was little or no successful result of using medicated feed. A similar proportion of farmers discharge antimicrobial compounds into the environment, with the possibility of antibiotic resistance occurring. The majority of farmers (86%) reported direct contact with hazardous chemicals during the preparation of medicated feed using bare hands. Handling of hazardous chemicals and antimicrobials has caused skin lesions, skin allergies, rough skin, coughing and irritation in eyes for a lot of the farmers.

This study indicated the importance of improving farmers' knowledge, practice and diagnostic services to ensure safe and environmentally friendly application of hazardous chemicals and minimize losses due to disease. These measures could be facilitated though the DoF, academic and research organizations, and non-government organizations (NGO). Knowledge sharing and learning centers could be established at the community level through linking the DoF with NGOs and the local community. Low-cost laboratory facilities and service centers could be developed in order to provide technical support to local service providers through government extension units and NGOs. Further research is required to understand chemical usage and to develop a strategy and implementation plan for safer and more appropriate use of these chemicals.

Introduction

Shrimp farming is one of the fastest growing economic activities in the coastal areas of the Asia-Pacific region, accounting for more than 85% of world's farmed shrimp. Bangladesh is the fifth largest aquaculture producing country in the world (FAO, 2014) and the sector plays a significant role in the national economy of Bangladesh, worth 2.09% of the country's export earnings (DoF, 2015a). Frozen seafood earned USD 615.35 million of foreign exchange in the financial year 2013-2014, 86% of which was shrimp (DoF, 2015a). Shrimp farming activities directly and indirectly employ more than 0.6 million people in the country (Islam et al., 2005). However, expansion of this sector is often unregulated, uncontrolled, and uncoordinated (Deb, 1998; Metcalfe, 2003; Samarakoon, 2004; Alam et al., 2005). Disease outbreaks have been recognized as the biggest obstacle to the development of shrimp farming in the country (Alam et al., 2007; Faruque et al., 2008; Rahman and Hossain, 2009; Paul and Vogl, 2011; Karim et al., 2012; Hossain et al., 2013a). Disease problems of aquatic animals have a range of negative impacts on the livelihoods of rural farming communities and their dependents including loss of production, income, and assets (Amin, 2000).

A number of diseases have been reported in the Bangladesh shrimp farming industry (Alam et al., 2007; Faruque et al., 2008; Rahman and Hossain, 2009; Karim et al., 2012, Ali et al., 2016). Fluctuations in water quality (pH, temperature, dissolved oxygen etc.) make shrimp susceptible to stress, leading to diseases (Paez-Osuna et al., 2003). Farmers also often discharge water with uneaten feed and wastes directly into the environment, which renders it extremely susceptible to carrying and propagating pathogens. The intake of polluted water from neighboring farms often spreads water-borne pathogens from farm to farm (Paez-Osuna, 2001), although this can be prevented through proper management practices (Hasan et al., 2013). However, most of the farmers lack a good understanding of fish health and disease issues in their farming systems. Treatment decisions are consequently made without accurate disease diagnosis, resulting in the use of a range of chemical and antimicrobial compounds for the prevention and treatment of disease (Faruk et al., 2008; Ali et al., 2016), which has led to residue problems. Residues of potentially toxic substances such as pesticides or antimicrobials can accumulate in treated animals, resulting in a potential hazard for consumers and for the marketing and export of aquaculture products (Sapkota et al., 2008; Heuer et al., 2009) while extensive use of antibiotics in aquaculture can contribute to the development of antimicrobial-resistant pathogenic bacteria both inside and outside aquaculture facilities (Inglis, 2000; Le et al., 2005).

Most farmers use chemicals in aquaculture without taking protective handling measures (Ali et al., 2016). The inappropriate use of chemicals can contribute to occupational health hazards[1] and the risk of respiratory, skin and other infectious diseases.

Zoonotic pathogens such as Vibrio spp. and Aeromonas spp. pose particular risks to both human and crustacean health (Cole et al., 2009; Moreau and Neis, 2009; Watterson, et al., 2012). There is an unfortunate lack of knowledge about occupational health hazards among farmers and workers in shrimp farming sector in Bangladesh.

Accurate disease diagnosis is essential for effective treatment of cultured aquatic animals, and Bondad-Reantaso et al. (2001) recommended three options for the diagnosis of disease: 1) field observation of the animal and the environment, and clinical examination; 2) laboratory observations using parasitology, bacteriology, mycology and histopathology and 3) laboratory observations using virology, electron microscopy, molecular biology and immunology. However, laboratory access is very limited for farmers in Bangladesh. For practical purposes, because of the lack of access to laboratory facilities, identification of aquatic animal diseases through the recognition of outwardly apparent clinical symptoms is most frequently exercised.

In the present study, we assessed the health problems and management practices for brackish water shrimp (*Penaeus monodon*) and freshwater prawn (*Macrobrachium rosenbergii*) farming systems based on a systematic survey of 380 grow-out farms. The survey covered three farm groups with different farm sizes. They were a) shrimp farms in Khulna and Satkhira, b) prawn farms in Bagerhat and Khulna, and c) concurrent shrimp and prawn production farms in Bagerhat and Khulna. The objectives of the present study were:

- to identify the demographic characteristics of farm households
- to assess farmers' disease diagnosis capacity and sources of relevant information
- to identify shrimp and prawn health problems and their clinical signs
- to assess management practices related to shrimp and prawn health problems
- to estimate costs in shrimp and prawn farm operations
- to identify the occupational health hazards related to the use of chemicals

Materials and methods

Study area

This study was conducted in four upazilas of Bagerhat and two upazilas of Khulna district as part of the Improving Food Security and Livelihoods for Poor Farming Household Project (IFSL) working areas covering mainly shrimp and prawn farming systems. Three additional upazilas, one from Khulna and two from Satkhira located outside the IFSL implementation area were identified as having high concentrations of shrimp and prawn farming areas and were also included in the study to characterize shrimp and prawn farming systems (Figure 1).

Sample design

A stratified random sampling strategy was followed, as shrimp and prawn farming development occurs in a geographically dispersed area, making it difficult to sample representatively. Multistage processes were

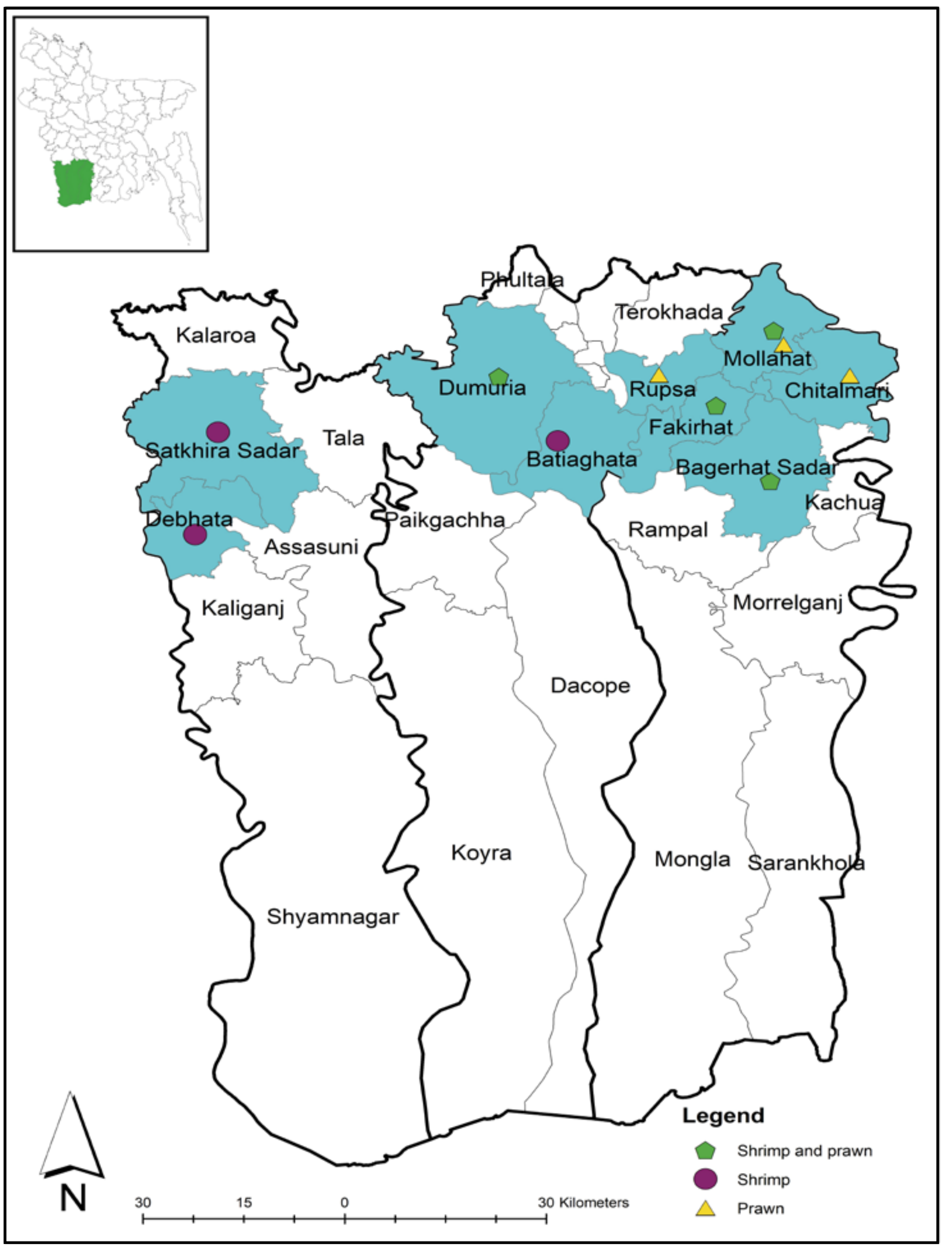


Figure 1. Map showing geographical distribution of study area.

followed to select sample farms for this study. Initial informal discussion sessions were organized with key informants (e.g. DoF officers, seed suppliers, feed and chemical suppliers, and development project officials) at the district level to identify the main aquaculture technologies. A further round of informal discussions was organized with key informants at upazila level to crosscheck findings and identify the unions and villages with highest concentrations of farms practicing the main aquaculture technologies. This was followed by field visits and village-level group discussions for further validation. When the potential villages were identified, 16 villages were selected randomly from a list of villages for further study (see Annex 1 for detailed information). Research staff conducted exploratory visits to all the selected villages and group discussions were organized in each village to develop village profiles. A census was conducted in each of the selected villages to identify the location of each individual farm owner and provide a sample frame for the structured questionnaire survey.

Survey design and data collection

The present study was conducted between January and March 2016. Six enumerators, who had completed Master's degrees in aquaculture, assisted in conducting the survey. A 3-day workshop was organized for the enumerators and survey supervisors prior to the implementation of the survey. A total number of 380 farms (out of 2015 farms) were surveyed randomly from the compiled farm census list, with interviews conducted of farm owners (99%) and farm managers (1%). These farms fit 95% confidence level with 5% error of margin which ensures the overall representativeness of the sample. The surveyed farms were divided into the three most important farm groups, defined in terms of the major species produced and the production technology used (see Table 1 for details of characteristics of the three farm groups). These farms were also classified into small (<0.61 ha), medium (0.61-1.41 ha) and large (>1.41 ha) farms. Participatory methods were used for primary data collection.

Questionnaire interviews

A structured questionnaire was developed for face-to-face interviews with main operators of grow-out farms. Information was collected on the education and training level of respondents and basic farm infrastructure and production characteristics (e.g. pond area, stocking density, input, production). The survey also covered detailed information on chemical and biological products used in aquatic health management (e.g. active ingredients, dosages, frequency of application) during the previous production season and whether they were used for

Farm group abbreviation	Main species	Main production system	Location	Number of farms surveyed
Shrimp	Shrimp (*Penaeus monodon*)	Improved extensive (brackish water gher[2])	Khulna/Satkhira	127
Shrimp and prawn	Both shrimp and prawn (*Macrobrachium rosenbergii*)	Improved extensive concurrent with rice (brackish water/ freshwater gher)	Khulna/Bagerhat	139
Prawn	Prawn	Improved extensive concurrent with rice (freshwater gher)	Khulna/Bagerhat	114

Table 1. Characteristics of the interviewed farms.

disease prevention or treatment. Interviews also incorporated less-structured in-depth discussions using disease picture cards (Annex 6) on the types and frequency of diseases, and the respondents understanding of the clinical symptoms of these diseases while the rationales for decision-making on chemical use were also explored. Respondents were asked about perceived health hazards associated with their work in farms, e.g. any protection equipment used when handling chemicals, understanding of toxicological and exposure risks of chemical use, and accidental occurrences due to use of chemicals. The draft questionnaire was pre-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. In order to triangulate the data on chemical and biological products reported by farmers, the data were cross-checked by comparing with product label indications and data from shops selling aquaculture chemicals.

Participatory rural appraisal

Participatory rural appraisal (PRA) is a method to collect information on a participatory basis from rural communities which allows a wider participation of the community, and information collected is thought to be more accurate (Chambers, 1994). The main PRA tool was focus group discussion (FGD) meetings which were organized at village level to obtain an overview of the main disease symptoms faced by each of the different farm groups. A set of disease picture cards (Annex 6) were shown in FGD sessions and respondents were asked about the main disease symptoms that they had observed during the production year 2015. Respondents were also asked about fish health management practices related to disease treatment or prevention and farmers' health hazards due to the use of chemicals. A total of 16 FGD sessions were conducted where each group size was 10-12 persons and the duration of each session was approximately 1.5 hours. These sessions were held in farmers' houses, in front of village shops, local schools and community clubs, wherever there were spontaneous gatherings and where participants could sit and feel comfortable.

Cross-check interviews with key informants

Key informants are persons with special knowledge on a particular topic. Key informants are expected to be able to answer questions about the knowledge and behavior of others, and about the operations of the broader systems (Theis & Grady 1991). Cross-check interviews were conducted with aquaculture medicine retailers and marketing representatives for veterinary chemical companies at the district, sub-district, union and village level. This was conducted to generate a database of product names and the principal active ingredients contained in such products, and to collect information on recommended dosages of the products.

Data processing and analysis

Compound classification

The reported chemical and biological products were classified into the following six categories: water and soil treatment compounds, disinfectants, antibiotics, pesticides, feedadditives, and probiotics. The main active ingredient(s) in each of the reported chemicals was recorded based on product labels.
Wherever unavailable, the active ingredient was obtained by searching the reported product name in the database generated during key informant interviews, and/or by cross checking the product name with published literature. The ingredient names identified were coded and entered into a customized electronic database, which was developed using MS Access software (Microsoft Corporation, Redmond, WA, USA).

Comparison of reported and recommended dosages

Farmers reported dosages that they had applied based on the amount of products used per unit area, and subsequently the farm-reported dosages were recalculated into standard dosage units. For example, mg L-1 or kg decimal-1 were calculated for the compounds added directly to water or mg per kg of feed for compounds applied mixed with feed. These dosages were compared with the maximum recommended dosages recorded from the labels of the products sold in the chemical supply shops. Where the recommended dosage information was not available, additional information was collected from published literature (e.g., Arthur et al. 2000; ANEP 2012).

Cost structure analysis

Farm production costs are grouped into variable costs and fixed costs. Variable costs include costs of seed, feed, fertilizer, chemical input (cost of water and soil treatment compound, antibiotic, disinfectant, pesticide, vitamin and probiotics), labor (family and haired), harvesting and marketing, and miscellaneous (cost of electricity, fuel, water supply). Cost of family labor was calculated as an opportunity cost to the farmer. Quantification of family labor was a challenging task because farmers were unable to accurately estimate the use of family labor for different purposes. To overcome this challenge, the daily lives of the family members were observed to collect data on their time allocation to different activities. Fixed costs included depreciation costs of capital items (i.e., water pump, net, harvesting trap etc.) and land use or lease costs.

Statistical analysis

Data from questionnaire interviews were coded and entered into a customized electronic database developed using MS Access (Microsoft Corporation, Redmond, WA, USA), then exported to MS Excel (Microsoft Corporation) and Statistical Package for Social Science,SPSS 16.0 (SPSS, Chicago, IL, USA). The data were checked for normal distribution before SPSS was used for analysis and producing descriptive statistics (mean, standard deviation and numbers). Results from data analysis, in combination with qualitative information collected through FGD and key informant interviews were used to describe the respondent and production characteristics, diseases and their symptoms, management practices, and occupational health hazards related to shrimp and prawn farming systems. A probability of less than 5% ($P \leq 0.05$) was considered as the level of significance in all instances.

Freshly harvested shrimps in Khulna, Bangladesh.

Farm group characteristics

Demographic characteristics of respondents

Almost all of the surveyed farmers were male and the average age was 42±11, 40±11 and 44±11 in shrimp, shrimp and prawn, and prawn farms, respectively (Table 2) All were classed as middle aged, considering the population of Bangladesh, suggesting that aquaculture is a livelihood option for rural households in the studied areas (Jahan et al., 2015). The number of years of formal education of farmers was found to be significantly higher ($p \leq 0.05$) in shrimp and prawn farms compared to only prawn farms and only shrimp farms. Aquaculture experience of shrimp, shrimp and prawn, and prawn farmers was 16±8.0, 14±6.8, and 15±6.5 years, respectively whereas aquaculture was the major occupation of 79% of households across the farm groups (Table 2). None of the farmers held higher educational aquaculture degrees. However, more than half of farmers sampled had participated in one or more aquaculture training courses from different sources such as Department of Fisheries (DoF), the Aquaculture for Income and Nutrition (AIN) or the Building Trade Capacity of Small-scale Shrimp and Prawn farmers in Bangladesh-Investing in the Bottom of the Pyramid Approach (STDF) project. Across all the groups they had attended training programs organized by the government extension services (16% farms), NGO extension programs (22% farms), and input (i.e., feed and chemicals) suppliers extension programs (16% farms).

Characteristics of farms

The mean farm size and water surface area of shrimp farms was 1.2±1.1 ha and 1.1±1.0 ha, respectively (Table 3) which was significantly higher ($p \leq 0.05$) than shrimp and prawn, and prawn farm. On the other hand, the water depth in shrimp farms was found to

Characteristics	Studied farm group			
	Shrimp	Shrimp and prawn	Prawn	Overall
Respondent age (years) (mean±SD)	42±11	40±11	44±11	42±11
Schooling years (years) (mean±SD)	6.2±3.9	7.6±3.1	5.9±3.9	6.6±3.7
Aquaculture experience (years) (mean±SD)	16±8.0	14± 6.8	15±6.5	15±7.1
Attended aquaculture education program (%)				
Government extension program	15	16	18	16
NGOs extension program	24	15	27	22
Input supplier extension program	9.6	16	21	16
Never attended	52	53	34	46
Major occupation of household head (%)				
Aquaculture	75	77	87	79
Agriculture	11	4.3	5.5	6.6
Self-employment	0.88	2.2	3.9	2.4
Daily labor	4.1	2.2	0.00	2.1
Salary employment	5.0	2.2	1.6	3.2
Trading	4.1	12	2.4	6.3

Table 2. Characteristics of the respondents.

be significantly lower than in other farm groups. The stocking densities of fingerling varied from 0.01 to 3.98 m-2 year-1 across the studied farm groups. However, shrimp farmers were found to stock higher ($p \leq 0.05$) densities of post larvae (PL) than shrimp and prawn, and prawn farmers (Table 3) which might be the result of multiple stocking over the culture period. The average total production (mt/ha/year) was highest in shrimp and prawn farms and lowest in shrimp farms.

Most of the shrimp, and shrimp and prawn farmers filled their ghers from canals and rivers as the main water source and depended on rainfall as secondary sources. The direct use of river water increased the chance of diseases entering the farms compared to ground pumped water and rain water (Islam et al. 2014). However, none of shrimp farmers used ground water, perhaps due to its expensive and low salinity levels. Furthermore, 23% shrimp and 2% shrimp and prawn farmers used neighboring farms as their source of water (Table 3) suggesting an increased likelihood of contamination and pathogen exposure. The intake of polluted water from neighboring farms often spreads water-borne diseases across different farms (Paez-Osuna, 2001). Conversely, rainfall was the main source of water for prawn farms. In some cases, farmers depended on multiple sources for water supply, particularly a combination of rainfall and groundwater. More than one quarter of shrimp, and 43% shrimp and prawn farmers exchanged farm water from rivers and canals at full and new moon with varying frequency at a rate of 5% to 80% of the total water volume annually. Almost all of the studied farmers dried their farms at the end of the season and the untreated water was discharged to canals (65% of farms), neighboring farms (23% of farms), rivers (8.9% of farms), and crop land (3.5% of farms). The direct discharge of wastewater may have negative effects on the surrounding water and soil (Deb, 1998; Flaherty et al., 1999). It is also risky when uneaten feed and wastes are discharged into the environment, as it could aid the spread of diseases (Paul and Vogl, 2011). On the other hand, nutrient enriched wastewater from shrimp and prawn farms also has the potential to increase the productivity of rice and other crops and reduce fertilizer costs (Haque et al., 2016), However, according to DoF (2011), the organic load and load of solid suspended materials of effluent water should be less than outside open water and farmers have to treat the wastewater before discharging it to any open water system. A number of options could be considered to mitigate the impacts of wastewaters from shrimp farms proposed by different studies. For example, polyculture of bivalve mollusks, fish, and shrimp (Lin et al., 1993; Sandifer and Hopkins, 1996), construction of wastewater oxidation-sedimentation ponds (Sandifer and Hopkins, 1996) and improvements in feeding practices and the nutrient composition of feeds (Avnimelech, 1999). Further research is needed to investigate the efficiency of these technologies in Bangladesh.

Characteristics	Studied farm group			
	Shrimp	Shrimp and prawn	Prawn	Overall
Farm type[a]	S (38), M (42), L a (47)	S (47), M (45), La (47)	S (55), M (46), La (13)	S (140), M (133), L a (107)
Farm area (ha) (mean±SD)	1.2±1.1	0.5 5±0.35	0.45±0.32	0.7 5±1.1
Farm surface water area (ha) (mean±SD)	1.1±1.0	0.46±0. 25	0. 39±0.28	0.66±1.0
Gher depth (m) (mean±SD)	0.81±0.15	0.92±0.19	0.97±0.26	0.90±0.21
Crop duration (days per year) (mean±SD)	299±17	283±31	264±33	283±31
Stocking density of shrimp/prawn (no./m^2) (mean±SD)	11±6.1	7.9±4.0	1.8±1.0	7.0±5.6
Stocking density of fish (no./m^2) (mean±SD)	1.0±1.5	0.15±0.20	0.10±0.10	0.42±0.95
Production (mt/ha/year) (mean±SD)	1.1± 1.0	1.5±0.85	1.2±0.83	1.3±1.0
Main water source (% of farm)				
River	23	26	0.00	17
Canal	54	44	3	35
Neighbor farm	23	2	0.00	8.4
Rainfall	0.00	28	97	39
Treat water before filling (% of farm)	0.00	0.00	0.00	0.00
Water exchange (% farm practicing)	28	43	11	29
Water exchange frequency (times/cycle)	5.6±4.9	4.9±3.4	1.6±0.9	4.6±3.9
Volume of water exchange (% of total water in gher)	43±20	26±14	12±10	29±19
Treat discharge water (% of farm)	0.00	0.00	0.00	0.00
Water discharge to (% of farm)				
River	10	15	0.00	8.9
Canal	54	72	69	64
Neighbor farm	36	13	19	22
Crop land	0.00	0.00	12	3.4

[a] S; Small, M; Medium, La; Large.

Table 3. Farm and production characteristics.

Disease diagnostic services

Disease diagnosis capacity and access to services

None of the studied farms had cultured animal health management plans and/or facilities in their farms. Fish and crustacean health management plans are recognized internationally as worthwhile parts of sustainable aquaculture management, often in the form of formally laid-out "Better Management Practices" (for example, see Belton et al. 2011). No such standards have been adopted for shrimp or prawn culture in Bangladesh. However, according to focus group discussions, farmers have adopted a few strategies to minimize the impacts of disease outbreaks such as multiple stocking, multiple harvesting, polyculture, and immediate harvesting, dead fish collection and underground burial once diseases appear. None of the subjects in our study group had formal training in disease diagnosis, suggesting poor capacity of farmers to diagnose disease accurately. Most of these farmers (92%) across farm groups reported that they have the capacity to identify some of disease symptoms based on prior experience (Figure 2) and no significant difference in disease diagnostic capability was apparent between small and large farms. In addition, 50% farmers also consulted with neighboring farmers and friends to assess disease symptoms. The tendency to visit chemical shops for diagnostic service was found to have higher likelihood in small than in medium and large farm groups. More than half of the shrimp and prawn, and prawn farmers used these services although it is noteworthy that the shop operators did not receive any specific disease diagnostic training, but almost all had attended a few sessions organized by aqua-medicine companies to become more familiar with the actions of chemicals. This indicates a need for further capacity building of local chemical shop operators and end-users to ensure proper diagnostic services and the use of appropriate medicines. According to interviews with chemical shop operators, they occasionally consulted with medicine company representatives to identify diseases based on symptoms and to take decisions on applying appropriate medicines. Also, a limited number of farmers went to government and NGO extension staff to identify diseases (Figure 2). The diagnosis of disease based on limited capacity is very difficult as superficial diagnoses based on clinical syndromes can be challenging. For example, definitive identification of the economically important white spot syndrome requires the use of laboratory facilities (Hossain et al., 2015; Karim et al. 2012). Farmers and farmer associations should develop linkages with research institutions that have diagnosticcapabilities and appropriate laboratory facilities like Bangladesh Fisheries Research Institute (BFRI) and Khulna University (KU).

Source of chemical use information

Farmers generally purchase chemicals from nearby shops, which were often the same as those supplying fish and crustacean seed (fingerlings and PLs) so familiarity and established networking plays a huge part in selecting the source of chemicals. Eighty seven percent of the farmers studied across different farm groups reported deciding to use medicine for fish health management based on their previous experience and/or following consultations with neighboring farmers or friends; however, 46% farmers also relied on the advice of the chemical shop operators (Annex 2). In general, farmers applied lime based on prior experience, but antibiotics, disinfectants, and pesticides were also applied following suggestions from chemical shop operators. Some farmers reported that the effect of the medicines was not satisfactory, but that could have been the result of applying the wrong medicines (Annex 2). Only 13% of farmers kept written records for management practices for cultured animal health including chemical types, amount, and month of application. The tendency to keep written records was found to be highest in large farms (28%), followed by medium (13%), and lowest in small (2.9%) farms (Annex 4). The identification of disease problems and treatment practices is important for health management of aquatic organisms. Fifty two percent of farmers suggested that NGO extension services need to be improved, while 44% wanted improved government extension services and 29% preferred locally trained service provider to be improved. Twenty four percent wanted the establishment of low cost laboratory facilities at farm level for better access to diagnostic services and knowledge on fish health management. According to the focus group discussions, the majority of large farmers are willing to pay disease diagnostic service charges in order to get better services. It is recommended to focus on improving the role of chemical shops in dissemination of information on prudent use of antimicrobials and other chemicals.

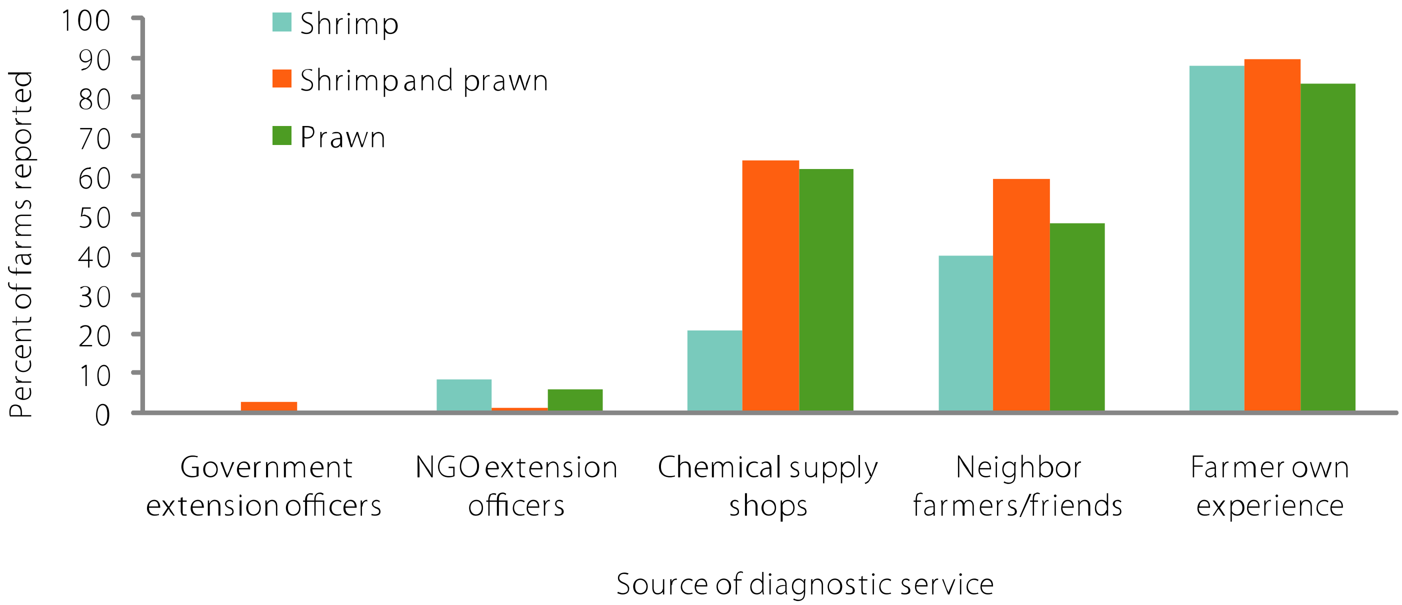


Figure 2. Sources of disease diagnostic service.

Animal health issues

The farmers reported nine different types of diseases and/or symptoms for shrimp and prawn species during 2015 (Table 4). These diseases were classified into four categories; viral disease, bacterial disease, fungal disease and other diseases. White spot disease (WSD) was the major disease reported for shrimp with 90% shrimp farms, and 40% shrimp and prawn farms having encountered it. This result is consistent with studies conducted by Shahabuddin et al. (2012). On the other hand, antenna and rostrum broken symptom was common for prawns (82% for prawn farms and 72% for shrimp and prawn farms), although farmers did not face serious any economic losses due to this symptom.

Viral diseases

Regardless of the specific disease problems occurring for shrimp species, farmers normally referred to them as "viral diseases". However, none of the farmers proceeded to isolate and identify any of the viral pathogens causing the disease. Karim et al. (2012) reported that white spot virus, now commonly referred to as white spot syndrome virus (WSSV- Annex 5) is responsible for WSD. It is generally regarded as one of the major constraints to the sustainability and further expansion of the shrimp sub-sector in Bangladesh. In the study, shrimp farms reported one to four WSD incidents per season (mean: 2); on the other hand, shrimp and prawn farms reported one to three incidents per season (mean: 1.5). Across the farm groups, 36% of the small farms reported experiencing WSD whereas 58% large farms reported the same (Annex 3). Most of the shrimp farms fall into large farm category that generally draw water directly from rivers, which may contribute to pathogen exposure and disease outbreaks (Islam et al. 2014). Water management is challenging for large farms and poor water management in shrimp is a major contributor to disease incidence due to the possible virus-contamination (Alam, 2007). WSD was experienced by 90% shrimp and 40% shrimp and prawn farmers (Table 4) and serious production and economic losses of shrimp generally occur within 3–10 days of WSD incidence (Lightner 1996). Farmers reported that WSD mainly appeared from April to August (Figure 3) possibly because of temperature and salinity fluctuations due to heavy rainfall, which is consistent with the conclusions of Debnath et al. (2012) and Islam et al. (2014). The effects of WSD grow more severe if the shrimp are exposed to extremely low salinity because WSSV affects the epithelial tissues of the gills that are involved in shrimp osmoregulatory (salt and water balance) processes (Funge-Smith, 1997) The farmers reported three most important clinical symptoms of WSD: (i) White spots on the carapace (shell) and/or sometimes on whole surface of the body (99% of affected farms reported) (ii) aggregation at the gher edges (66% of farms reported), and (iii) sluggish movement (64% of farms reported). Focus group discussions (FGD) revealed a few other symptoms such as decreased appetite, reduced preening activities, swimming erratically or spinning near the gher surface and reddish discoloration (Table 4). Takahashi et al. (2003) and Alam et al. (2007) characterized this disease by the presence of white spots on the carapace and the body and the color of affected shrimp becoming pale or reddish. The WSD affected shrimp displayed rapid reduction in feed intake, lethargy, increased difference in size, gathering close to the pond surface, swimming near the pond-edge, and reddening of body and appendages (Corbel et al., 2001; Pazir et al., 2011; Monwar et al., 2013; Jahan et al., 2015). During the FGD sessions, all farmers reported that severe disease occurrence typically starts among shrimp of 10-15 g at the age of one and a half months, and continues at reduced intensity up to the age of two and half months. Not all of the shrimp were affected at the same time, partly because of multiple stocking and partial harvesting practices. Farmers also reported collecting dead and disease affected shrimp manually. Although most of the dead shrimp were buried underground, some farmers also reported consuming them and occasionally selling them at discounted prices in the market. Around one quarter of farms did not practice any treatments in response to the appearance of disease in farms. However, 51% farmers applied lime and 34% farmers used disinfectants (e.g. sodium percarbonate, chlorine) to disinfect farm water, and 10% of farmers said they used pesticides.

Bacterial disease

Three different types of bacterial diseases were identified in the study farms. Hepatopancreatic necrosis (Annex 5) is a bacterial disease caused by Vibrio spp (Zorriehzahra and Banaederakhshan, 2015) and 14% of prawn farms and 7.2% shrimp and prawn farms reported that they had observed this disease. Symptoms include swelling of gills, water

Diseases/symptoms	Percent of farm reported			Clinical symptoms
	Shrimp	Shrimp and prawn	Prawn	
Viral disease				
White spot disease	90	40	0.00	White spot mainly on carapace and/or sometimes a little bit on whole body surface, aggregation at the gher edge, sluggish movement, less appetite, reduced preening activities erratic or spinning swimming near to gher surface, reddish discoloration
Bacterial disease				
Hepatopancreatic necrosis	0.00	7.2	14	Swelling of gills or water accumulation under carapace, sluggish movement, erratic swimming at gher edge, less appetite, discoloration of hepatopancrease
Vibriosis	9.4	2.9	0.00	lethargic, black spot on different parts of the shell, abnormal swimming behavior at the edge or surface of gher
Fungal disease				
Cotton shrimp	3.9	1.4	0.00	Spongy body, sluggish movement, opaque and whitish muscle (looked like cooked shrimp)
Unidentified disease	10	0.00	5.3	Blue or greenish scum on body surface, lethargic, less appetite, aggregation near the gher bottom
Other diseases				
Antenna and rostrum broken	0.00	74	82	Antenna and rostrum broken, erosion of antenna and rostrum, lethargic, less appetite, aggregation at the gher edge
Black gill disease	0.00	19	17	Black spot on gill under carapace, bacterial erosion on carapace and gill, sluggish movement, less appetite, damage gill
Soft shell disease	0.00	10	12	Shell is thin and persistently soft, shell is rough and wrinkled, lethargic, slow growth rate

Table 4. Diseases and symptoms reported by the farmers.

accumulation under the carapace (in the head), sluggish movement and erratic swimming at gher edge. Although most of the affected farms (73%) did not use chemicals to treat disease outbreaks, water and soil treatment compounds, disinfectants and antibiotics were used by 19%, 3.8% and 3.4%, farms, respectively to treat hepatopancreatic necrosis outbreaks.

In addition, 4.5% of the farmers reported vibriosis disease (caused by Vibrio spp.) in their shrimp (Alavandi et al., 1995). Vibriosis often acts as an opportunistic pathogen or secondary invader, causing mortality ranging from slight to 100% among affected animals depending on the degree of stress (Lightner, 1988). Clinical manifestations include lethargy, black spots on the shell and abnormal swimming behavior at the edge or surface of gher. Moreover, the pereopods and pleopods of affected shrimp may appear reddish due to the expansion of chromatophores and there may be slight flexure of abdominal musculature (Alavandi et al., 1995). In the present study, only one quarter of affected farmers applied water and soil treatment compounds and disinfectants to treat disease outbreak. A poor pond environment, poor water quality parameters, and deteriorating pond bottom conditions are recognized as significant contributory factors that can result in fish farm bacterial disease outbreaks (FAO, 1997; Alam et al., 2007).

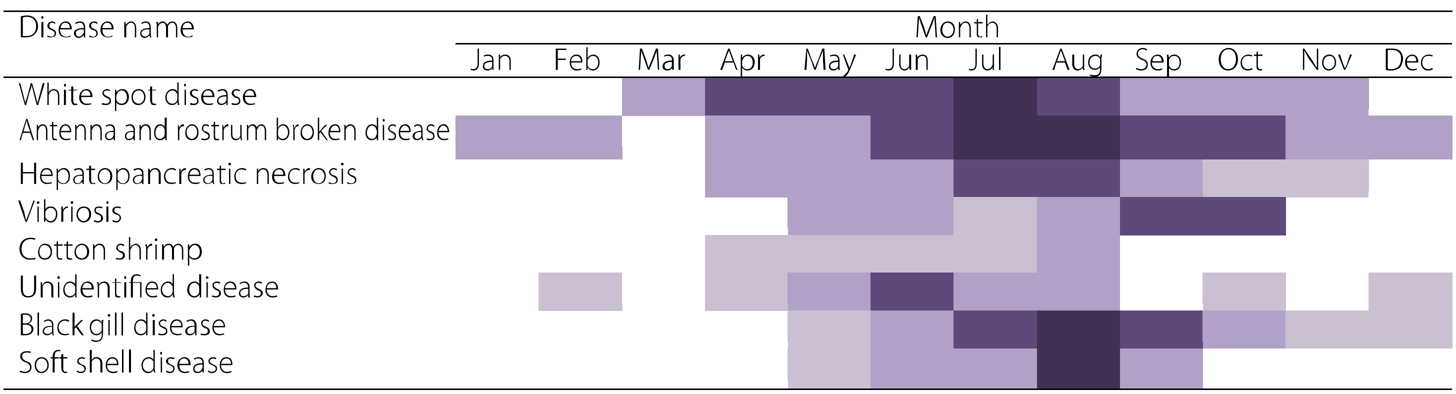
Fungal infections

Fungal diseases often cause extensive losses although fungi are usually considered to be secondary invaders following physical and physiological injury, or exposure to poor quality water (low dissolved oxygen, and high organic loads) due to inadequate water circulation. In the present study, an unidentified fungal disease was reported by 10% of shrimp farms and 5.3% of prawn farms. The symptoms of the disease were the appearance of blue or greenish scum on the body surface, lethargic behavior, and reduced appetite. Moreover, 3.9% of shrimp and 1.4% of shrimp and prawn farms also reported observing cotton shrimp disease which has symptoms including spongy body and sluggish movement and blue or greenish scum on body and opaque and whitish muscle accumulating on the abdomen (an appearance that resembles cooked shrimp). Alavandi et al. (1995) described the cotton shrimp disease as follows; muscle of affected shrimps appears cooked and the exoskeleton appears bluish black, with white tumor-like swellings that may be found on gills and sub cuticle. Most of the farmers (73%) did not take any management practice to treat the disease outbreak. However, a small number of farms applied water and soil compounds to disinfect the affected farm water.

Other diseases

Other diseases such as antenna and rostrum broken symptom (Annex 5), black gill disease, and soft shell disease were identified in the study. Among them, antenna and rostrum broken was a very common problem for prawn species and 82% prawn and 74% shrimp and prawn farms experienced this during the most recent production cycle (Table 4). On the other hand, none of the farmers reported this symptom in shrimp. Prawn farmers experienced one to three antenna and rostrum broken symptom outbreaks per season (average: 1.39) whereas shrimp and prawn farms reported one to four outbreak per season (average: 1.40). Prevalence of the disease was 54% of small scale, 53% of medium scale and 47% of large scale farms (Annex 3). Figure 3 shows that it mainly appeared from June to October when the water quality and pond conditions generally deteriorate. Farmers reported different clinical manifestations in the antenna and rostrum including broken antenna and rostrum (87% of farms), erosion of antenna and rostrum (53% of farms), and lethargic movement (30% of farms). Prawns are susceptible to broken antenna and rostrum problems and display antenna and rostrum rotting, infection and ulceration of the antenna that may eventually spread to head, and removal of the rostrum (MacRae et al., 2002). According to the FGD, in addition to the above conditions, affected prawns also showed reduced appetite and accumulation at the gher edge. However, many farmers also reported these symptoms for bacterial diseases. Almost half of the farmers (43%) applied water and soil treatment compounds followed by disinfectants (33%), antibiotics (11%). On the other hand, 16% farms did not have any management response to bacterial diseases on their farms. Black gill disease was reported by 19% shrimp and prawn farms and 17% prawn farms for prawn species only (Table 4) and it mainly appeared at the time of harvesting. This disease is mainly caused by the precipitation of nitrogenous wastes in ponds with high levels of ammonia and nitrite, usually occurring near the end of the growing cycle when the water quality has deteriorated (MacRae et al., 2002). Clinical manifestations included black spots on gills under the carapace, gradual turning black over the entire gill region with atrophy and necrosis, bacterial erosion on carapace and gill, sluggish movement, and decreased appetite. Of the disease affected farms, 40% reported applying antibiotics to mix with feed whereas 31% and 18% farms reported applying water and soil treatment compounds and disinfectants respectively.

Soft shell is another key disease of prawns and the aetiology of this disease is unknown. However, adverse environmental conditions, inadequate dietary protein, contamination through agricultural run-off, high soil pH, low organic matter content in soil, and low phosphate levels might be contributory factors. The outbreak of soft shell disease was found to be slightly higher in prawn farms (12%) compared to shrimp and prawn farms (10%). Symptoms include thin and soft shells, shells that are rough and wrinkled, lethargy, and slow growth rate. Most of the farmers did not apply any medicinal products for this disease; however, some farmers applied feed additives as nutritional supplements. Furthermore, some farmers with access to the resources also replaced the farm water.



Thickness of color indicates intensity of disease outbreak

Figure 3. Seasonal variation of different disease outbreaks.

Health management practices

Thirty five different chemical and biological substances were used the sampled farms as preventive measures and/or disease treatments (Table 5). These substances were classified into six groups based on their main intended use, but some of these substances were used for multiple purposes. The same active substance was in many cases represented by multiple products with different brand or trade names (for example, oxy-gold and quick oxygen are both brand names of sodium percarbonate). Therefore, the assessment is based on the main active substance contained in these products, rather than the products themselves.

Chemical and biological products use in health management

Water and soil compounds

Almost all of the sample farms used at least one kind of soil and water treatment compound in their farm management. Among them, liming compounds (e.g. calcium carbonate and calcium oxide) were applied by all of the farm groups (Table 5). Around three quarters of farms applied these compounds directly to the water or sediment to neutralize acidity, and/or as a disinfectant to kill pathogens and potential pests. Generally, the liming compounds were mixed with water and applied to the pond water and sediments to neutralize acidity and increase total alkalinity (Boyd and Tucker, 1998). However, some farmers have also reported the use of liming compounds to treat disease outbreaks and minimize the effects of these diseases. In the present survey, zeolites were used by 39% farmers across the farm groups. The majority of the farms used it to reduce the turbidity in the farm water to facilitate phytoplankton growth. Removal of ammonia was also reported to be a key purpose of zeolite. Nevertheless, the efficacy of this practice has been broadly questioned (Boyd, 1995; GESAMP, 1997) since the ammonia absorption is greatly repressed by the high concentrations of dissolved cations in brackish waters, meaning that the cavities of zeolites can hardly absorb any gases. In some cases, farmers also reported using zeolite to treat disease outbreaks and control pathogen. Zeolite has also reportedly been used to remove ammonia and hydrogen sulfide gas to minimize toxicity and limit exposure to pathogens (Ali et al., 2016). Farmers among various farm groups reported using aluminum potassium sulfate and calcium magnesium carbonate to decrease the turbidity in their culture water and in the treatment of disease outbreaks. Furthermore, some farmers used sodium thiosulfate to treat disease outbreaks (mainly antenna and rostrum broken disease in prawn) and as a disinfectant for farm water between production cycles.

Disinfectants

Ten different active ingredients were applied by half of the sample farms (Table 5) for disease prevention, being applied directly to the water during the production cycle and/or to treat disease outbreaks. The percentage of farms that reported using disinfectants was highest in shrimp and prawn (52%) farms followed by shrimp (47%) and prawn (46%) (Figure 4). Disinfectants were mainly used for disease prevention (65%) and to control disease outbreaks (35%). Commonly used disinfectants were potassium permanganate, hydrogen peroxide, sodium percarbonate, and chlorine and chlorine releasing compounds such as quaternary ammonium compounds (i.e., benzalkonium chloride) (Table 5). Potassium permanganate was reportedly used on shrimp (22%), prawn (9.6%) and shrimp and prawn (7.2%) farms to treat infectious disease as well as to disinfect farm water. It is a strong oxidizing agent used to treat fungal infections and as a piscicide or general disinfectant, principally in aquaculture (Ali et al., 2016). Chlorine and chlorine releasing compounds were used by shrimp and prawn (35%), shrimp (34%) and prawn (21%) farms directly in the water to disinfect water and sediment between production cycles. In some cases, farmers also used these substances to treat disease outbreaks. Chlorine is widely used as a disease

Substance	Studied farm group			
	Shrimp	Shrimp and prawn	Prawn	Overall
Water and soil treatment compounds (n=6)				
Calcium carbonate	99	96	100	98
Calcium oxide	7.1	5.0	1.8	4.7
Calcium magnesium carbonate	4.7	3.6	0.88	3.2
Zeolite	43	42	32	39
Sodium thiosulfate	1.6	7.2	7.9	5.5
Aluminum potassium sulfate	7.1	1.4	3.5	3.9
Disinfectants (n=9)				
Sodium percarbonate	1.6	3.6	7.9	4.2
Hydrogen peroxide	0.79	6.5	8.8	5.3
Calcium peroxide	0.00	0.00	2.6	0.79
Tetra acetyl ethylene diamine	0.79	0.00	0.88	0.53
Potassium permanganate	22	7.2	9.6	13
Benzalkonium chloride	4.0	9.4	11	8.1
Chlorine	30	25	9.6	22
Potassium peroxymono sulfate	0.79	1.4	0.00	0.79
Unidentified	3.1	17	7.9	9.5
Antibiotics (n=4)				
Chlortetracycline	0.00	4.3	1.8	2.1
Oxytetracycline	0.00	24	2.6	9.5
Doxycycline	0.00	1.4	0.88	0.79
Neomycin sulfate	0.00	1.4	0.00	0.53
Pesticides (n=13)				
Rotenone	16	17	21	18
Saponin (teaseed cake)	0.00	8.6	1.8	3.7
Malathion	1.6	0.72	0.00	0.79
Methylene blue	0.79	10	0.88	4.2
Copper sulfate	14	0.00	0.00	4.7
Tobacco dust	8.7	0.00	0.00	2.9
Carbofuran	4.7	0.00	0.00	1.6
Diazinone	2.4	0.00	0.00	0.79
Cartap	6.3	0.00	0.00	2.1
Cypermethrin	0.79	0.00	0.00	0.26
Thiamethoxam	0.00	0.72	0.00	0.26
Endrin	2.4	0.00	0.00	0.79
Thydrine	3.1	0.00	0.00	1.1
Feed additives (n=2)				
Vitamin premix	2.4	10	7.0	6.6
Vitamin-C	0.79	12	5.3	6.1
Probiotics	13	11	4.4	9.5

Table 5. Chemicals in use and percentage of farms using chemicals.

preventative measure in intensive aquaculture (Graslund, 1998) and it also kills small crustaceans and other invertebrates that could act as vectors for the disease-causing organisms (Boyd, 1996; Dierberg and Kiattisimkul, 1996; Kongkeo, 1997). According to Ali et al. (2016), confirmed by the present study, the most commonly used oxidizing agents used in brackish water aquaculture in Bangladesh are hydrogen peroxide and sodium percarbonate. Oxidizing agents were used by prawn (17%), shrimp and prawn (10%) and shrimp (2.4%) farmers to increase dissolved oxygen in water, to reduce hardness and to prevent the formation of ammonia, thus improving water quality and the health status of cultured aquatic animals.

Antibiotics

Four antibiotic substances were used by farms in this study, (Table 5) all of which were approved by the national code of conduct for regulation of shrimp and prawn farming in Bangladesh (DoF, 2011). The Government of Bangladesh has restricted the use of chloramphenicol and the nitrofuran group, which are banned in all countries in aquaculture. However, famers can use approved chemicals with the advice of fisheries professionals or by qualified personal, who have education and knowledge in health and disease management of aquatic animals and they have to keep written document of all used products (DoF, 2015b). The highest frequency of application was in shrimp and prawn farms (30% of the farms applied antibiotics) followed by prawn farms (5.3%) (Figure 4). Most of the farmers (83%) applied antibiotics to treat mainly antenna and rostrum broken syndrome, and black gilldisease outbreaks and 17% farmers used then as a preventive measure. However, farmers of shrimp alone were not found to use any antibiotics in the present study. Compared with the results of the survey performed by Ali et al. (2016) during 2011-2012, the percentage of shrimp and prawn farms that use antibiotics has increased several times over last five years. These results suggesting a need to pay special attention to antimicrobial use in this sector and to search for reliable alternatives such as probiotics (Wang et al., 2008). The majority of the farms in the present study used their bare hands to mix antibiotics with feed. The most commonly used antibiotics were tetracycline (i.e., chlortetracycline and oxytetracycline) antibiotics to treat disease affected shellfish followed by doxycycline and neomycin sulfate. Tetracyclines are used in aquaculture in different concentrations and spectrums in most Asian countries (Baticados et al., 1990; Primavera, 1993; Faruk et al., 2008; Ali et al., 2016). These antibiotics are effective against a wide range of Gram-positive and Gram-negative bacteria, including the Gram-negative Vibrio spp. (GESAMP, 1997). However, regular application of antibiotics and the use of dosages below therapeutically effective dosages has resulted in the development of antibiotic resistance among pathogens, which compromises both human and cultivated animals' health (Holmström et al., 2003) with a consequent loss of the efficacy of these antibiotics (Dung et al., 2009; Bartie et al., 2012). Almost all farms in the present study used a single antibiotic compound. It must be noted, however, some antibiotic formulations used by farmers contained a mix of two different active ingredients (oxytetracycline and doxycycline; neomycin sulfate and doxycycline). In most cases, antibiotics were applied once a day mixed with feed for a period varying between one and five days.

Pesticides

The farms in this study used of a total number of 14 pesticide ingredients to kill unwanted organisms and to treat fungal infections in the culture species. The use of pesticides was highest in shrimp farms (48%) followed by the shrimp and prawn farms (33%) and prawn farms (24%) (Figure 4). There was a marked difference in the compounds used among the different farm groups. Shrimp farmers tended to rely on different types of pesticides more than the shrimp and prawn, and prawn farms (Table 5). It was found that 25% of shrimp and prawn, 22% of prawn and 16% of shrimp farmers used rotenone and saponin to kill unwanted animals entering the farms with the inflow water, which is consistent with the findings of Ali et al. (2016). However, saponin is also used to induce molting in shrimp aquaculture (GESAMP, 1997; Boyd and Massaut, 1999). Rotenone is the cheapest fish toxicant which is widely used in freshwater and brackish water grow-out farms to remove unwanted fish and other harmful aquatic organisms (Chowdhury et al., 2012; Ali et al., 2016). Rotenone is not associated with any food safety hazards (Boyd and Massaut, 1999). Nevertheless, the application of this substance to kill unwanted species in aquaculture is disruptive to the plankton community, often causing a significant decline in zooplankton, particularly affecting cladocera and copepoda (Ling, 2003). In the present study, 14% of shrimp farmers applied copper sulfate directly to the farm water to kill unwanted organisms between production cycles, which is highly toxic to the planktonic organisms (De Oliveira-Filho et al., 2004). The over use of copper sulfate in aquaculture may result in human health issues owing to bioaccumulation of copper in the cultured species (Li et al., 2005). Around 9.7% of shrimp farmers also used tobacco dust to kill unwanted organisms entering the farms with the inflow water before stocking post larvae and between production cycles. The highest frequency of application of methylene blue was found among shrimp and prawn farms (10%) followed by prawn (0.88%) and shrimp (0.79%) farms whereas malachite green was used by only one shrimp and prawn farm (0.72%). The fungicides (methylene blue and malachite green) are moderately to highly toxic to aquatic invertebrates, fish, and primary producers depending on their specific mode of action (Maltby et al., 2009). Malachite green is also used as a powerful bactericide (Hernando et al., 2007) but its use in aquaculture is internationally banned, as it is a recognized carcinogen (Srivastava et al., 2004). Generally, farmers did not report the use of any chemicals banned under the 2011 national code of conduct for the regulation of aquaculture in Bangladesh. Highly toxic insecticides and pesticides (i.e., carbofuran, diazinone, cartap, cypermethrin, thiamethoxam, endrin and thydrine) were used by some shrimp farmers during gher preparation and between production cycles to kill unwanted organisms. Possible effects of these substances on fish and human health may need clarification by further research. WorldFish recommends farmers to use

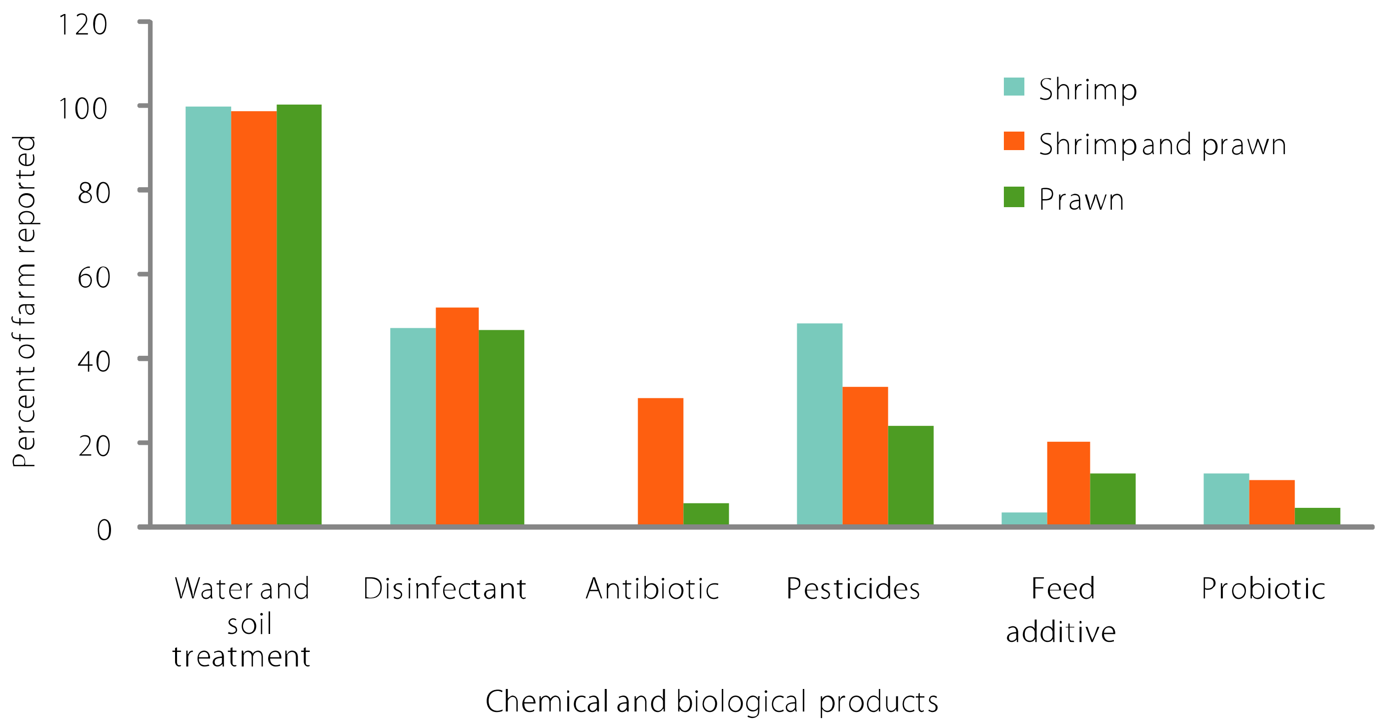


Figure 4. Percentage of farm groups uses chemical and biological products.

saponin, mahagoni seed (Swietenia mahagoni), neem leaves (Azadirachta indica), diesel, and kerosene to kill unwanted organisms in shrimp and prawn nursery and grow-out farms.

Feed additives

Feed additives (i.e., vitamin premix and vitamin C), mixed with feed or directly applied to the farm water, were most frequently used in shrimp and prawn farms (20% of farms), prawn farms (12% of farms), and shrimp farms (3.1% of farms) (Figure 4). In the present study, farmers reported using feed additives to improve immunological status, to ensure optimal diet quality for better growth, and to treat disease outbreaks. When used for disease treatment, feed additives are typically administered after mixing with feed once per day. To treat soft shell disease, farmers administered vitamins in feed to improve the immunological status of the shrimp or prawn while farmers also said they used both antibiotics and vitamin C mixed with feed to treat antenna and rostrum broken disease.

Probiotics

Probiotics are considered an environmentally safe alternative to the prophylactic use of antibiotics and are used to improve water quality and immunological status (Decamp et al., 2008; Wang et al., 2008). The use of probiotics was found to be the highest in shrimp farms (13%) compared to shrimp and prawn (11%), and prawn (4.4%) farms (Figure 4 and Table 5). Most of the probiotics marketed in the study area claimed to contain different concentrations of beneficial organisms such as *Bacillius spp., Nitrosomonas spp., Nitobacter spp., yeast, Rhodopseudomonas sp., Rodobacter sp., Rodococcus sp., and Streptococcus spp*. The bacterial genre were listed on the product labels but the species name and their concentration in the products were not usually declared. Farmers applied probiotics directly to the water in order improve its quality, to treat the disease outbreaks and to reduce stress. Probiotics compete with bacterial pathogens for nutrients and/or inhibit the growth of pathogens and are only effective and cost-beneficial when properly applied under suitable farm management conditions (Decamp et al., 2008). Therefore, knowledge of intestinal microbiology and effective preparation and safety evaluation of probiotics are very important for commercial aquaculture (Wang et al., 2008). In the surveyed farms the main types used were Bacillus spp., Nitrosomonas spp. and Nitobacter spp. with the aim of improving water quality, and survival, growth rates and the health status of shrimp and reducing the prevalence of pathogenic Vibrio spp. (Dalmin et al., 2001; Hossain et al., 2013b). According to key formant interviews and focus group discussions, the probiotics were effective but the majority of the farmers were unaware or skeptical about their use. The percentage of the surveyed farms using probiotics was very small compared to fish farms in other Asian countries, like shrimp and pangasius in Vietnam, and tilapia and shrimp farming in Thailand (Rico et al., 2013), where alternatives to intensive antimicrobial use have been intensively researched and implemented.

Preparation and use of chemical and biological products

Antimicrobial products and feed additives are generally mixed with feed in their powder form although liquid solutions are available as well. In both cases, farmers add the product into water with a container. The product is dissolved by stirring in with bare hands or with a stick. Next, the solution is added to 5 kg of pelleted feed or flattened rice and hand mixed. Farmers normally follow the dosage instructions provided by the chemical suppliers although some farmers based the dosage on the total weight of the fish as well. Medicated feed is then sundried for 20-30 min to ensure proper absorption of the medicine by the feed. Usually, farmers apply ordinary feed to the carp in their polyculture pond first and then apply medicated feed 15-20 min later to ensure that only prawns consume the treated feed.

The other compounds (e.g. water and soil treatment compounds, disinfectants, pesticidies, probiotics) used for improving water quality were diluted in the pond water and spread over the pond surface using a mug according to dosage instructions given by chemical shop operators, on own experience, and/or advice from neighboring farmers or friends. However, some farmers reported using probiotics mixed with sandy soil and spread over the water surface. On the other hand, all farmers who used zeolite reported applying it by spraying directly onto the water surface.

Comparison of reported and recommended dosages of chemical applied

A number of chemical and biological products were used to manage cultured animal health and the comparison between reported and recommended dosages for these products is presented in Figure 5 as ratios between reported and maximum recommended dosages. Across the studied farm groups, 59% reported single application dosages below the maximum recommended application dosages (ratios below 1) (Table 6). On the other hand, 5.3% of all the total number said they used dosages that exceeded recommended levels (ratios above 3) in shrimp farms (n=3), and shrimp and prawn farms (n=1). These cases mainly corresponded to applications of disinfectants and pesticides between production cycles. The majority (86%) of farmers said they used single applications of antibiotic at rates that exceed maximum recommended dosages (ratios above 1) which could result in significant antibiotic residues in aquaculture products (Alderman and Hastings 1998).

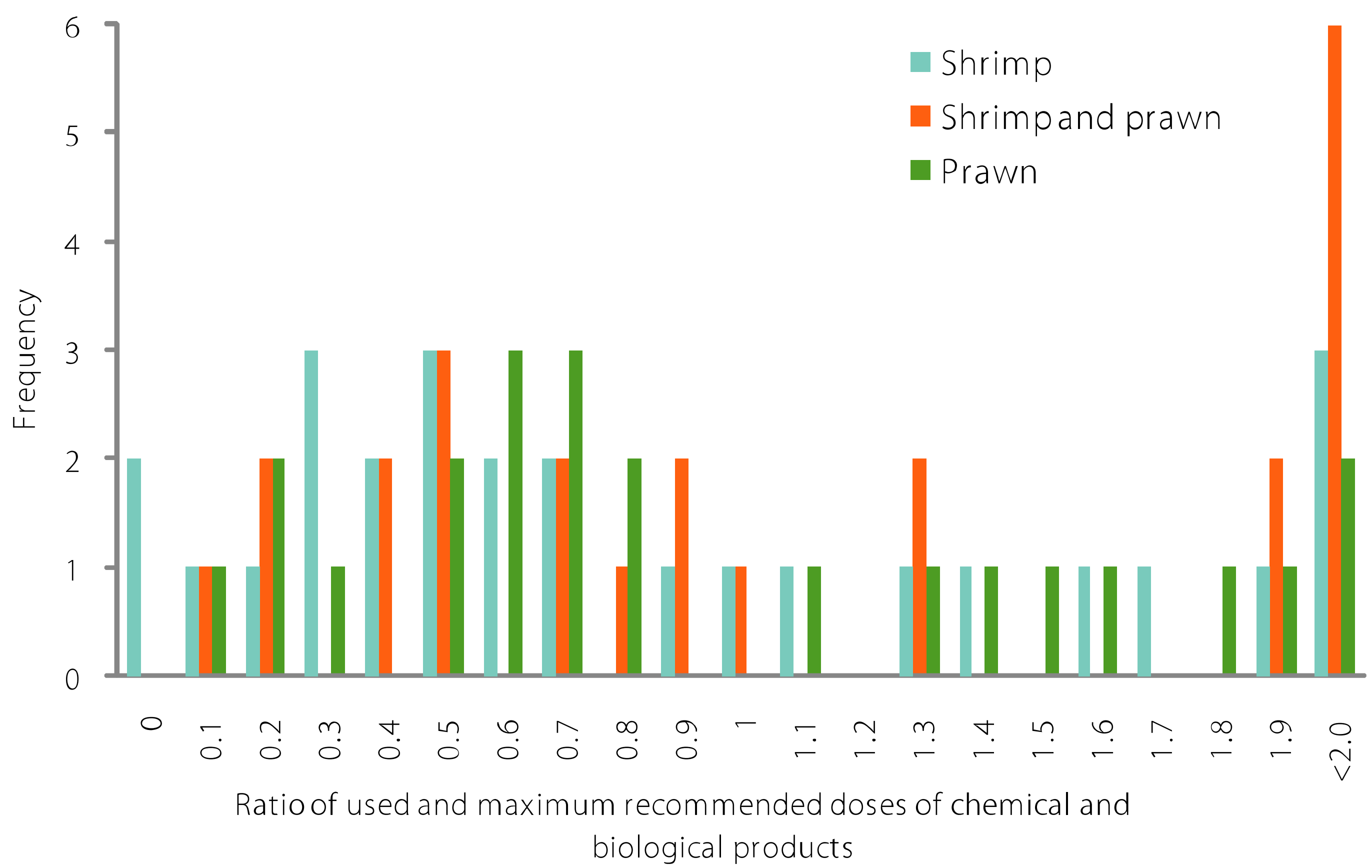


Figure 5. Ratios between applied and maximum recommended dosages of chemical and biological products.

Dosages type	Substance name	Reported dosage (average)	Recommended dosage	Unit
Under dosage	Calcium carbonate	0.66	1.00	kg/dec.
	Calcium oxide	0.42	1.00	kg/dec.
	Zeolite	2.87	2.05-4.10	mg/L
	Aluminum potassium sulfate	1.06	1.37-2.73	mg/L
	Hydrogen peroxide	0.12	0.05-0.14	mg/L
	Calcium peroxide	0.1	0.05-0.14	mg/L
	Potassium permanganate	0.2	0.5-2	mg/L
	Chlorine	3.99	5.47-6.84	mg/L
	Potassium peroxymono sulfate	0.1	0.08-0.16	mg/L
	Rotenone	0.41	1.09-1.97	mg/L
	Saponin	8.35	15 -19	mg/L
	Methylene blue	0.17	0.14-0.19	mg/L
	Malachite green	0.05	0.1	mg/L
	Copper sulfate	0.45	0.2-0.5	mg/L
	Carbofuran	0.06	1.09-1.37	mg/L
	Cartap	0.04	0.05-0.08	mg/L
	Cypermethrin	0.05	0.16-0.22	mg/L
	Endrin	0.05	0.03-0.08	mg/L
	Thydrine	0.05	0.05 -0.11	mg/L
Over dosage	Calcium magnesium carbonate	163	90 -151	g/dec.
	Sodiu m thiosulfate	0.61	0.33-0.55	mg/L
	Sodium percarbonate	0.31	0.05-0.14	mg/L
	Tetra acetyl ethylene diamine	0.06	0.05	mg/L
	Benzalkonium chloride	0.59	0.14 -0.27	mg/L
	Chlortetracycline	9.01	5	g/kg of feed
	Oxytetracycline	9.49	5	g/kg of feed
	Doxycycline	9.67	5	g/kg of feed
	Neomycin sulfate	7.50	5	g/kg of feed
	Malathion	0.24	0.14	mg/L
	Thiamethoxam	0.05	0.01	mg/L
	Vitamin premix	5.42	1-3	g/kg of feed
	Vitamin-C	4.70	1-3	g/kg of feed
	Probiotics	0.39	0.03-0.25	mg/L

Table 6. Dosages of chemical and biological products.

Chemical costs

In the present study, production costs are grouped into variable costs and fixed costs. The variable costs are seed, feed, fertilizer, chemical, labor, harvesting and marketing, and miscellaneous costs such as irrigation and water exchange. On the other hand, fixed costs include capital items and lease money. The average annual variable costs in shrimp and prawn farms were estimated at USD 1982 ha-1, compared with USD 1484 ha^{-1} in prawn farms and USD 630 ha-1 in shrimp farms (Table 7). There was a significant difference ($P \leq 0.05$) of variable costs in different studied farm groups. On average, variable costs accounted for 88%, 86%, and 72% of total costs in shrimp and prawn, prawn, and shrimp farms respectively (Table 7). Seed, feed and labor were identified as the three major production cost items in the farms with the exception of shrimp farms, for which the contribution of feed to total production costs was minimal. This is because natural feed significantly helps the growth of shrimp (Jahan et al., 2015). The seed and feed costs varied from 2.6 to 65% and 0.0 to 83%, respectively across all studied farms. On the other hand, the annual chemical costs ranged from USD 3.2 to 150 ha-1 for shrimp, USD 0.0 to 256 ha-1 for shrimp and prawn and USD 6.0 to 88 ha-1 for prawn farms. This suggests that it should be possible to reduce chemical costs in different farm groups by following proper management practices. However, Jahan et al. (2015) reported that the chemical cost varied from USD 23 to 74 ha-1 $year^{-1}$ for gher based aquaculture systems. Chemical costs amounted to 3.8% of total costs in shrimp farm compared with 2.2% in shrimp and prawn farm and 2.0% in prawn farm. Comparing chemical costs across all farms, water and soil treatment compounds contributed most to costs followed by disinfectants, antibiotics, pesticides, feed additives, and probiotics. Water and soil treatment compound costs on average amounted to 74% of the total chemical costs in shrimp farms, 55% in shrimp and prawn farms and 76% in prawn farms (Figure 6). Figure 6 also indicated that

Cost items	Studied farm group			
	Shrimp	Shrimp and prawn	Prawn	Overall
Variable costs (USD/ha)	630 (72)	1982 (88)	1484 (86)	1381 (84)
Seed	297 (34)	770 (34)	468 (27)	521 (32)
Feed	52 (5.9)	730 (32)	613 (36)	468 (29)
Fertilizer	17 (1.9)	4.5 (0.20)	4.1 (0.24)	9.0 (0.52)
Chemical	33 (3.8)	49 (2.2)	34 (2.0)	39 (2.4)
Labor	178 (20)	245 (11)	223 (13)	216 (13)
Harvesting and marketing	34 (3.9)	147 (7)	107 (6.2)	97 (6.0)
Miscellaneous	19 (2.1)	36 (1.6)	34 (2.0)	30 (1.8)
Fixed costs (USD/ha)	249 (28)	275 (12)	242 (14)	257 (16)
Depreciation	86 (10)	177 (7.9)	179 (10)	147 (9.0)
Lease money	164 (19)	98 (4.3)	64 (3.7)	109 (6.7)
Total costs (USD/ha)	879 (100)	2257 (100)	1726 (100)	1637 (100)

Figures within parentheses indicate the percentage of total costs

Table 7. Production costs and budget shares.

disinfectants and pesticide costs ranked second and third highest costs among total chemical costs across the farm groups. The average annual fixed costs were USD 249 ha-1, USD 275 ha-1, and USD 242 ha-1 in shrimp, shrimp and prawn, and prawn farms, respectively, were not significantly different. The contribution of fixed costs varied from 12 to 28% between the different types of farms.

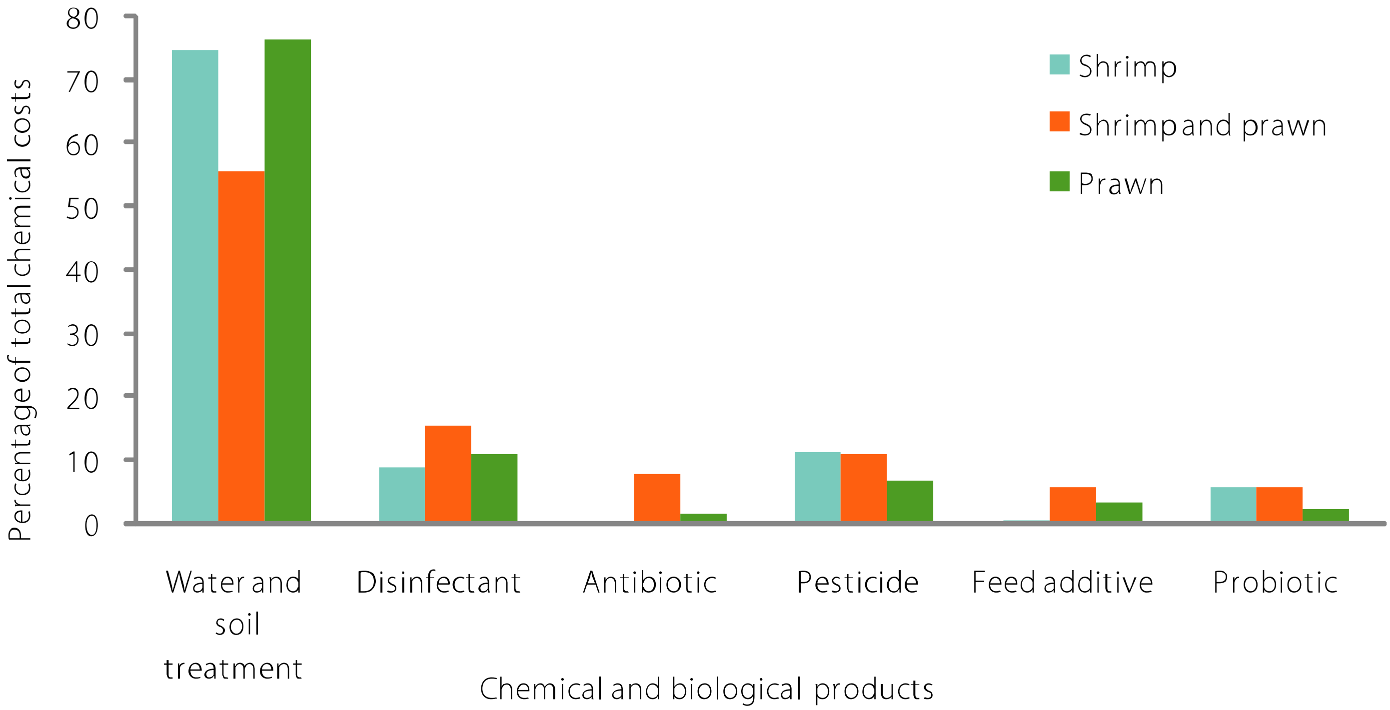


Figure 6. Percent of different chemical and biological products costs reported by studied farm groups.

Occupational health hazards

Most of the farmers (86%) reported that they had direct skin contact with chemicals and water containing chemicals through handling (Table 8). A higher rate was reported in small farms than in the large farms (Annex 4), perhaps because of greater awareness of the risks. Hands and arms have a particularly high risk of exposure due to hand mixing of antimicrobials into feeds and during the preparation and application of water and soil treatment compounds, disinfectants, and pesticides. Fifty eight percent of farmers used protective measures, mainly face masks and polythene, when handling chemicals and they were used more in large farms than in medium and small farms (Annex 4). However, face masks were made mainly of cloth that provided little protection against gaseous toxicants such as chlorine-based disinfectants. Health risks associated with antimicrobials and disinfectants include skin allergies and organ or systemic reactions (Erondu and Anyanwu, 2005). More than half of farmers reported that they were inspired by neighboring farmers or friends to use protection. However, they also reported wearing protection only if they had previously experienced health problems when handling a chemical compound or participated in an extension service program.

Most of the farmers have little knowledge or concern about the longer term health effects of the use of these chemicals used in their farms. Additionally, most of the packages containing disinfectants lacked adequately written health warnings on the product labels despite this being recommended practice (DoF, 2015b). Almost all of the farmers used agricultural lime which is safe to handle although some farmers used burnt lime which can cause blindness, and severe

Variables	Percent of studied farms reported			
	Shrimp	Shrimp and prawn	Prawn	Overall
Chemicals administrated according to				
Safety instructions on product label	2.4	2.3	6.7	3.6
Instructions by chemical supplier	19	56	52	42
Instructions by govt. extension staff	0.79	3.1	0.00	1.4
Instructions by NGO extension staff	22	3.8	7.6	11
Information from neighbor farmers/friends	29	40	18	30
Farmers own experience	70	56	53	60
Use protection during handling chemicals	46	71	56	58
Direct contact between skin and chemicals	75	59	75	68
Direct contact between skin and water containing chemicals	81	85	88	84
Farmers were informed about the health and environmental risks associated with chemical use	64	57	46	56
Farmers were instructed on safely handling of chemical	18	42	33	32
Farmers were informed about banned chemicals	43	20	25	29
Health problem faced followed by using chemicals (skin lesion, skin allergy, coughing)	53	41	46	46
Record keeping of chemical use	14	17	8.8	13

Table 8. Farmers perceptions on occupational health hazards associated with use of chemicals.

irritation following eye or skin contact (Boyd & Massaut, 1999). More than one quarter of the surveyed farmers reported receiving advice on safe chemical handling from chemical suppliers, extension service programs, and neighboring farmers or friends but they were unable to describe safe handling of chemicals, suggesting a need for further education and training. Fifty seven percent farmers in the present study reported that they stored the chemicals in their house or in the temporary shelters constructed for guards. One quarter of farmers said they have an idea about chemicals that have been banned for use in aquaculture. Also that they were instructed on how to handle chemicals safely and were informed about the associated health risks when handling chemicals. However, when farmers were asked to list the banned chemicals, they were only able to list one or two pesticides by name and they were not able to describe appropriate measures for safe handling of chemicals and associated health risks.

DoF (2015b) has developed guidelines for using chemicals in aquaculture and specified that farmers must keep detailed written records of any chemicals used. They must store chemicals safely, must wear protective equipment and must be instructed on safe handling. NGO programs supporting farmers in Bangladesh also recommend following these instructions as they should lead to reduced exposure to toxic chemicals and improved health of farmers and their families. However, 46% of farmers reported skin lesion, skin allergy, rough skin, coughing, and problems in their eyes after handling chemicals (Table 8), which calls for further studies involving specialized health experts and a focus on education and training.

Small trader buying shrimp from a farmer in Bagerhat.

Conclusions and recommendations

The present study revealed that nine different types of shrimp and prawn diseases were identified in the study area; of these, white spot disease and antenna and rostrum broken symptom were the most widespread of problems for shrimp and prawn species, respectively. Preventive measures can reduce the incidence of disease outbreaks in shrimp farms and a wide range of chemical and biological products are used to prevent and treat these diseases. However, some of the chemicals used could potentially pose a risk to aquatic animal health, the surrounding environment, and to human health. In addition, most of the farmers also discharged farm water into surrounding ecosystem without pre-treatment or cleaning. A small sediment trap pond could be set up in a corner of the gher for the treatment of wastewater which will improve the water quality as well as reduce the sediment, nutrient, and pollution load. The Department of Fisheries is the main institution for implementing rules and regulations for development of the shrimp and prawn farming sector in Bangladesh. Therefore, they should promote and enforce guidelines on wastewater treatment and pollution abatement. Farmers reported using probiotics which may provide an alternative to the increasing use of antimicrobial compounds in aquaculture has become more widespread in other Asian countries (Rico et al., 2013). Further intensive research is required to test the efficacy and carry out cost-benefit analysis of these products in Bangladesh. The need for further education and training for farmers and chemical shop operators about disease management was also apparent. Many of the farmers used chemicals based on their own assumptions or following advice from neighboring farmers and chemical shop operators without diagnosis of disease. However, disease identification can reduce the amount, costs, and undesirable side effects of chemicals without negatively impacting animal health and production. Most of the farmers reported that they had direct skin contact with the chemicals or water containing the chemicals when handling them with bare hands, which raises concerns about human health risks. Farmers who used antimicrobial products often did so without taking any protective handling measures, indicating a need for further education and training. A research in development approach could be helpful to understand chemical use patterns and to develop education and training plans and implementation for safer and more appropriate use of these chemicals.

The farmers often combat disease outbreaks through early harvesting and collecting and disposing of dead shrimp and prawns to reduce economic losses. However, none of the farms had animal health management plans or a good understanding of and access to diagnostic services, which are essential for prudent use of chemicals and effective disease prevention and control. There is an urgent need to improve knowledge on the prudent use of chemicals including the diagnostic capacities of farmers and their access to diagnostic and veterinary services through training on aquatic animal health and the provision of more responsive public services. Therefore, knowledge sharing and learning (KSL) centers could be developed at the community level in coordination with government extension units, development organizations, local service providers/chemical shop operators, and farmers. The centers should provide information including descriptions of disease symptoms, means of diagnosis, and ways to prevent and treat diseases. Low-cost laboratory facilities could be developed at farm level for easy access to diagnostic services and costs could be shared jointly among farmers, government extension units and development organizations (e.g. WorldFish). Chemical shop operators or local service providers are important sources of information on chemicals. However, chemical product sellers often promote the use of chemical treatments without proper disease diagnosis, which is a questionable practice. Therefore, it is important to develop the capacity of chemical shops and local service providers to provide improved diagnostic services to farmers.

An innovative approach is needed, reconsidering the roles of existing government and NGO extension services, and the private sector including chemical sellers in providing information to farmers. One approach might be the adoption of a comprehensive set of Better Management Practices for shrimp and prawn farmers in Bangladesh. Additionally, government research organizations and universities should working towards an improved system for evaluation the risks posed by chemicals used in aquaculture in Bangladesh, the establishment of an effective registration system and training on their safe use.

Nehar and his wife happy with their production in shrimp farming.

Photo credit: < M. Yousuf Tushar> < WorldFish>

A fish farmer showing shrimps caught from his pond in Khulna, Bangladesh.

Notes

1 Occupational health hazards are hazardsof farm operators for exposure of chemical and biological products used in their grow-out farms.

2 Shrimp, commercial shrimp culture in gher; shrimp and prawn, commercial shrimp and prawn culture in gher; prawn, commercial prawn culture in gher. The term gher refers to a paddy field which has been modified for shrimp or prawn production. Typically, paddy is cultivated in the middle of the field, which is surrounded by canals with high wide dikes into which the shrimp and prawn are stocked.

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Annex 1. List of surveyed farm group distributed by studied villages

Farm group	District	Sub-district	Union	Village	Number of surveyed farms
Shrimp	Satkhira	Satkhira sadar	Fingri	Ellarchar	28
	Satkhira	Satkhira sadar	Dhulihar	Matiadanga	32
	Satkhira	Debhata	Shokipur	Shokipur	24
	Satkhira	Debhata	Nowapara	Paikpara	22
	Khulna	Botiaghata	Gangarampur	Titukhali	20
Shrimp and prawn	Khulna	Dumuria	Shahos	Shahos	23
	Bagerhat	Bagerhat sadar	Shatgumbuj	Badokhali	21
	Bagerhat	Bagerhat sadar	Baraipara	Baraipara	25
	Bagerhat	Fokirhat	Mulgor	kolkolia	22
	Bagerhat	Fokirhat	Noldamoubon	Kathuli	24
	Bagerhat	Mollarhat	Gaola	Matiarghati	22
Prawn	Bagerhat	Mollarhat	Udoypur	Udoypur	16
	Bagerhat	Chitalmari	Hizla	Shibpur katakhali	23
	Bagerhat	Chitalmari	Santoshpur	Dariumazuri	20
	Khulna	Rupsha	Ghatvog	Dhopakhola	31
	Khulna	Rupsha	Shreefoltola	Shreefoltola	27

Annex 2. List of chemical information sources used by studied farm groups

Sources of information	Studied farm group		
	Shrimp	Shrimp and prawn	Prawn
Chemical uses			
Government extension agency	1.6	2.9	0.00
NGO extension program	31	6.5	11
Input supplier	46	41	54
Neighbor farmer/friend	56	46	40
Farmer own experience	65	69	53
Instructions follow			
Government extension agency	0.79	2.2	0.00
NGO extension program	30	5.8	7.0
Input supplier	69	71	77
Neighbor farmer/friend	44	37	32
Farmer own experience	44	45	35
Chemical shops			
Government extension agency	0.00	0.72	0.00
NGO extension program	3.1	1.4	2.6
Input supplier	0.00	5.8	0.00
Neighbor farmer/friend	42	50	56
Farmer own experience	72	66	61
Chemical quality perception			
Very bad	3.2	1.4	20
Bad	13	0.00	3
Moderate	19	22	20
Good	56	70	52
Very good	8.7	6.5	5.3

Annex 3. List of diseases reported by studied farms based farm size

Disease name	Percent of farm reported			
	Small	Medium	large	Overall
Viral disease				
White spot disease	36	43	58	44
Bacterial disease				
Hepatopancreatic necrosis	7.9	6.8	5.6	6.8
Vibriosis	7.9	0.8	4.7	4.5
Fungal disease				
Cotton shrimp	1.4	0.75	3.7	1.8
Unidentified disease	2.1	3.8	10.3	5.0
Other disease				
An tenna and rostrum broken	54	53	47	52
Black gill disease	8.6	15.0	13.1	12.1
Soft shell disease	8.6	7.5	5.6	7.4

Annex 4. Perceptions on occupational health hazards by different farm size

Variables	Percent of studied farms reported		
	Small	Medium	Large
Chemicals administrated according to			
Safety instructions on product label	2.3	3.2	5.8
Instructions by chemical supplier	47	39	39
Instructions by govt. extension staff	1.5	2.4	0.00
Instructions by NGO extension staff	14	10	10
Information from neighbor farmers/friends	26	30	33
Farmers own experience	55	64	62
Use protection during handling chemicals	52	60	64
Direct contact between skin and chemicals	74	68	63
Direct contact between skin and water containing chemicals	86	86	64
Farmers were informed about the health and environmental risks associated with chemical use	49	52	69
Farmers were instructed on safely handling of chemical	29	32	35
Farmers were informed about banned chemicals	25	27	38
Health problem faced followed by using chemicals (skin lesion, skin allergy, coughing)	53	41	46
Record keeping of chemical use	2.9	13	28

Annex 5. Major diseases/syndromes reported for shrimp and prawn

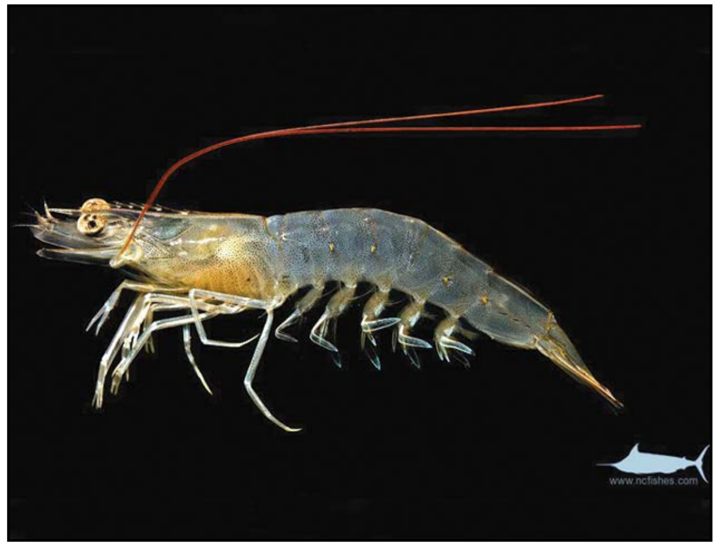
Fig 7. White Spot Syndrome Virus (WSSV).

Fig 8. Hepatopancreatic necrosis.

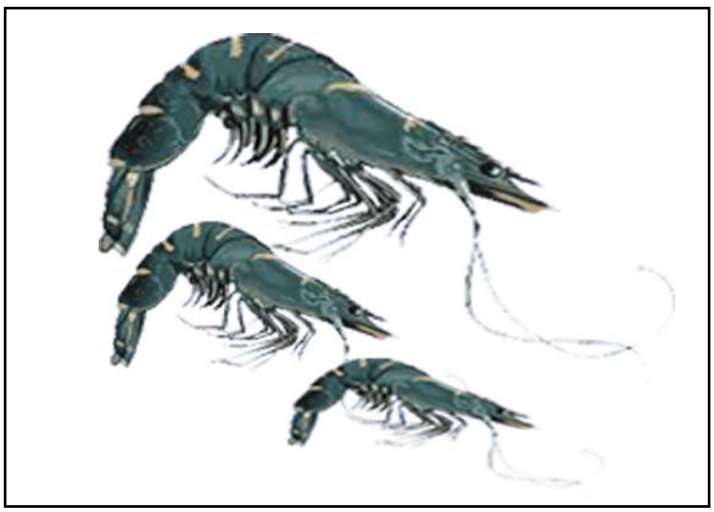
Fig 9. Antenna and rostrum Broken Symptom.

Annex 6. A set of disease picture cards

White Spot disease=1



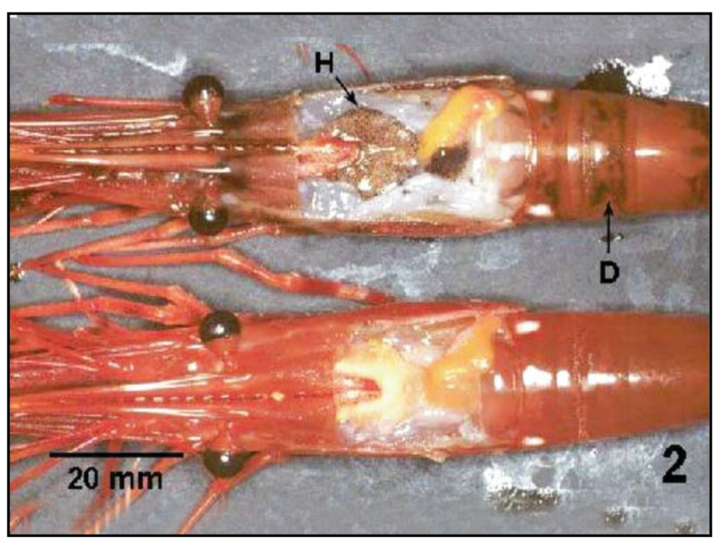
Yellow head disease=2



Monodon slow growth syndrome=3

Vibrosis=4

Mycrobacterosis=5



Rickettsial infection=6

White Cotton Fisease=7

Fungal disease=8

Black & brown gill-disease=9

Shell Soft Disease=10

Soft shell disease=11

Muscle opacity and necrosis=12

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