Perceived Risk and Risk Management Strategies in Pond Aquaculture

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ABSTRACT

The growing aquaculture industry is facing several challenges including risks and uncertainties. Studies exploring farmers' risk perceptions and risk management strategies are, however, limited within pond aquaculture, although they are well described within the field of agriculture. This study explores farmers' risk perceptions and risk management strategies in pond aquaculture and the relationship of risk perceptions and risk management strategies with farm and farmers' characteristics. The data are analyzed using principal component analysis and multivariate regression. The results show that price variability and financial risks are perceived as the most influential risk factors. Farm management and financing are perceived as the most effective risk management strategies. In most cases, farmers need to focus on more than one risk management strategy to address a particular type of risk. This study provides knowledge of farmers' risk perceptions and strategies, which can be used to develop better and more focused management strategies.

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Key words: Aquaculture, management strategies, risk perception.
JEL codes: C01, D22, Q12, Q14, Q22.

INTRODUCTION

Aquaculture is growing fast in developing countries (Belton, Bush, and Little 2018). The fast growth is in many cases driven by an uncontrolled expansion of small-scale subsistence farmers, who in most cases have limited knowledge of management practices and lack managerial abilities (Rahman et al. 2020). Because of the lack of knowledge and absence of spatial planning, these farmers may also be more exposed to some of the risks and uncertainties within the aquaculture farming industry. These risks include yield loss due to diseases and poor management, increasing costs on inputs due to increasing demand, and fluctuations in prices on outputs due to increased supply (Lebel, Lebel, and Chuah 2018; Kobayashi et al. 2015; Le and Cheong 2010). Furthermore,

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small-scale subsistence farmers are often financially constrained (Mitra, Khan, and Nielsen 2019) and may also be confronted with regulatory and environmental issues (Asche 2015). Thus, many types of risks are associated with fish farming in terms of production, marketing, financial, human, and institutional risks.

The expansion and consolidation of the aquaculture sector in developing countries is important because the sector provides food security and income for the rural poor in many of these countries (Belton, Bush, and Little 2018). Being able to identify the major risk factors and provide tools to mitigate these are important for the further development of this sector, with the aim to increase food security and alleviate poverty. However, only a limited amount of empirical work addresses risks and uncertainties in pond aquaculture (production to market). Therefore, more attention is needed to identify the factors that contribute to risks and uncertainties and which methods can be used to mitigate these (Tisdell et al. 2012).

The objectives of this study are (1) to identify pond aquaculture farmers' perceptions of risk (subjective risks) and perceived risk management strategies based on ranking of sources by risk level, and (2) to assess the impacts of farm characteristics and farmers' sociodemographic characteristics on farmers' perception of risk and choice of risk management strategies. The insights provided will improve knowledge on how small-scale pond farmers cope with risks. Furthermore, a better understanding of farmers' perceived risks and management strategies may help policy makers, financial institutions, input providers, and fish traders to adjust their future strategies, adding to a more productive and efficient farming sector for the benefit of the whole value chain, which will in turn improve food security and alleviate poverty in developing countries.

MOTIVATION OF THE STUDY

A literature survey on risks in aquaculture indicated that most of the existing research has been conducted on assessing ecological risks, disease-related risk, and risks of climate change on aquaculture (Kabir et al. 2017; Kabir, Alauddin, and Crimp 2017; Chitmanat et al. 2016; Lebel, Lebel, and Lebel 2016). In contrast, several studies have focused on risk related to productivity and economic efficiency (Khan, Guttormsen, and Roll 2018; Sarker et al. 2016; Tveteras 1999) and price risk related to profitability (Asche, Sikveland, and Zhang 2018; Guttormsen 1999). Studies related to risk management strategies include Watson et al. (2018), Quagraine, Kuethe, and Engle (2007), and Bergfjord (2007), looking at contracts and insurance as a risk mitigating tool. Though aquaculture farmers' risk perceptions play an important role in decision-making processes, only a few studies (Ahsan 2011; Le and Cheong 2010; Bergfjord 2009) have comprehensively analyzed sources of risk, perceptions of risks, and risk management strategies in aquaculture. Furthermore, only Ahsan (2011) and Le and Cheong (2010) focus on risk perception in aquaculture within a developing-country context.

This study differs from other studies of risk in pond aquaculture in the sense that it focuses on extensive inland freshwater pond aquaculture producing pangas and tilapia mainly aimed for consumption in the domestic market. In contrast, Ahsan (2011) and Le and Cheong (2010) focused on shrimp and catfish produced in intensive production systems that use more sophisticated inputs (feed, seeds, and medicine) and that aim products to export markets. Furthermore, regional heterogeneity in perceived risks and management strategies is included while estimating effects on farming attitudes, sociodemographic characteristics, and past experiences of perceived risks and management strategies.

To advise farmers and policy makers on risk mitigating strategies, it is important to understand in depth farmers' risk-taking behavior to be able to design strategies and policies that support farmers' needs.

This study is structured as follows: the next section introduces the Bangladesh pond aquaculture industry. The third and fourth sections report survey data and provide a description of the method. The fifth and sixth sections describe and discuss the results. The seventh section concludes the paper.

BANGLADESH POND AQUACULTURE INDUSTRY

Bangladesh is the world's fourth-largest aquaculture-producing country (FAO 2018). Aquaculture production has been steadily growing during the last decades with increasing contributions from pond-raised species like pangas and tilapia. Figure 1 shows the development of aquaculture production from 2005 to 2018, including the contribution from tilapia and pangas, covering 44% of pond production in 2018. The two species have been successful because they are easy to grow, have relatively low production costs, and are resistant to disease, and because there is a large domestic market for low-priced fish. The farms are mainly small homestead earthen ponds (80%), and the production is consumed domestically (Rahman, Nielsen, and Khan 2019).

Some of the difficulties that farmers face are relatively high input prices (such as for seeds, feeds, fertilizers, disinfectants, and labor), poor quality of inputs, restricted access to markets and to formal credit systems, poor transport facilities, and lack of supportive public policies.

Figure 2 shows the real price for tilapia and pangas from 2010 to 2019. Prices have been relatively constant from 2014 to 2018. However, prices have fallen during the period of data collection

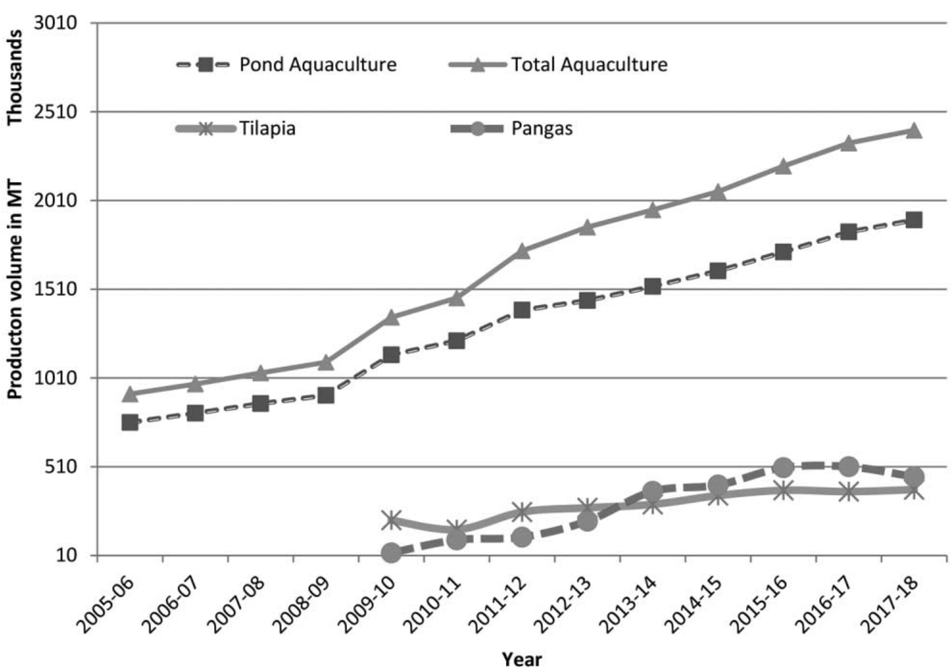

Figure 1. Historical Production Trend of Inland Capture, Pond Aquaculture, Total Aquaculture, Marine Capture, Tilapia (2009–18), and Pangas (2009–18) in Bangladesh. A color version of this figure is available online.

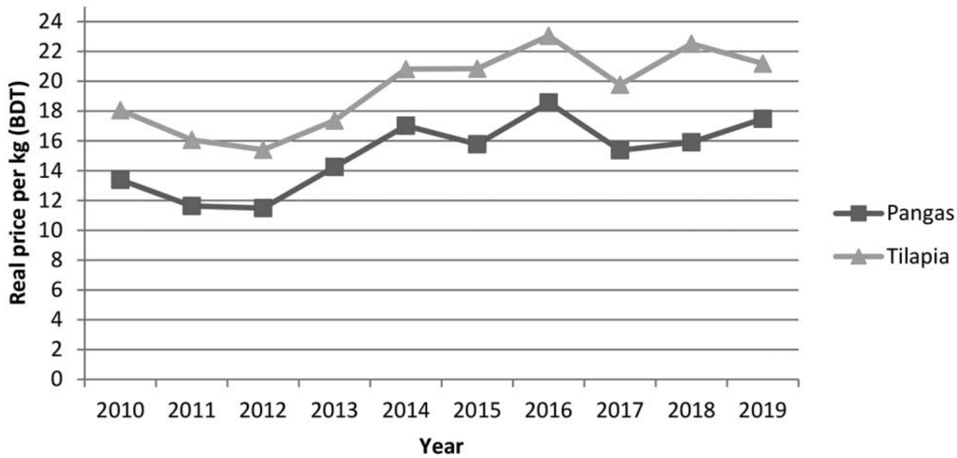

Figure 2. Retail Price Trend of Pangas and Tilapia Fish in Bangladesh (at real price). A color version of this figure is available online.;

for this study (2017). In figure 3, annual percentage changes in costs of the most important inputs—feed (80%), fingerlings (12%), and labor (6%)—and output values are shown per hectare from 2014 to 2018. The figure shows that changes in output values (revenues) are lower than changes in costs of some of the inputs, especially labor and feed, which can put profit margins under pressure if farms are not continuously able to increase productivity (Rahman et al. 2020).

A few large feed producers dominate the feed markets in Bangladesh and have higher bargaining power than the farmers. Consequently, farmers who are financially and institutionally credit constrained—that is, most farmers in Bangladesh—are dependent on feed sellers, paying higher prices for feed than the average market price while buying feed on credit (Islam et al.

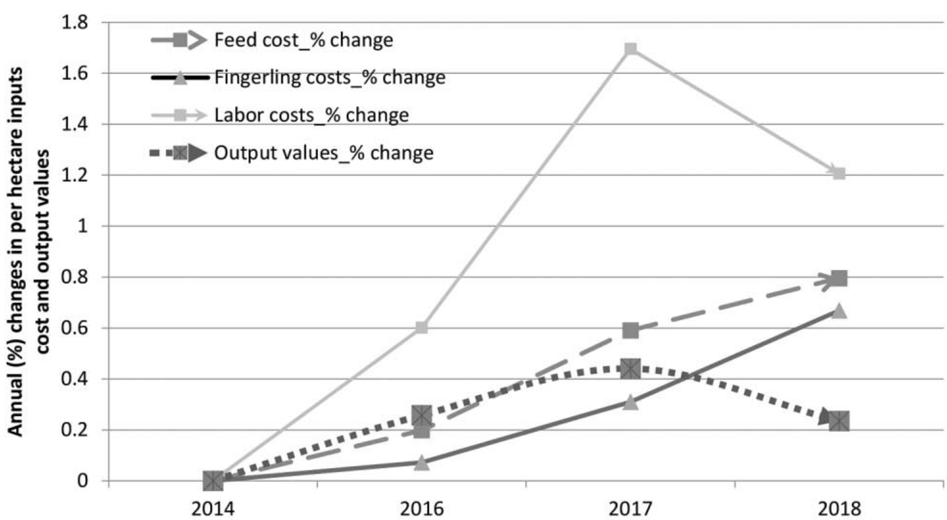

Figure 3. Annual Percentage Changes in Input Costs (Feed, Fingerlings, and Labor) and Output Values at the Farm Level (per hectare at 2014 constant). A color version of this figure is available online.

2020). Furthermore, farmers often receive cash credits from feed sellers and wholesale fish buyers on the condition that they will buy feed from and sell fish to them, respectively, affecting the farmers' profitability and productivity (Mitra, Khan, and Nielsen 2019).

Furthermore, lack of proper aquaculture training and farm management knowledge often lead the farmers to follow improper farm management practices (Rahman et al. 2020; Watson et al. 2018; Chitmanat et al. 2016), which cannot efficiently mitigate business risks.

DATA

Before conducting the survey, a literature survey covering scientific articles and information from governmental published reports was conducted to add to the understanding of farmers' risk perceptions and management strategies within the context of Bangladesh. After constructing the interview schedule based on the knowledge obtained, preliminary interviews with 10 farmers were conducted to validate the schedule and obtain information on the potential risks and risk management strategies that might have been overlooked. Finally, a pilot survey of 20 farmers was conducted in order to further validate the relevance of the questions and to identify ambiguous or missing questions. For instance, questions addressing the issues of water quality, soil quality, natural conditions, and some other environmental factors were dropped following responses and views at this stage, since most farmers do not know the water and soil quality and because they have neither the knowledge nor the instruments to check it regularly. Furthermore, farmers are less concerned about environmental change/impacts on farming. Most of the questions were designed as closed questions, mainly in the form of five-point Likert scales and dichotomous questions with the possible responses of yes or no. The questionnaire included questions regarding the following issues: (1) farming attitudes, farm characteristics, the farmers' sociodemographic variables, and the economic performance of the farm; (2) farmers' perceptions of risk (including different sources of risks); and (3) farmers' perceptions of various risk management strategies.

The data were collected from aquaculture pond farmers engaged in pangas and tilapia production in Bangladesh. The data were collected using face-to-face interviews. A cluster sampling technique was used, because it saves time and is more convenient when collecting data from a huge, geographically scattered area (Levy and Lemeshow 1991). However, there can be problems due to sample homogeneity. Nevertheless, in this case, the data seem reasonably heterogeneous within the clusters because of differences in socioeconomic status and other variables (e.g., different education levels, income levels, trained/nontrained farmers, and experience). Therefore, considering all the variables collected, it is reasonable to believe that statistical accuracy and validity are in order. In total, 645 farms were randomly selected for the survey. The seven selected districts cover 57% of the tilapia and 82% of the pangas production in Bangladesh. Figure 4 shows the districts from which the data were collected.

In total, 27 sources of risks and 36 risk management strategies found to be relevant to pond aquaculture were included in the questionnaire. Farmers were asked to score each source of risk on a Likert scale from 1 (no or very low impact) to 5 (very high or severe impact) to express how significant they considered each source of risk to be in terms of its potential impact on economic performance. Furthermore, the likelihood of occurrence of each risky event was reported on a Likert scale from 1 (never) to 5 (very often). Thus, the perceived risk scores were calculated by multiplying the associated scores of perceived probability (likelihood of occurrences) and impact of the various sources of risk. The farmers were also asked to indicate their perceived importance

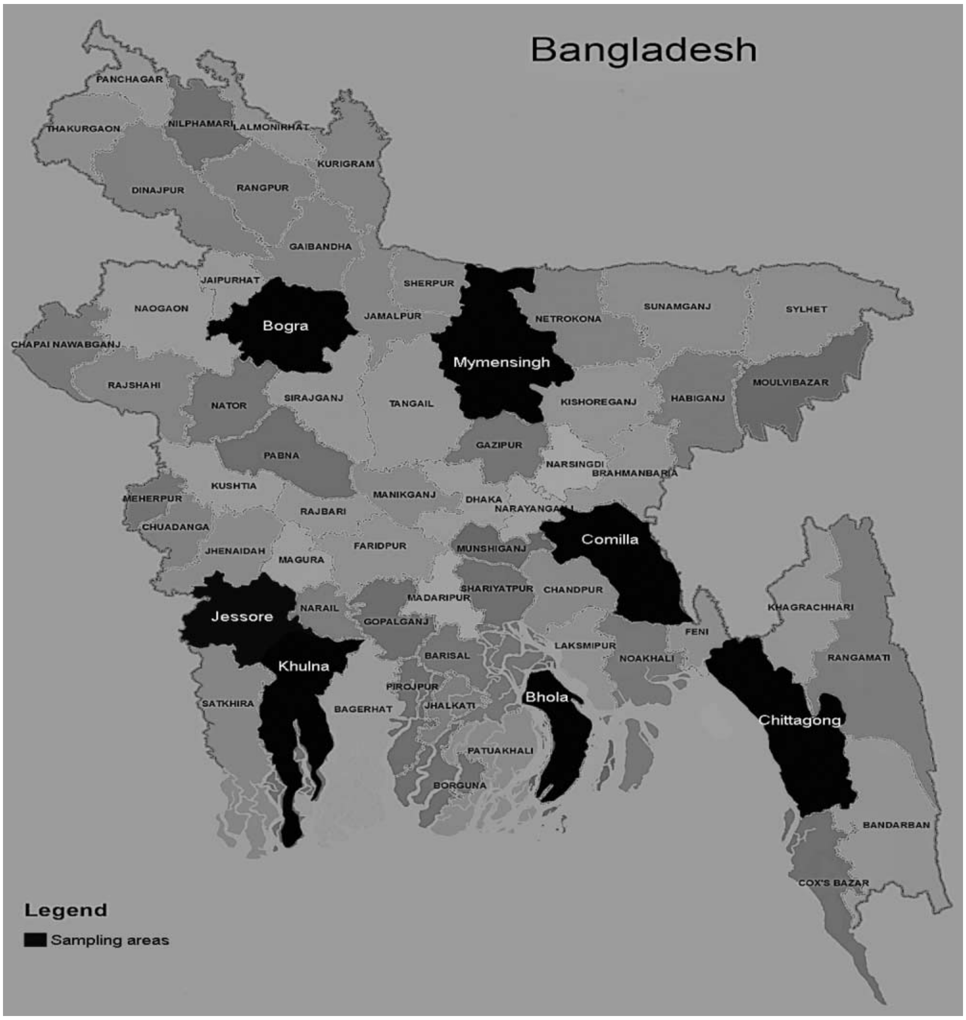

Figure 4. Study Areas. A color version of this figure is available online.

of each risk management strategy on a Likert scale from 1 (no or very negligible effect) to 5 (very significant effect).

Table 1 includes the mean values of farm and farmers' characteristics, highlighting the socio-economic profiles of the farmers. These variables are later used as independent variables in a multivariate analysis to see how they affect farmers' perceptions of risks and risk management strategies.

METHOD

Rowe (1977, 24) defines risk as "the potential for realization of unwanted negative consequences of an event." The characteristics of a risk event are, therefore, a choice of action, a perceived magnitude of loss, and the chance of realizing the loss.

Every risk has two domains: objective risk and subjective risk. An objective risk is a situation in which an individual knows the probability of an event and the consequences of that probability

Table 1. Characteristics of Farms and Farmers in Bangladesh

Characteristics (Description of Variables)	Variable Name (Independent Variables)	Farms in Survey ($n = 645$)
Personally owned farms (%)	OwnerF	90
Personally owned land (%)	OwnerL	46
Equity financed farms (%)	SourceF	94
Agricultural land converted to aquaculture farms (%)	LandCon	83
Age of farm operator (years)	Age	40
Full-time fish farmers (%)	OccM	91
Years of education (mean)	Edu	10
Years of experience (mean)	Exp	11
Trained farmers (%)	Train	55
Large farms (area ≥ 2.0 hectares)[a]	DummyL	27
Medium farms (area ≥ 0.5 < 2.0 hectares)[a]	DummyM	52
Small farms (area < 0.5 hectare)[a]	DummyS	22
Family size (mean)[b]	FamilyS	6
Household income (mean) (in USD; 1 BDT = 80 USD)[c]	LnIncome	12,717.49

Note: [a] Farm size refers to the total land area of ponds under harvest in the relevant year. [b] Family size refers to a single family living in the same house and does not include extended family. [c] Household income refers to the yearly net income of the family and is expressed in USD.

(either positive or negative; Wolff, Larsen, and Øgaard 2019). A risk is subjective if the probability of a risky event and the consequences are measured based on the judgment of an individual (Sjoberg, Moen, and Rundmo 2004; Sjoberg 1998). Risk perception (individuals' judgment) is affected by a large number of factors, including heuristics, socioeconomic factors (e.g., age, education, income, and gender), the voluntariness of the risk, the expectation of control, the severity of the consequences, the equity of distribution of risk and benefits, and the perceived benefit itself (Van Winsen et al. 2016; Pennings and Garcia 2001; Willock, Deary, and McGregor 1999).

Empirical evidence has shown that in a risky situation, an individual does not always behave according to the key assumptions of expected utility theory (Bocqueho, Jacquet, and Reynaud 2014) and rather makes decisions based on a subjective estimation using a personal probability of loss or gain (Slovic 1987; Sitkin and Pablo 1992). Thus, "subjective" risk estimates cannot be ignored or underestimated in risk management, as it is the individual who makes the decision of being a farmer and investing in the farm.

Psychometric models (Slovic 1987; Sjoberg 1998; Ahsan 2011) have been widely used to estimate risk perception and the influence of perceived risks in management strategies in several research studies, including behavioral economics and business management. In this model, differences in risk attitudes across domains can be attributed to a different perception of risk (Weber, Blais, and Betz 2002; Weber and Milliman 1997). An individual's economic behaviors are determined by the perceived economic environment (Lien et al. 2006), which changes over domain and time. Furthermore, if variables representing the economic environment (such as farmer and farm characteristics) are excluded from an objective model, it may lead to inappropriate policy recommendations (Bishu et al. 2018). In this paper, a psychometric model is used to ascertain risks and risk management strategies of pangas and tilapia aquaculture farmers in Bangladesh.

ANALYTICAL METHODS

There are 27 sources of risks and 36 management strategies in the sample collected. The farmers' perceptions of risks and risk management strategies are measured based on the impacts and efficacies of risk sources and management strategies, respectively. The impacts of risks are ranked by the mean values of risk level calculated by multiplying Likert scale responses to consequences of an individual risk source with the corresponding responses to likelihood of occurrence (probability), in order to evaluate the perceived importance of various sources of risks. Similarly, the risk management strategies are ranked to evaluate the perceived importance of an individual risk management strategy. Standard deviation is used to evaluate the variability in farmers' perceptions of both risk and risk management strategies.

There are different approaches to reduce dimensionality of variables and to investigate the relationship of reduced variables with other variables, preferably partial least square regression (PLS) and principal component regression (PCR). In PCR, the analysis follows a two-step procedure. In the first step, the observed variables are transformed into smaller numbers of variables (commonly known as principal components or factors) using a principal component analysis (PCA) technique. In the second step, the principal components derived from the PCA are used as dependent variables in a multiple regression model (D'Ambra and Sarnacchiaro 2010). So, in PCR, instead of regressing the dependent variable on the explanatory variables directly, the principal components of the explanatory variables are used as regressors (Shaw 2003).

It should be noted that from a computational point, the mean and standard deviation of principal components are 0 and 1, respectively (Duinen et al. 2015; Everitt and Hothorn 2011, 74). Both PCR and PLS techniques help in solving multicollinearity problems, whereas PLS uses more degrees of freedom than PCR (Krämer and Sugiyama 2011).

Thus, the reasons for using PCA in this study for extracting principal components and using them in multiple regression models are that the correlations between independent variables (farm and farmers' characteristics) in this study are very low and the numbers of independent variables are few (Jolliffe and Cadima 2016; Sawatsky, Clyde, and Meek 2015; Abdi 2003). The model provides robust results and performs at least as well as PLS. Furthermore, there are many empirical studies in agriculture and aquaculture that follow similar methodology; these include Hayran (2019); Cullen et al. (2018); Asravor (2018); Bishu et al. (2018); Duinen et al. (2015); Ahsan (2011); and Le and Cheong (2010).

Accordingly, because of the large number of risk sources and management strategies, PCA was employed to group the factors into smaller numbers of factors (e.g., categories of risk sources and types of risk management strategies for this research) for subsequent analysis that can more easily be interpreted and evaluated empirically. This has been done based on the latent root criterion (eigenvalue ≥ 1).[1] Furthermore, in order to have the most relevant and parsimonious set of factors, PCA is repeated with varying numbers of factors (Hair et al. 2006).

To ensure maximum independence of the resulting factors, the orthogonal (varimax) rotation extraction method was used. Missing responses were replaced with mean values of obtained valid responses following Lien et al. (2006) and Flaten et al. (2005). The Kaiser-Meyer-Olkin (KMO)[2] test is used to check the suitability of data for principal component analysis (Cerny and

1. The eigenvalue indicates how much of the variance of the observed variables (27 sources of risk and 36 risk management strategies) that a factor (categories of risk sources and types of risk management strategies) can explain. Any factor (risk category / management strategy) with an eigenvalue ≥ 1 explains more variance than a single observed variable.

2. The formula for the KMO test is given by the following:

$$KMO_j = \frac{\sum_{i \neq j} r_{ij}^2}{\sum_{i \neq j} r_{ij}^2 + \sum_{i \neq j} u_{ij}},$$

where r_{ij} is an element in the correlation martrix, and u_{ij}, is an element in the partial covariance matrix.

Kaiser 1977). A high KMO value (maximum 1.0) generally indicates that the PCA method is useful when aiming to reduce the number of factors. In PCA, factors with factor loadings (which indicate the relationships of each variable with the underlying factors) greater than 0.30 are considered to be significant (Le and Cheong 2010; Ahsan 2011).

Principal component regression was used to identify relationships between farm characteristics and farmers' sociodemographic variables, risk perceptions, and risk management strategies. In the regression model for risk perception, categories of risk sources (principal components/factors extracted from 27 risk sources) are taken as dependent variables (table 6) and farm and farmers' characteristics are taken as independent variables. On the other hand, in the regression for perception of risk management strategies, types of risk management strategies are taken as dependent variables (i.e., the principal components/factors extracted from 36 management strategies by PCA), and both farm and farmers' characteristics including categories of risk sources are taken as independent variables.

To account for regional heterogeneity, regional dummies are included in both regression models, taking Mymensingh as the reference region since it is considered to be the cradle of aquaculture production in Bangladesh (Rahman, Nielsen, and Khan 2018). If heteroscedasticity is present, robust regression (maximum likelihood method) is applied. The correlation coefficients between all the pairs of independent variables have been estimated. However, all correlation coefficients were low. All variance inflation factor (VIF) values are less than or equal to 2.0, indicating that there are no multicollinearity problems within the studied variables. The regression models are constructed as follows:

$$\begin{aligned} RF_i = {} & \beta_0 + \beta_1 OwnerF + \beta_2 OwnerL + \beta_3 LandCon + \beta_4 Age + \beta_5 OccM \\ & + \beta_6 Edu + \beta_7 Exp + \beta_8 Train + \beta_9 DummyL + \beta_{10} DummyM \\ & + \beta_{11} FamilyS + \beta_{12} \mathrm{Ln} Income + \beta D_i + \varepsilon, \end{aligned} \tag{1}$$

$$\begin{aligned} RMS_j = {} & \beta_0 + \beta_1 OwnerF + \beta_2 OwnerL + \beta_3 LandCon + \beta_4 Age + \beta_5 OccM \\ & + \beta_6 Edu + \beta_7 Exp + \beta_8 Train + \beta_9 DummyL + \beta_{10} DummyM \\ & + \beta_{11} FamilyS + \beta_{12} \mathrm{Ln} Income + \beta RF_i + \beta D_i + \varepsilon, \end{aligned} \tag{2}$$

where the following applies:

- RF_i: Standardized principal components scores defined as categories of risk sources ($i =$ production risk, financial risk, market-related risk, and institutional risk). The principal components/factors and their scores are derived by extracting observed 27 risk sources using the PCA technique.
- RMS_j: Standardized principal components scores defined as types of risk management strategies ($j =$ financial support, farm management, quality control, marketing and logistics, farmers' cooperation, extension and collaboration, diversification, disease management, and input supply). The principal components/factors and their scores are derived by extracting observed 36 risk management strategies using the PCA technique.

D_i[3]: Regional dummies (i = Mymensingh [reference region], Bogura, Comilla, Khulna, Jessore, Chittagong, and Bhola).

RESULTS

The data are analyzed at four stages: (1) descriptive statistics of farm and farmers' characteristics, (2) risk factors and risk management strategies, (3) principal component analysis technique extracting principal components, and (4) multiple regression, where the extracted principal components are used as dependent variables and farm and farmers' characteristics are used as independent variables.

According to the hypotheses stated in the introduction, farmers' socioeconomic profiles may influence their perceptions of risk and risk management. Thus the economic profile—in terms of farm ownership, primary occupation (*OccM*), level of training (*Train*), and the state of the land before it was converted into a fish farm—is taken into consideration to identify farming attitudes and commitments to fish farming. Two pond types are used: homestead ponds (used for fish farming and household purposes) and commercial ponds (used only for fish farming). Table 1 highlights the socioeconomic profiles of the farmers. Ninety percent of the farms are personally owned, and 46% of the farms use personally owned land for fish farming. Farm ownership (*OwnerF*) and pond land ownership (*OwnerL*) have statistically significant influences on perception of risk and risk management strategies. Eighty-three percent of the aquaculture ponds in the sample are developed by converting agricultural land. Interviews under the field study indicate that a common motivation for this conversion is higher returns for fish farming than for agriculture. The main concerns when converting farmland to fish ponds are liquidity and limited access to credit (Khan, Guttormsen, and Roll 2018) needed to be able to buy fingerlings, feed, and medicine.

FARMERS' PERCEPTIONS OF RISK SOURCES

Table 2 presents the 27 risk sources and their ranking, mean scores, and standard deviations. The source of risk that the farmers found most important (highest mean) is ranked as number 1, and the subsequent risk factors are presented in descending order. The standard deviations for all the risk factors are approximately 1.0, indicating a high level of consensus among the respondents.

Price variability has a mean value of 3.76 and is considered the greatest risk to pond aquaculture in Bangladesh; this finding is similar to the findings for catfish farming in Vietnam (Le and Cheong 2010) and shrimp in Bangladesh (Ahsan 2011). Interviewed farmers reported that in the last few years (especially in the year of data collection, 2017), they have experienced losses due to fluctuating prices of fish and at the same time increasing costs of the main inputs (e.g., feed, fingerlings, and labor). This situation often motivates farmers to partially or temporarily withdraw from production.

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3. Mymensingh is considered the cradle of fish farming because of the availability of inputs including seeds, labor, feed, fertile soil, and key research institutions; however, the region lacks access to fresh water. Bogura is known for housing many small and medium-size industries including feed mills and hatcheries; it has good road connectivity but lacks fresh water. Comilla is popular for its road connectivity with the larger cities and housing export processing zones, making labor scarcer. Chittagong and Khulna are closer to the coast; water is abundant and inputs are more available since Chittagong is a business capital. Two seaports are also located in these two regions. Bhola is surrounded by larger rivers with access to open water; however, it lacks access to markets and quality seeds and feeds. Jessore is a small city and popular for hatcheries, but it has limited access to open water.

Table 2. Means, Standard Deviations, and Ranks of Risk Consequences

Risk Sources	Rank	Mean	Std. Dev.
Fish price variability	1	3.763	1.065
High death rate due to disease	2	3.743	1.090
Low quality of fingerlings (not healthy)	3	3.606	1.040
Low quality of feed	4	3.575	1.128
Timely supply and price of fingerlings	5	3.543	1.047
Lack of own capital	6	3.530	0.983
Fingerlings infected by diseases	7	3.509	1.126
Price variations of feed and chemicals	8	3.439	1.086
High cost of operating inputs/farm equipment	9	3.409	1.047
Lack of credit from banks/financial institutions	10	3.384	1.085
Lack of storage and transportation facilities	11	3.364	1.117
Low credit availability	12	3.361	1.043
Inappropriate size of fish harvest	13	3.326	1.060
Low awareness of disease prevention by farmers	14	3.240	0.984
Use of undersized fingerlings	15	3.222	0.992
Limited knowledge about the usage of chemicals and medicines	16	3.216	1.012
Using chemicals and medicines improperly	17	3.206	0.986
Overfeeding, causing pollution and waste accumulation	18	3.203	1.081
Over (density) stocking fingerlings	19	3.177	0.989
High interest rate for loans	20	3.161	1.052
Changes in consumer preferences	21	3.141	0.946
Fingerlings with unknown origin	22	3.135	0.984
Supply of microcredit from NGOs	23	3.084	1.012
Supply of private capital (debt, equity)	24	3.051	0.973
Exploitation from middlemen	25	2.949	0.939
Weak enforcement in conducting sales contracts with processors	26	2.887	1.002
Farms have no reserved areas for waste management	27	2.808	1.089

Other factors that receive a high score are high death rate due to diseases (2), low quality of fingerlings (3), and fingerlings infected by diseases (7), which all stress that disease problems are major risk factors. Furthermore, low quality of feed (4) also seems to affect farms. In extensive pond farming, the two primary cost-return drivers are feed and fingerlings because the future possible harvest quantity is closely related to the quality and management of these two inputs. Anwar (2011) also found that fish price variability and fish diseases were common risk factors for pangas and tilapia fish farmers in Bangladesh.

Another issue that seems to be highly relevant is the availability of capital or credits. Lack of own capital (6), lack of credit from banks/financial institutions (10), and low credit availability (12) are found to be major challenges for farmers. This supports the findings of Ahmed, Alam, and Hasan (2010) that indicate that farmers may use low-quality feeds (4) and fingerlings (3, 5, and 7) because of financial constraints.

Inappropriate size of fish harvest (13) is another source of risk. This finding is supported by information that farmers provided during the interviews; they claimed that they have to sell undersized fish because of financial constraints.

Furthermore, overfeeding (ranked 18) and fingerling density (ranked 19) are also identified as major sources of risk. It seems that farmers who are not suffering from credit constraints are facing problems of overfeeding and overstocking due to the lack of knowledge of input management (Alam, Khan, and Huq 2012). This finding is also supported by Khan, Guttormsen, and Roll's (2018) study of production risk in pangas farming.

To provide a deeper understanding of the farmers' perceptions of risk, the principal component extraction method in combination with the varimax rotation method has been applied. Using these methods, the 27 sources of risks are reduced to four main risk factors (termed later as categories of risk sources): production-related risk, financial risk, market-related risk, and institutional risk, shown in table 3. An individual source of risk is assigned to a category of risk source based on its corresponding factor loading value (highest). These four categories of risk sources have eigenvalues exceeding 1.0 and total variance of 60%. The applicability of PCA is verified using the KMO test of sample adequacy and Bartlett's test of sphericity. The KMO measure of adequacy is 0.96, and Bartlett's test of sphericity is statistically significant at 1% (table 3). All of the tests indicate that PCA is a good fit for this dataset. Sources of risk having factor loadings above 0.30 are considered to be important (Flaten et al. 2005). Production-related risk shows high loading for most factors related to production inputs, such as fingerlings, feed, chemicals, and medicines. Financial risk includes factors like supply of credit and capital, with the highest loading including changes in consumer preferences for fish, among others. Marketing risk includes factors like fish price variability. Institutional risk includes factors like weak enforcement of sales contracts with producers and waste management with highest factor loading.

FARMERS' PERCEPTIONS OF RISK MANAGEMENT STRATEGIES

Farmers rated the efficacy of 36 risk mitigating strategies on a five-point Likert scale, with 1 as a negligible effect and 5 as a very significant effect. Table 4 presents the average scores of the efficacies and their ranks in descending order. The risk management strategies have mean scores between 3.1 and 4.0. In general, inputs of good quality, such as feed, fingerlings, and water, are perceived as the most effective risk mitigating strategies, and the choice of a good brand of feed is considered the best risk management strategy. These findings are consistent with the findings of Alam, Khan, and Huq (2012), who point out that farms using commercial feed are more efficient, and Ahmed (2007), who points towards commercial feed as the most effective way of cultivating fish if efficiently managed. However, most small and medium-sized farms use homemade feed (traditional) because it is less costly, and feed constitutes the most important input in terms of costs (Alam, Guttormsen, and Roll 2019; Ali, Rahman, et al. 2018).

Selecting good-quality fingerlings and buying from reliable sources are ranked as the 2nd and 4th most effective strategies. In Bangladesh, fingerlings are most often provided from three sources: own production, small traders of fingerlings, or larger fingerling agents (Hernandez et al. 2018). Farmers with small and medium-sized farms mostly depend on small fingerling traders that provide low quality but at a relatively low cost, negatively affecting productivity (Hernandez et al. 2018).

Available market information and an appropriate price policy (price floor, taxes, etc.) are ranked 6th and 8th. There is no formal arrangement to provide market information, which could benefit the farmers. Attending workshops or training is ranked 10th and is provided by the Fisheries Department, but resources for this extension service are limited. Fifty-five percent of the surveyed farmers have received training, but this is often limited to one time and is quite short (one day to one week), which means that there is no continuous training and updating of skills and knowledge at the farmers' level. This leads farmers to follow "farming by seeing" and "learning by doing," which affects farm productivity and profitability (Rahman, Nielsen, and Khan 2018). The study by Hernandez et al. (2018) notes that improving aquaculture-supportive infrastructure,

Table 3. Varimax Rotated Factor Loadings for Risk Sources

		Principal Components / Factors[a] (Categories of Risk Sources)			
Risk Sources	Communalities[b]	Production Risk (1)	Financial Risk (2)	Market-Related Risk (3)	Institutional Risk (4)
Low quality of fingerlings (not healthy)	0.648	**0.682**	0.240	0.351	–0.032
Fingerlings with unknown origin	0.622	**0.607**	0.368	0.116	0.324
Timely supply and price of fingerlings	0.571	**0.706**	0.129	0.117	0.205
Fingerlings infected by diseases	0.600	**0.692**	0.269	0.217	0.047
Over (density) stocking fingerlings	0.639	**0.704**	0.319	0.012	0.203
Use of undersized fingerlings	0.525	**0.548**	0.166	0.261	0.359
Low quality of feed	0.609	**0.654**	0.255	0.339	0.035
Overfeeding, causing pollution and waste accumulation	0.669	**0.714**	0.280	0.110	0.260
Using chemicals and medicines improperly	0.515	**0.503**	0.339	0.268	0.275
Price variations of feed and chemicals	0.690	**0.619**	0.124	0.493	0.221
Limited knowledge about the usage of chemicals and medicines	0.540	**0.477**	0.183	0.259	0.460
High death rate due to disease	0.628	**0.554**	0.140	0.552	0.076
Low awareness of disease prevention by farmers	0.569	**0.473**	0.255	0.471	0.388
Farms have no reserved areas for waste management	0.701	0.212	0.143	–0.013	**0.797**
Inappropriate size of fish harvest	0.533	0.228	**0.466**	0.386	0.337
Fish price variability	0.682	0.263	0.236	**0.737**	0.117
Weak enforcement in conducting sales contracts with processors	0.714	0.104	0.069	0.032	**0.835**
Exploitation from middlemen	0.387	0.139	0.344	0.208	**0.454**
Lack of storage and transportation facilities	0.556	**0.520**	0.340	**0.355**	0.209
High cost of operating inputs/ farm equipment	0.514	0.434	**0.537**	0.438	0.105
Changes in consumer preferences	0.504	0.206	**0.606**	0.136	0.275
Lack of own capital	0.590	0.145	**0.727**	0.270	–0.024
Lack of credit from bank/institutions	0.593	0.263	**0.685**	0.222	0.071
Supply of private capital (debt, equity)	0.630	**0.345**	**0.706**	0.092	0.066
Supply of microcredit from NGOs	0.683	0.260	**0.771**	0.133	0.049
High interest rate for loans	0.568	0.162	**0.611**	0.343	0.225
Low credit availability	0.594	0.218	**0.610**	0.378	0.178
Percentage of total variance explained		44.021	6.152	5.528	3.822
Percentage of total cumulative variance explained		44.021	50.173	55.701	59.523
KMO test		0.961			
Bartlett's test of sphericity chi-square value at 1% with df 351		9,506			

Note: [a] Categories of risk sources are production, financial, marketing, and institutional. The categorizations are based on the factor loading (loadings > 0.30) of individual risk sources. The highest loading values are given in bold. [b] Indication of how much variance is explained by the corresponding source of risk out of the total variance.

such as establishing storage facilities (9th) and improving transportation facilities (20th), may improve the contribution of aquaculture to the national economy of Bangladesh.

Similar to the sources of risk, the numbers of risk mitigating strategies are reduced by PCA. Principal component extraction in combination with the varimax rotation method is applied.

Table 4. Efficacies of Risk Management Strategies: Ranks, Means, and Standard Deviations

Risk Management Strategies	Rank	Mean	Std. Dev.
Choose a good brand of feed	1	3.957	0.935
Select good-quality fingerlings	2	3.927	0.870
Maintain a well-managed water environment in pond	3	3.816	0.961
Buy fingerlings from reliable sources	4	3.741	0.817
Carefully check the fingerlings when buying	5	3.732	0.946
Acquire available market information	6	3.722	0.947
Obtain timely supply of fingerlings	7	3.690	0.786
Request appropriate price policy	8	3.661	0.911
Establish storage facilities	9	3.611	0.857
Attend workshops or training	10	3.594	0.919
Apply medicines, chemicals to prevent disease	11	3.575	0.868
Keep cash on hand for farming	12	3.566	0.894
Produce at lowest possible costs	13	3.564	0.911
Prevent disease by regularly checking and observing pond	14	3.550	0.934
Strictly follow the recommended guide	15	3.526	0.891
Use large-size fingerlings	16	3.487	0.906
Buy fingerlings only from certified producers	17	3.474	0.839
Secure bank loans	18	3.461	0.954
Enter into sales contract with middlemen/processors	19	3.454	0.927
Improve transportation facilities	20	3.447	0.895
Involve production contract with predetermined size	21	3.442	0.846
Collaborate with association of fish farmers	22	3.434	0.938
Reduce farm size to appropriate scale	23	3.431	0.909
Use only factory-made (pellet) feed	24	3.428	0.869
Remove influence of middlemen	25	3.409	0.878
Reduce density of fingerling stocking	26	3.402	0.852
Secure available microcredit	27	3.371	0.913
Collect information on consumer preferences	28	3.366	0.809
Involve off-farm work	29	3.363	0.884
Use laborers with aquaculture knowledge	30	3.305	0.873
Check prohibited substances (hormones, chemicals)	31	3.293	0.886
Use economic consulting services	32	3.259	0.950
Diversify products	33	3.257	0.875
Engage in farmers' cooperative association	34	3.251	0.850
Increase cooperative marketing	35	3.223	0.942
Share ownership of equipment/partnership	36	3.164	0.903

The KMO is 0.80, and Bartlett's sphericity is statistically significant at the 1% level (table 5). A total of nine factor[4] solutions (types of risk management strategies) are selected, accounting for 51% of the total variance. Based on the factor loadings, the nine types of risk management strategies and their respective loadings are presented in table 5. The risk management strategies are financial support, farm management, quality control, marketing and logistics, farmers' cooperation, extension and collaboration, diversification, disease management, and input supply. The most appropriate risk mitigating strategies have the highest factor loadings (table 5).

Financial support has the highest loadings for keeping cash on hand for farming (0.718) and share ownership of equipment/partnership (0.564), both of which make perfect sense as risk

4. The statistical package by default suggested 12 factors with a total variance of 58%. However, for ease of interpretation, the package directed a nine-factor solution. The cost is only the loss of 7% (58% – 51%) of the total variance.

mitigating strategies. Other strategies with loadings related to financial support are assurance of available microcredit (0.488), off-farm work (0.406), and assurance of bank loans (0.392).

Farm management is mostly related to the control of inputs such as choosing a good brand of feed (0.687), selecting good-quality fingerlings (0.631), buying fingerlings from reliable sources (0.558), using large-size fingerlings (0.434), and having a well-managed water environment in the pond (0.421).

Quality control is related to activities controlling the quality of inputs, such as using laborers with aquaculture knowledge (0.702), using only factory-made feed (0.523), strictly following the recommended guide (0.433), and checking chemicals (0.425). Similarly, all the other risk management strategies are named based on the factors (risk management strategies) with higher factor loadings (see table 5).

RELATIONSHIPS AMONG PERCEPTIONS OF RISKS AND FARM CHARACTERISTICS

The relationships among the farmers' risk perceptions, farm characteristics, and the farmers' socioeconomic characteristics are analyzed using multiple regression (equation 1). The results are presented in table 6. Four models are regressing farm and farmers' characteristics with each category of risk source. Regional dummies are included as well to see whether the risk perceptions significantly vary between regions. All the models are statistically significant at the 1% level and are homoscedastic; only the model for market-related risk shows signs of heteroscedasticity. Thus, this model is reestimated using the robust regression maximum likelihood method (Fox and Weisberg 2013). All of the models have low adjusted R^2, indicating that some of the variables that may explain the farmers' perceptions of risk are not included in the models. However, earlier studies on risk perception in both agriculture and aquaculture, including Hayran (2019), Cullen et al. (2018), Asravor (2018), Patrick and Musser (1997), Meuwissen, Hurine, and Hardker (2001), Flaten et al. (2005), Le and Cheong (2010), and Ahsan (2011), also observed very low R^2 values. Durbin-Watson statistics for all four models are estimated following earlier studies (Le and Cheong 2010) and are between 1.04 to 1.18 (table 6), suggesting that autocorrelation is not a problem. For the test of multicollinearity, the variance inflation factor is used. No multicollinearities are found since all the values of VIF are approximately 2.00.

The results reveal that the perceived production risks are higher for farms that are made from converting agricultural land (commercial ponds) into fish ponds. That means homestead ponds have lower production-related risks such as diseases and so on. Furthermore, the volume of production in homestead ponds is lower than in the commercial ponds. They are less sensitive to production risk, since the lower the volume of production, the lower the potential loss when something bad occurs at a farm (Le and Cheong 2010).

Perceived financial risk is higher for the personally owned pond land and farms than for farms that have rented land and shared ownership. Larger and medium-sized farmers also assume higher financial risks than the small farmers do, perhaps due to higher capital requirements. It is also higher for trained farmers. Furthermore, farm operators who are more educated perceive financial risks to be lower than the less educated farm operators do.

Perceived marketing risk is higher for trained farmers. However, perceived marketing risk is lower for personally owned and self-financed farms than for shared and debt-financed farms.

Furthermore, perceived institutional risk is higher for personally owned and self-financed farms and lower for trained farm operators. Interestingly, the household incomes of farm operators have

Table 5. Varimax Rotated Factor Loadings for Risk Management Strategies

		Principal Components / Factors[a] (Types of Risk Management Strategies)								
Risk Management Strategies	Communalities	Financial Support (1)	Farm Management (2)	Quality Control (3)	Marketing and Logistics (4)	Farmers' Cooperation (5)	Extension and Collaboration (6)	Diversification (7)	Disease Management (8)	Input Supply (9)
Select good-quality fingerlings	0.515	0.004	**0.631**	–0.008	0.170	–0.100	0.134	0.085	0.150	0.173
Buy fingerlings from reliable sources	0.446	0.153	**0.558**	–0.037	–0.014	0.201	–0.080	0.139	0.064	0.199
Buy fingerlings only from certified producers	0.423	0.164	0.124	0.042	0.067	0.040	–0.069	0.540	–0.072	0.267
Obtain timely supply of fingerlings	0.525	0.179	0.428	0.101	–0.036	0.040	0.050	0.006	–0.008	**0.542**
Carefully check the fingerlings when buying	0.522	–0.012	0.211	0.090	0.107	0.043	0.003	0.174	0.028	**0.651**
Strictly follow the recommended guide	0.523	0.253	0.051	0.433	–0.351	0.146	0.105	0.159	0.266	0.133
Reduce density of fingerling stocking	0.507	0.168	0.204	**0.496**	–0.097	0.260	–0.148	0.491	0.094	0.018
Use large-size fingerlings	0.476	0.037	0.434	**0.473**	0.133	–0.010	–0.139	0.212	0.222	–0.127
Choose a good brand of feed	0.559	–0.018	**0.687**	0.128	0.250	0.071	0.016	0.036	0.014	–0.031
Check prohibited substances (hormones, chemicals)	0.465	–0.004	0.197	**0.425**	0.114	0.417	–0.014	0.136	–0.103	–0.196
Use only factory-made (pellet) feed	0.419	0.162	–0.044	**0.523**	0.223	–0.011	0.154	0.122	0.151	0.079
Use laborers with aquaculture knowledge	0.528	0.036	0.056	**0.702**	0.111	–0.033	0.104	0.077	0.020	–0.017
Request appropriate price policy	0.561	0.185	0.117	0.410	**0.502**	–0.051	0.061	0.069	–0.021	0.284
Maintain a well-managed water environment in pond	0.487	0.073	**0.421**	0.096	0.374	–0.108	–0.039	–0.068	0.365	–0.065
Apply medicines, chemicals to prevent disease	0.667	0.038	0.153	0.101	–0.059	0.024	0.092	–0.110	**0.774**	0.091
Prevent disease by regularly checking and observing pond	0.660	0.006	0.051	0.028	0.001	0.189	–0.168	0.186	**0.747**	–0.008
Attend workshops or training	0.499	**0.561**	–0.028	0.154	0.310	0.064	–0.132	–0.071	0.115	0.155

Involve production contract with predetermined size	0.384	0.335	0.057	0.030	0.150	–0.026	0.294	–0.053	**0.393**	–0.017
Enter into sales contract with middlemen/ processors	0.506	–0.084	0.016	–0.031	–0.055	0.469	**0.473**	0.102	0.170	–0.111
Collaborate with association of fish farmers	0.549	–0.138	0.066	0.081	0.082	**0.594**	0.209	0.265	0.212	–0.021
Acquire available market information	0.550	0.308	0.203	–0.019	0.331	**0.507**	0.103	–0.129	0.050	0.133
Increase cooperative marketing	0.638	0.048	–0.127	0.068	–0.024	**0.782**	–0.012	0.042	–0.017	0.006
Engage in farmers' cooperative association	0.521	–0.023	–0.135	0.097	0.022	0.107	**0.683**	0.098	0.021	–0.064
Remove influence of middlemen	0.375	0.094	–0.301	0.047	0.156	0.223	0.250	0.325	0.123	0.126
Establish storage facilities	0.540	0.211	0.136	0.042	**0.642**	0.221	–0.069	–0.043	–0.079	–0.035
Improve transportation facilities	0.525	–0.048	0.088	0.008	**0.546**	0.026	0.319	0.309	0.094	0.102
Produce at lowest possible costs	0.448	0.072	0.178	0.189	**0.607**	0.019	0.012	0.071	0.034	–0.015
Collect information on consumer preferences	0.476	0.231	0.197	0.154	**0.615**	0.101	0.160	0.178	–0.055	–0.538
Diversify products	0.525	–0.052	0.063	0.129	0.093	0.113	0.302	**0.614**	–0.064	–0.089
Reduce farm size to appropriate scale	0.319	0.172	**0.411**	0.058	–0.236	0.095	0.401	–0.063	0.104	–0.034
Secure bank loans	0.427	**0.392**	0.067	0.155	0.057	–0.082	0.100	0.321	0.249	–0.244
Involve off-farm work	0.417	**0.406**	0.204	0.072	0.003	0.036	0.288	0.239	–0.076	–0.242
Secure available microcredit	0.571	**0.488**	–0.018	0.048	–0.002	–0.019	–0.082	0.501	0.189	–0.192
Use economic consultant services	0.499	0.256	0.024	0.036	0.168	–0.068	**0.600**	–0.039	–0.180	0.063
Keep cash on hand for farming	0.610	**0.718**	0.111	0.089	0.191	–0.087	0.104	0.130	0.050	–0.006
Share ownership of equipment/ partnership	0.503	**0.564**	–0.042	0.297	–0.131	0.094	0.222	0.091	–0.102	0.036
Percentage of total variance explained		15.468	6.612	5.491	4.902	4.206	3.716	3.553	3.198	3.056
Percentage of total cumulative variance explained		15.468	22.08	27.571	32.472	36.678	40.394	43.947	47.145	50.201
KMO test		0.801								
Bartlett's test of sphericity chi-square value at 1% with df 703		5,298								

Note: [a] The categorizations are based on the factor loading (loadings > 0.30) of individual risk sources. The highest loading values are given in bold.

Table 6. Results of Multiple Regression for Categories of Risk Sources

	Dependent Variables (Categories of Risk Sources That Are Derived from PCA)			
Independent Variables	Production Risk	Financial Risk	Market-Related Risk	Institutional Risk
Intercept	1.790***	1.283***	0.820***	0.824*
OwnerF	–0.150	0.162*	–0.151**	–0.151
OwnerL	–0.047	0.239***	0.074	0.348***
SourceF	0.130	–0.010	–0.355**	0.300*
LandCon	0.280**	0.156	0.145	0.047
Age	0.003	–0.007*	–0.003	0.003
OccM	0.039	–0.038	–0.033	–0.350**
Edu	0.007	–0.019**	0.004	–0.014
Exp	0.004	0.007	0.009	–0.003
Train	0.078	0.010*	0.233***	–0.167**
DummyL	0.181	0.412***	0.079	0.285
DummyM	–0.047	0.221*	0.028	0.221
FamilyS	–0.002	–0.033***	0.016	–0.013
LnIncome	–0.181***	–0.121***	–0.141***	–0.063*
Bogura	0.121	–0.004	–0.400	–0.103
Comilla	0.207*	0.207*	–0.067	–0.016
Khulna	0.200	–0.047	–0.447	0.296
Jessore	–0.108	–0.136	–0.279*	0.044
Chittagong	0.147	0.169	–0.288*	–0.021
Bhola	0.213	0.183	–0.243	0.580***
Adjusted R^2	0.043	0.040	0.046	0.055
Durbin-Watson	1.042	1.098	1.130	1.181

Note: ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

a statistically significant negative influence on the farmers' perceptions of all the categories of risk sources. Perhaps individuals with diversified income sources are less exposed to different types of risks because of a higher ability to adjust to changing market requirements. For instance, they can adjust harvest time when prices are low.

The economic implications of the above risk perceptions are that the farmers perceive more risk, either because they objectively face more risk or because they have a higher subjective perception of the risks. For instance, in the case of financial risks, farmers may not share ownership because doing so would also mean sharing profit, which they objectively see as the same as facing higher risks. On the other hand, smaller farms subjectively face lower financial risks. It is worth mentioning that this paper is about subjective risk assessment. Furthermore, farmers who perceive more risk may decide to reduce production to hedge against possible production, financial, and marketing risk, or in the long run they may quit the industry. That may cause contraction of the industry, reducing fish supply in the market.

RELATIONSHIPS AMONG PERCEPTIONS OF RISK MANAGEMENT STRATEGIES AND FARM CHARACTERISTICS

Corresponding to the risk sources, the relationships among the perceptions of risk management strategies and farm characteristics and farmers' socioeconomic characteristics are determined using multiple regression including regional dummies. Furthermore, the relationships among four categories of risks and nine risk management strategies (types of risk management strategies) are determined. All of the models are statistically significant at the 1% level, with R^2 varying from 0.014 to 0.180, which seems to be very low (table 7). All the models are tested for heteroscedasticity and misspecification by Breusch-Pagan and Ramsey RESET tests; models 1, 2, 3, 4, and 6 were heteroscedastic and models 5, 7, 8, and 9 were found to be homoscedastic. Thus, models 5, 7, 8, and 9 were reestimated by robust regression maximum likelihood method.

Land ownership, land condition, farm size, and household income have statistically negative associations with financial support strategies. This indicates that these types of farmers consider financial support to be less important. However, only farm ownership has statistically significant positive associations with financial support strategies.

Farmers' age and household income have a statistically positive association with farm management and a negative association of age with input supply. It is not unusual for older farmers to put more emphasis on management than younger farmers do. On the other hand, younger people tend to focus on input supply and suppliers, perhaps because younger farmers are generally more motivated to develop and build their business through strong business relationships with suppliers and customers and are more open to the external business environment than older farmers, who tend to emphasize internal farm management (May et al. 2019). This finding is similar to that of Van Winsen et al. (2016), that older farmers are less inclined to use modern technology and inputs than younger farmers are.

Farmers having personal ownership consider quality control, extension and collaboration, and disease management more important risk minimizing strategies compared with other types of farm ownership. This may be because activities like quality control, extension and collaboration, and disease management are more difficult than when the ownership is shared.

Land ownership, sources of funds, and household income have statistically significant positive associations with extension and collaboration strategies. This indicates that the farmers with personally owned farmland, own capital, and higher household income consider extension and collaboration to be more important than their counterparts do. However, trained farmers consider it to be less important than the nontrained farmers. This might be due to their higher ability compared with that of the nontrained farmers to explore opportunities.

Medium to large farms put more emphasis on disease management. This may be because the larger farms follow intensive production systems that are more prone to diseases (Alam, Guttormsen, and Roll 2019; Khan, Guttormsen, and Roll 2018). Such perceptions may motivate the farmers to follow extensive or semi-intensive farming systems, negatively affecting productivity. Medium-size and more household income-generating farm operators consider farm diversification to be an effective tool for risk mitigation.

Overall, knowledge of improved farm management, increased extension services, and supports to control disease management (access to water, quality feeds and seeds) may improve productivity and profitability and support industry expansion.

Implications are that since risk-taking behavior influences risk management strategies, a risk-averse farmer may prefer to act passively by downsizing production or the farm and by saving rather than investing further. However, a risk-seeking (willing to take more risk) farmer may be proactive through farm and income diversification and by linking to the market to optimize production and profit.

The differences in perceived risks and management strategies also imply that individually designed risk management strategies should be applied for different regions when national policies are designed.

Table 7. Results of Multiple Regression for Types of Risk Management Strategies

	Dependent Variables (Types of Risk Management Strategies That Are Derived from PCA)								
Independent Variables	Financial Support (1)	Farm Management (2)	Quality Control (3)	Marketing and Logistics (4)	Farmers' Cooperation (5)	Extension and Collaboration (6)	Diversification (7)	Disease Management (8)	Input Supply (9)
(Constant)	1.017*	–1.670***	–0.916*	0.984*	–1.239**	–1.278***	–0.358	–0.357	0.827
OwnerF	0.084*	0.046	0.554***	–0.076	0.146	0.214**	–0.011	0.349**	–0.089
OwnerL	–0.089**	–0.011	–0.070	–0.040	0.048	0.165*	0.049	–0.178	–0.026
SourceF	–0.154	0.196	–0.190	–0.200	0.117	0.307**	–0.177	0.168	0.013
LandCon	–0.167***	0.045	0.083	0.036	–0.115	0.045	–0.143	–0.090	–0.133*
Age	0.001	0.004**	0.002	–0.001	0.004	–0.004	–0.002	–0.002	–0.008**
OccM	–0.054	0.093	–0.025	–0.160	–0.033	0.021	0.162	0.002	–0.016
Edu	0.009	0.011	–0.002	–0.006	0.008	–0.001	0.003	0.001	–0.007
Exp	0.005	–0.008	0.002	–0.000	–0.006	0.011	–0.001	–0.002	0.005
Train	0.015	–0.100	0.114	0.086	0.006	–0.228***	0.007	–0.122	0.037
DummyL	–0.307***	–0.092	–0.094	0.047	0.115	–0.134*	0.077	0.075**	0.067
DummyM	–0.165**	0.059	0.067	0.044	–0.020	–0.026	0.007*	0.122***	0.106
FamilyS	–0.003	–0.008	0.008	–0.004	–0.019	–0.015	0.001	0.017	–0.002
LnIncome	–0.073*	0.074***	0.030	–0.022	0.058*	0.068***	0.059*	–0.002	–0.037
Production risk	–0.115***	0.386***	0.009	0.072*	–0.057	–0.117***	0.010	–0.032	0.092*
Financial risk	0.203***	0.118***	0.152***	0.003	0.010	0.019	0.199***	–0.004	–0.237***
Market-related risk	0.171***	0.158***	0.053	0.323***	–0.115***	–0.026	–0.160***	–0.015	0.207***
Institutional risk	0.032	0.013	0.115***	0.027	0.073*	0.342***	0.056	0.017	–0.014
Bogura	0.610***	0.523**	0.159	–0.182	0.192	0.004	–0.411**	–0.242*	–0.167
Comilla	0.375***	0.496**	0.189**	–0.090	0.154	0.251*	–0.382***	–0.348**	–0.007
Khulna	0.349	–0.215	–0.483**	–0.409	0.024	0.032	–0.308	–0.719**	0.292
Jessore	–0.020	0.236	0.050	–0.514**	–0.143	–0.086	–0.704***	–0.485**	–0.389**
Chittagong	0.233	–0.118	0.233	–0.292**	0.353**	0.038	–0.612***	–0.557***	0.016
Bhola	0.223	0.216	–0.116	–0.173	0.032	0.179	–0.540***	–0.365**	–0.046
Adjusted R^2	0.145	0.162	0.049	0.120	0.016	0.180	0.053	0.014	0.098
Durbin-Watson	1.651	1.440	1.652	1.592	1.588	1.491	1.703	1.521	1.959

Note: ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

REGIONAL HETEROGENEITY IN PERCEIVED RISK AND RISK MANAGEMENT STRATEGIES

There are statistically significant differences in perceived sources of risk and management strategies across the regions within the study. Farmers in Comilla perceive production and financial risks to be more important than do farmers in the reference region (Mymentsingh). Farmers in Bhola perceive institutional risks to be more important, while they consider marketing risks to be less critical. Such differences in perceived risks may be due to differences in production environments, access to important inputs like water, feed, and fingerlings, availability of labor, and access to markets and supporting infrastructure. Other studies, including Mitra et al. (2019) and Rahman, Nielsen, and Khan (2018, 2019), indicate that differences in local production environments and access to inputs and markets influence farm productivity and efficiency.

Similarly, risk management strategies are perceived differently among the regions. Farmers outside Mymensingh (base region) perceive farm diversification and disease control as less effective. Farmers in Comilla perceive financial supports, farm management, quality control, and extension as more effective risk management strategies, whereas farmers in Khulna, Chittagong, and Jessore perceive quality control, marketing and logistics, and input supply strategies as less effective than the base region does. Similarly, earlier studies by Mitra et al. (2019) and Rahman, Nielsen, and Khan (2018) found that there are interregional differences in farm density, access to extension, and quality inputs that affect farm productivity and profitability.

DISCUSSION

That perceived production risks are higher for farms that are made from converting agricultural land (commercial ponds) may be due to intensive production systems and poor management of the water environment in these ponds (Lebel, Lebel, and Chuah 2018).

Perceived financial risk is higher for personally owned farms than for farms that have shared ownership. It may be that in case of shared farm ownership, risk can be shared among the owners, which is not possible in cases of personally owned farms. Similarly, medium and large farms are experiencing higher financial risk than the smaller farms. Investment and thereby risk are larger for larger-scale farms, a finding reflected in Neira, Engle, and Ngugi (2009) for large-scale commercial tilapia farms, and Khan, Guttormsen, and Roll (2018) for pangas.

More-educated farm operators and larger families perceive financial risks as less important. More-educated operators may be able to obtain income from other sources and have more knowledge on how to access other means such as institutional borrowing, whereas farm operation and financing activities may be shared in larger families.

Perceived marketing risks are lower for those having personal ownership, own-financed farm, and higher household income because of the lower volume of production and alternative sources of income. However, for trained farmers marketing risks are higher, which is also found in Ali, Upraity, et al. (2018). The reason may be that marketing risk becomes more important if the ownership is shared and if the farmers have debt and lower household income.

Perceived institutional risk is higher for farms in personally owned land and self-financed farms. This may be due to limited access to institutional support. For example, these types of farmers do not get access to the large processors who offer better prices. By contrast, full-time farmers and trained farmers perceive institutional risk to be less important, perhaps because they are fully devoted to fish farming.

The higher emphasis that operators of personally owned farms place on financial supports, quality control, extension and collaboration, and disease management as risk mitigating strategies indicate that shared farming (cooperative farming) can provide an improved solution to the risk associated with these risk management strategies.

Production-related risks are significantly associated with multiple risk management tools like financing, farm management, marketing and logistics, and extension and collaboration. It seems reasonable since quality inputs, better management, and knowledge are commonly known as determinants of higher yields. Since efficient input management can have positive impacts on yield (Alam, Guttormsen, and Roll 2019; Khan, Guttormsen, and Roll 2018; Alam, Khan, and Huq 2012; Valderrama and Engle 2001), whereas marketing contracts can reduce price risk (Quagraine, Kuethe, and Engle 2007), long-term strategies may include organizing small-scale farmers in a group, which will help them to gain the advantages of economies of scale, scope, and flexibility in accessing services and markets that are mostly limited to large-scale commercial aquaculture farmers.

The negative associations of household income with all of the categories of risk sources indicates that farmers with higher incomes are relatively less dependent on the next harvest and furthermore have the opportunity to invest more in risk mitigation measures, such as training, information, and specialized inputs, improving economic performance.

In the majority of risk management strategies, the strategies have significant influence on farmers' perceived financial risks. This means that the common motive of any risk management strategy is to minimize financial loss since there are no formal financial risk management tools like insurance. However, formal financial risk management tools can contribute to reducing production, revenue, and environmental risks in aquaculture (Watson et al. 2018).

Marketing risk is considered to be very important. In this regard, formal marketing contracts can effectively reduce price risk (Quagraine et al. 2007; Bergfjord 2007). Thus, efforts to link traders or retailers with farmers may reduce concerns over market risks. Institutions, especially the extension department of the government, can help farmers to link up with retailers and traders because farmers usually do not have the ability to link up with the downstream value chain.

Only quality control, farmers' cooperation, and extension and education have significant influences on mitigating institutional risks. Thus, institutional risks can be reduced by implementing appropriate quality control activities, forming farmers' cooperatives, and improving extension and education services to farmers. Ahsan (2011) found that shrimp aquaculture farmers place more emphasis on organization supports, collaboration, disease control, and diversification strategies to reduce institutional risks.

Risk management is a dynamic and complex process. Like any other form of aquaculture, farming of pangas and tilapia is also associated with diverse sources of risks. Therefore, to adopt one particular risk management strategy is not always enough to minimize risks; rather, it demands a set of multiple risk management strategies (Ahsan 2011; Le and Cheong 2010; Meuwissen, Hurine, and Hardker 2001). This study reveals that the farmers are aware of this, indicating the importance of multiple risk management strategies (table 7). Thus, the multidimensional relationships between perceived risk sources and management strategies suggest that there are no one-to-one risk management strategies. However, a particular risk management strategy can be applied to different sources of risk.

If the fish farmers themselves are not able to respond efficiently to the risks, government agencies could provide support to develop the farmers' abilities to adopt the appropriate risk management tools and strategies. In this, financial institutions play an important role because they can be a tool to reduce financial risks. Furthermore, the sharing of market risk can be facilitated if farmers can be linked horizontally and vertically in the value chain.

CONCLUSIONS

The objective of this study is to provide empirical insights into pond aquaculture farmers' perceptions of risk sources and their management strategies. Descriptive statistics and a principal component analysis technique are used to assess farmers' perceptions towards sources of risk and risk management strategies. Furthermore, the relationships of risk perception and risk management strategies with the farmers' socioeconomic characteristics are investigated by using a principal component regression model.

The results suggest that, in general, price variability and quality of inputs are perceived as the most important sources of risk. The use of quality inputs is perceived as the most important risk management strategy, whereas strategies focusing on price risk reduction, like sales contracts, are not considered to the same extent as input quality.

Overall, household income, training, and land ownership have the most significant influences on farmers' risk perceptions. Similarly, owners of larger and medium-sized farms consider financial risk to be more important than do owners of smaller farms. Financial risks are also considered to be an important risk source by single owners and owners who personally own land. Farmers having higher household incomes perceive all sources of risk to be less influential. Accordingly, a variety of risk management strategies are needed to address a specific source of risk. Furthermore, cooperative farming can also help farmers minimize many risks associated with financing, quality control, extension and collaboration, and disease management. Altogether, the most important risk management strategies are better access to financial resources and improved farm management.

Furthermore, the perceived risks and their management strategies statistically significantly vary across the studied regions, indicating that a common framework for risk management undertaken either at a farm level or at a policy level may not be effective.

This study identifies means of interventions targeting either risk perception or risk response (strategy). The paper will be a contribution to help policy makers, development NGOs, consultants, and farm operators to identify, guide, and formulate appropriate risk management strategies. A further contribution is to direct future research towards more integrated approaches, taking into account the perceptions of risk, risk attitudes, and risk responses when looking at managing aquaculture in developing countries. Another domain of future research could be in relation to ecological risks since the sector is growing fast, possibly at the cost of biosecurity and environmental degradation.

Further research could also look at objective risks and how those risks could be shared and reduced if small-scale farmers are organized in cooperatives (horizontal integration) or linked with buyers, retailers, and institutional lenders (vertical integration), which could potentially increase earnings and improve livelihoods and food security in the growing aquaculture sectors in developing countries.

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