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Are shrimp farmers actual gamblers? An analysis of risk perception and risk management behaviors among shrimp farmers in the Mekong Delta

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ABSTRACT

Shrimp farming is considered a “risky business” and often compared to gambling for farmers. It is associated with a diverse range of risks and uncertainties, including volatile markets, climate variability, and production risks. In order to mitigate the effects of unpredictability farmers may decide on a particular stocking density and adopt different risk management strategies. Aquaculture research has paid little attention to the influence played by the evaluation and selection of different farming practices, risk perceptions associated with shrimp farming, and the farmers' confidence in their own ability to mitigate risk. The objective of this paper is to analyze the case of shrimp farming in Vietnam's Mekong Delta, where different types of shrimp farms (extensive, semi-intensive and intensive) co-exist within the same landscape, to identify the underlying factors driving stocking behavior and the adoption of different risk management strategies.

A survey of 250 farms showed that perceptions toward different stocking behaviors (from extensive to intensive) varied according to the species raised (*Penaeus monodon* or *P. vannamei*) and the type of farm. At low density, farmers consider *P. monodon* as more productive and easier to adopt than *P. vannamei*. Adoption of intensive farming practices for both species is negatively associated with risk of disease emergence. However, expected productivity is not a predictor of adoption of intensive shrimp farming practices. Mediation analysis indicates that risk management strategies are significantly influenced by perceived market risk. The perception of this type of risk is a key predictor of risk management strategies. The farmers' lack of access to efficient market risk mitigation measures reflects inadequate or missing regulations or lack of specific value chain organization to mitigate this type of risk. Using a behavioral approach provides new insight on how farmers manage their farms, address risk and implement risk management strategies. It showed that farmers, unlike actual gamblers, adopt diverse management strategies after carefully evaluating species and stocking density as well as critically assessing different sources of risk.

1. Introduction

The Aquaculture sector is experiencing rapid growth and is embedded in a highly versatile and uncertain context because of climate change and internationalization of trade. Driven by market demand, the improvement of technologies available to farmers, diversification of farmed species, intensification of production and, at the same time, expansion of aquaculture farms (Ottinger et al., 2016), the world's aquaculture production increased from 6.2 to 70.2 million tons between 1983 and 2013 (FAO, 2015). This trend is expected to continue with global aquaculture production estimated to reach 187 million tons by 2030 (The World Bank, 2013), equaling global capture fisheries production. Ninety percent of the total aquaculture production (FAO, 2015) is sourced from Asia, where a large share of the production is sourced from commercially-oriented small and medium-scale farms that are increasingly intensifying their production system (Belton et al., 2017).

The tremendous growth in aquaculture contributes to water and ecosystem pollution, habitat degradation (Ottinger et al., 2016), and environmental degradation, which in turn leads to increased production risks for aquaculture farmers (Walker and Mohan, 2009), such as the occurrence of regional disease outbreaks affecting shrimp farming. In addition, competition with other sectors for land and water (Bostock et al., 2010), global warming, rising sea level, saline intrusion and extreme weather events (floods, droughts, storms) (Handisyde et al., 2016) make the sector vulnerable and will further increase production

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risks in aquaculture production systems in the near future. Furthermore, globalization of the aquaculture value chain, with several commodities such as shrimp and pangasius traded worldwide, increases market risk and unpredictability for farmers (Jespersen et al., 2014).

Within aquaculture, shrimp farming is a showcase example of an aquaculture subsector that has expanded and intensified rapidly in the past decades. The sector's growth was driven by international market demand and government and development aid policies, and fueled by technical and institutional innovations (Béné, 2005). The two dominant species are *Penaeus monodon*, the tiger shrimp endemic to South East Asia, and *P. vannamei,* the whiteleg shrimp originating in South America but now widely raised in Asia. The latter species is considered to be more resistant to diseases, has a shorter growth cycle, is more tolerant to a larger range of water salinity and temperature, and its production is more consistent in terms of quality and size (Yi et al., 2018). These production characteristics combined with favorable public policies have encouraged its rapid diffusion and adoption in several Asian countries (Thailand, Indonesia) and more recently, Vietnam. These favorable conditions have provided producers with an additional alternative species. Meanwhile, risk related to climate, disease and market has increased, with intensification causing farmers and practitioners to now consider shrimp cultivation a gamble (Daily Mail 2017[1]; New York Times 2008[2]). Researchers tend to agree (Szuster et al., 2003; Flaherty et al., 2009). Although shrimp farming is highly risky and considered by many a gamble, it is still a widespread production system, thus raising questions around how farmers perceive and manage the related risks.

Production systems are distinguished according to the species produced and the three main levels of intensification or farm types: extensive, semi-intensive and intensive farms. Each farm type has distinctive structural and functional characteristics and faces different degrees of risk (Joffre and Bosma, 2009; Hoa et al., 2011). Adequate responses to mitigate risk vary, with different risk management strategies being employed (Kabir et al., 2017). For this study, we consider risk management strategies in a broader sense, including not only on-farm strategies and technological adoption (farming technology and practices, level of intensification), but also risk-sharing strategies (price contracting, insurance), and off-farm investments. Within the process of adoption of risk management strategies, perception of the magnitude of the risk and the confidence to mitigate specific types of risk both play a significant role (Greiner et al., 2009; Niles et al., 2016). We define adoption as taking measures to recognize risk and implement technologies and practices to mitigate it.

Risk research in aquaculture, so far, has mostly been limited to ecological risk assessment (Aerni, 2004; Moreau, 2014; Tidbury et al., 2016; Young and Liston, 2016) or has relied on an economic approach that looks at production risks at the farm level (Piamsomboon et al., 2015; Clegg et al., 2014; Gustafson et al., 2014; Hanson et al., 2008; Oidtmann et al., 2014). The latter group of referenced studies uses a risk factor analysis approach to explain and optimize farm management practices. The risk source considered in this type of risk analysis varies (disease, fish price, input price, climate, or funding sources) and outputs from this sort of risk analysis support better management of the farm and help to address uncertainty in farm management. Ecological risk relates to the degradation of the environment resulting from the development of aquaculture activities, such as the introduction of genetically modified species (Aerni, 2004; Moreau, 2014), or exotic species (Tidbury et al., 2016), or the effects of new production systems (Young and Liston, 2016). Finally, a few studies provide analysis of fish farmers' perceptions of climate-related or disease-related risk (Chitmanat et al., 2016; Lebel et al., 2016; Lebel, 2016; Kabir et al., 2017), while Bush (2017) explores how production risk influences the organization of shrimp and salmon value chains.

Both the ecological (e.g. climate-related) and economic approaches to risk factor analysis in aquaculture surprisingly omit farmers' perception of, or attitude toward, risk. These approaches also fail to analyze both the adoption of risk management strategies and the farmers' self-confidence in mitigating perceived risks. In other resource management-related sectors, such as agriculture, the role of perceived risk has been studied more extensively using behavioral approaches. Greiner et al. (2009) looked at correlation between risk perception and adoption of conservation practices. Hunecke et al. (2017) investigated the role of social capital in risk perception and its influence on trust and adoption of agricultural practices to mitigate risk, while Niles et al. (2016) explored the influence of risk perception on actual and intended adoption of climate change mitigation and adaptation strategies. Building on this work in agriculture, and in striving to understand underlying drivers that influence how farmers choose different risk management strategies in aquaculture, we argue that the role of the farmers' risk perception, self confidence in mitigating risk and their evaluation of production practices need to be studied. Understanding farmers' decision making in shrimp farming management and how they choose their risk management strategies require i) insight into how farmers perceive different sources of risk and ii) how different external drivers, farm and farmers characteristics influence farmers' behavior. Farm characteristics influence risk perception and risk management practices (Meuwissen et al., 2001). This study is premised on the assumption that different shrimp farm types lead to different types of risk management. First, we analyze choices related to farming practices by unpacking the farmers' evaluation of the differing farming intensities of two main shrimp species. Second, we hypothesize that underlying factors such as risk perception and perceived capacity to control risk explain adoption (or not) of risk management strategies, and that differences regarding specific risk management strategies exist across farm types.

The paper is organized as follows. The theoretical framework in the second section partially builds upon work from agricultural research and is premised on the approach used to explain linkages between perception of risk and behavior being applicable to aquaculture, as farmers face similar types of risk and can deploy similar types of risk management strategies (risk sharing, on farm strategies and technologies and off farm investment). Section 2 illustrates the study area and method used. The third section offers results on farmer stocking behaviors (section 3.3) and farmer risk management strategies (section 3.4), followed by discussion in the fourth section and conclusion in the fifth section.

2. Theoretical framework

We study two categories of farming behaviors: stocking behaviors and risk management strategies. Both behaviors are important indicators of current farm operations (Engle et al., 2017; Boyd and Engle, 2017), and of good farm management in the future (Li et al., 2016).

To explore the two behaviors we frame our analysis, using different farm types based on stocking intensity: extensive, semi-intensive and intensive farms. Typologies based on farming intensity are widely used in the aquaculture sector but show limitations in supporting farm-level analysis (Engle et al., 2017). We integrate the farm typology in our analytical framework in addition to the characteristics of farms and farmers as we hypothesize that stocking intensities not only influence technical operations on the farm, but also how farmers evaluate and view these operations and, in turn, assess stocking behavior, perceive risk and adopt risk management strategies.

First, we explore stocking behaviors per farm type: the level of farming intensity and species raised and the underlying reasons informing different behaviors. We distinguish seven types of stocking

[1] http://www.dailymail.co.uk/wires/afp/article-4773658/Rice-riches-Vietnams-shrimp-farmers-fish-fortunes.html

[2] http://www.nytimes.com/2008/03/20/business/worldbusiness/20iht-rbogcoast.1.11278833.html

behaviors (from low to very high intensity) based on the two main species cultivated (*P. monodon* and *P. vannamei*). The farmers evaluate each of the practices according to four distinct dimensions: the perceived cost, productivity, risk of diseases and applicability (or the 'easiness' of implementing the innovation). Our analysis investigates the influence that the farmers' evaluation of these factors has on their adoption of stocking behaviors.

The second part of the analysis explains the risk management strategies implemented by farmers to remove or mitigate the effects of risk-causing factors (Akcaoz and Ozkan, 2005). Here, we analyze how the perception of risk severity and confidence in own ability to mitigate risk according to each farm type explain risk management strategies. We hypothesize that in a context of unpredictability and with various impending hazards, farmers' risk perceptions influence their on-farm decision-making. Based on Hardaker et al. (1997)'s definition, the two main types of risk in agriculture can be identified as business and financial. Business risk includes production risk (related to uncertainty of climate or crop performance). Price risk, on the other hand, includes, for example, market insecurity, input price and personal risk (illness, death of household members operating the farm). Business risk also includes institutional risks related to government policy and market governance that impact farm profit. The second component of risk in agriculture, financial risk, pertains to how farms are financed. This study focuses on business risk as it is complex, involves different dimensions that are interlinked, and is paramount to understand the adoption of innovation beyond solely the economic dimension. Financial risk and how it influences adoption is beyond the scope of the present article and should be investigated in a separate study using different approaches, methods and tools.

We base our approach on elements of the Protection Motivation Theory (PMT; Rogers, 1975) which states that an individual's protective behavior is predicted by two main determinants: risk perceptions and a person's perceived capacity to counter risk (Rogers, 1975). The perception of risk severity determines the consideration that farmers allocate to each source of risk and to the potential impacts on the economic performance and productivity of their farm. The framework included the farmers confidence in their ability to mitigate diverse sources of risk such as controlling disease, making suitable pond management choices, mitigating climate and market risks. We thus applied PMT theory to the field of aquaculture, also including in our analysis: farm and farmer's characteristics, type of farm and how it is affected by risk perception and the farmer's capacity to mitigate different sources of risk.

2.1. Study site

The Mekong Delta coastal area has undergone tremendous transformations since the 1990s with expansion of shrimp culture, *Penaeus monodon* (commonly named "tiger shrimp"), at the expense of mangrove and rice fields (Nguyen, 2014). After a rapid expansion of extensive systems, the sector quickly evolved under the influence of both public and private extension services, enabling access to knowledge, new technologies and practices for smallholder farmers. As a result, a wide a range of production systems co-exist in the Mekong Delta, from extensive to intensive systems (Table 1). This trend of intensification led to doubling the production area between 2000 and 2010, while production increased by 342% (GSO, 2017).

This rapid development did not come about without risks for producers. Shrimp farmers face high risks from different sources, with the danger of disease outbreak due to contaminated inputs, pollution from the wider ecosystem and also climate shocks triggering disease outbreaks. Shrimp is an internationally-traded good, hence the global market influences supply and demand, causing farm gate price fluctuations to be sudden and unpredictable. Access to international markets implies stricter quality norms (absence of antibiotic traces for example) that create another source of risk and influence management practices.

In 2008, an exotic shrimp species, *Penaeus vannamei* (commonly named whiteleg shrimp) was introduced in Vietnam, broadening options for local farmers who previously cultivated *P. monodon* only. Each species has its own distinctive husbandry technique, market and risk. *P. monodon* has a higher price on the market, but its culture is usually longer, thus requiring inputs for longer periods and increasing risk of disease. *P. vannamei* has a lower value on the international market but can be raised at higher density, resulting in higher productivity across a shorter growth cycle.

2.2. Survey

The survey sample included 251 farms within 2 main shrimp producing provinces in the Mekong Delta, Soc Trang and Bac Lieu provinces (Fig. 1). In our survey, we distinguish the following systems as: Extensive system (Ext), Semi-intensive system (SI) and Intensive system (Int) (Table 1).

The survey included questions regarding farm and farmers' characteristics (education level and years of experience, farmed area, number of ponds, access to loans, and membership in a cooperative or farmers' group). We identified seven stocking behaviors based on the species stocked (either *P. monodon* or *P. vannamei* stocked at low, average, high or very high density. The last level of intensity was found only for *P. vannamei* (Appendix A). For each stocking behavior, we asked about perceptions related to cost, productivity, risk of disease, and easiness to adopt. We then asked about the severity of different types of risk as well as the perceived capacity to mitigate them.

Adoption of risk management strategies covered different dimensions of risk and risk mitigation (disease, climate, knowledge response, market, financial risk) detailed over a set of 34 potential strategies deployed by farmers. We included risk related to water quality in the survey tool but not about water availability and access, since shrimp farmers in the Mekong Delta and aquaculture experts do not find it problematic. Risk management strategies correspond to the adoption of technology such as probiotics, liner, or bio-security measures, but also include access to knowledge and information, knowledge networks, reducing farming intensity, changing shrimp species or seeking alternative an livelihood. The questions were framed using a Likert-type scale (e.g.: currently applying: 1 = not at all; 2 = not often; 3 = sometimes; 4 = often; 5 = always).

2.3. Analyses

We analyzed the results as follows according to farm type: i) general farm's and farmers' characteristics and ii) stocking behavior, before iii) exploring how perceptions of each given practice influence stocking behavior and iv) exploring links between underlying reasons for stocking behaviors. The analysis continued with v) analysis of differences in risk management strategies and vi) looking at perceptions of risk severity and confidence in own ability to mitigate risk as an exploratory variable for the adoption of a risk management strategy. Finally, in the last section we performed mediation analyses to test whether underlying perceptions can explain differences between farm types and the adoption of specific risk management strategies.

We first analyzed the dataset using basic descriptive statistics (SPSS, 2007). We created a smaller set of variables whenever possible, either by checking the internal reliability of the set of variables or by performing a factor analysis with principal component. In order to test the internal reliability of the data set, the grouping of variables was accepted when the Cronbach alpha values were found to be above 0.7. We also used factor analysis to aggregate variables that were measuring similar constructs. The factor analysis we tested, the Kaiser–Meyer–-Olkin (KMO) measures of sampling adequacy for sources of risk, showed a value of 0.70. The factors were rotated using VARIMAX with Kaiser Normalization, an orthogonal rotation procedure, to increase the

Table 1
Description of the shrimp production system and sample size (*n*) used in this study.[a]

Type	Description	n
Extensive	Ponds are managed with limited amount of inputs (fertilizer and lime), aeration is not used, manufactured pellet feed is not used, and feed depends on the natural productivity of the pond. Stocking density is below 8 PL/m^2 (*P. monodon*) and below 10 PL/m^2 for *P. vannamei*. Farmers usually follow a multi-stocking/harvesting approach every month. Production is below 400 kg/ha/yr for *P. monodon* and below 700 kg/ha/yr for *P.vannamei*. Those farms are found mostly in Bac Lieu and Ca Mau area.	89
Semi – intensive	Ponds managed under semi-intensive system feed are mostly based on manufactured pellet feed. Water quality management includes the use of probiotics, fertilizer and other inputs. The ponds are aerated, and stocking density is between 8 and 19 PL/m^2 (*P. monodon*) and between 10 and 29 PL/m^2 for *P. vannamei*. The production reach up to 3.5 tons per hectare and per cycle for *P. vannamei* (usually 2 cycles per year) and below 3 tons per hectare and per cycle for *P. monodon* (up 2 cycles per year). Those farms are found along all the coastal area.	103
Intensive	Intensive ponds are entirely dependent on manufactured pellets for feeding the shrimp. Aeration is essential and inputs used to manage and control water quality are important. Intensive farms usually have a water treatment pond. The stocking density is above 20 PL/m^2 and 30 P/m^2 when stocking *P. monodon* and *P. vannamei* respectively. The productivity of those farms varies widely, from above 3.5 tons/ha/cycle to > 10 tons/ha/cycle for *P. vannamei* and *P. monodon* (2 cycles per year). Those types of production systems are found close to the coastline, in Soc Trang and Bac Lieu and Ca Mau province.	59

[a] Based on Joffre and Bosma, 2009, Engle et al., 2017 and updated following consultation with local expert.

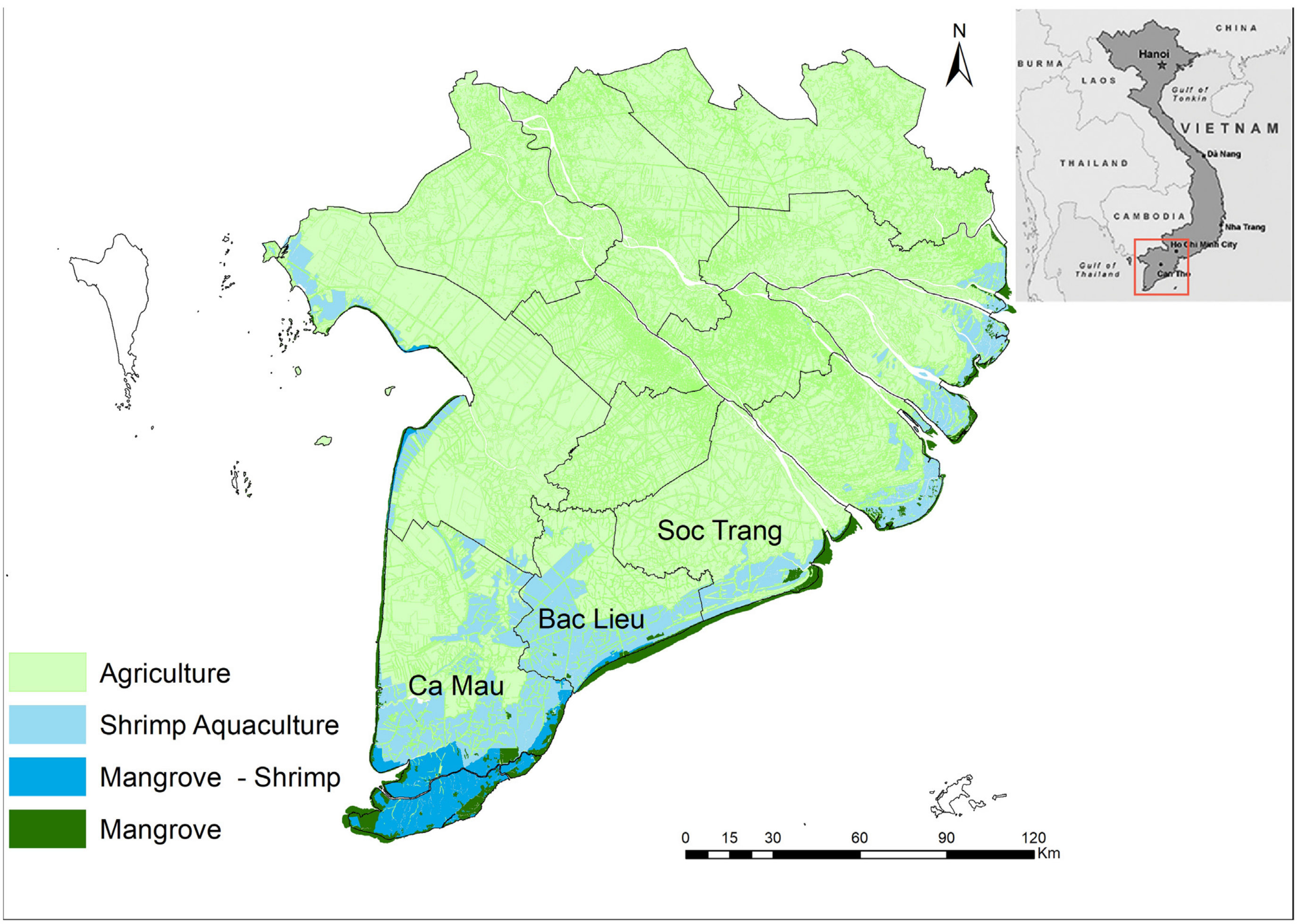

Fig. 1. Study area (Bac Lieu, and Soc Trang provinces) in the coastal zone of the Mekong Delta, Vietnam.

interpretability. Factor solutions with different numbers of factors were examined before the most representative and parsimonious model was identified. Factor analyses yielded single factor solutions with factor loadings above 0.40. Identified factors were then labeled based on variables loaded on the factor.

In a second step, to test if variables are significantly different between different farm types, we used ANOVA and post hoc tests (Games and Howell in SPSS, 2007). In addition to underlying factors explaining reasons for adoption we also tested how farms differ in structural and organizational characteristics and farmers characteristics using ANOVA and post-hoc tests (Games and Howell, Kruskall-Wallis in SPSS, 2007). In order to explore associations between underlying reasons for stocking behaviors and to establish a causal chain (Spencer et al., 2005), we regressed stocking practices based on perceptions of cost, expected productivity, disease control, impact on pond ecosystem, and ease of adoption of different practices.

Finally, to test whether differences in risk strategies per farm type could be described by the proposed explanatory mechanisms, we performed mediation analyses. To formally test for mediation, bootstrap analyses (Preacher and Hayes, 2004; Shrout and Bolger, 2002) were employed to test the reduction in the direct effect. This powerful approach allows for testing and controlling for the role of multiple mediators simultaneously, and involves computing 95% confidence intervals (CIs; 5000 bootstrap resamples) around indirect effects; mediation is indicated by CIs that do not contain zeroes.

3. Results

3.1. Data reduction

3.1.1. Risk management strategies

For risk management strategies, we used a factor analysis to reduce the number of variables, resulting in a seven-factor model explaining 60.1% of the variances. We labeled the factors based on their composition (Appendix B, Table B1). The first factor represents the *"input way",* whereby farmers aim for high productivity based on quality inputs to reduce risk, as opposed to the polyculture approach which is loaded negatively on this factor. The second factor corresponds to two opposite behaviors: "*training vs risk spreading*", whereby trainings – either support from extension services or following the official cropping calendar – are positively loaded on this factor and multiple stocking and low-cost inputs (i.e. risk spreading) negatively loaded on the factor. The third factor corresponds to "*management and marketing strategies*" which include adopting Best Management Practices, contract farming and joining a cooperative. The fourth factor corresponds to adoption of "*bio-floc technology*" and the fifth factor concerns adoption of "*local and accessible knowledge",* such as advice from retailers and neighbors or testing their own experiments. The sixth factor corresponds to "*de-intensification"* (reducing the stocking density) and the last factors relates to farms' "*livelihood diversification*".

3.1.2. Severity of perceived risk

A five-factor model explaining 64% of the variance was chosen to explain the complexity of how severe the farmers perceive the risks to be (Appendix B, Table B2). Among the different risks, we identified "*climate risk*" as loaded on factor 1 including risk of increased temperatures, drought risk, rainfall, and water salinity fluctuation. The second factor concerns risk associated with "*market and input cost*", the third factor risk of "*water and shrimp quality*", the fourth factor "*disease*" risk and finally the fifth factor encompasses changes in "*norms and regulation*".

3.1.3. Perception of farmer confidence to mitigate risk

Confidence in mitigating or controlling different aspects of risk in shrimp farming was assessed using a Likert-type Scale (five points). The ten questions covered different domains, such as confidence in mitigating diseases and market risk, but also mitigating climate variability or managing the pond water quality and choosing adequate inputs. A four-factor model was elaborated using a factor analysis that explained more than 68% of the variability (Appendix B, Table B3). It covers confidence in: controlling disease (factor 1), selecting the right input and providing sound technical management of the pond (factor 2); mitigating climate risk (factor 3) and mitigating market risk (factor 4).

3.2. Characteristics of farm and farmers

When the structural and organizational characteristics of the different types of farms and farmers' backgrounds were compared, striking differences emerged. The number of ponds, area and years of farming to date were found to be significantly different across farm types (Table 2). Extensive farms had fewer ponds but were larger than other farms, while with intensification the number of ponds increased but the total farm area decreased. Intensive farmers operated smaller ponds that were easier to manage with the water quality also easier to maintain during harvest. The extensive farms we surveyed had generally been operating for a longer time than the semi-intensive ones. Semi-intensive farms were more often part of a cooperative than intensive and extensive farms. Cooperatives were usually organized as a cluster of farms that manage water intake and discharge, and purchase inputs as a group to reduce cost. The education level differed significantly ($P < .05$) according to farm types, with a higher percentage of intensive farmers having completed high school or higher. Semi-intensive farmers presented the highest frequency of loans, which was significantly different across farm types.

Table 2
Farm and farmer characteristics per farm type. Values in same row in superscript fonts or followed by * are significantly different ($p < 0.05$). Standard deviation in parenthesis.

	Extensive	Semi-intensive	Intensive
Area (ha)	1.75 (1.54)[a]	1.37 (2.60)[ab]	1.12 (0.93)[b]
Number of ponds	1.74 (0.99)[b]	2.76 (1.81)[a]	3.11 (1.87)[a]
Cooperative membership	17%*	49%*	37%*
Contracted loan	22%*	39%*	39%*
Years of farming	17.64 (6.60)[a]	14.344 (6.47)[b]	16.80 (6.15)[ab]
Age	50 (12.90)[a]	45.36 (11.54)[a]	47.81 (10.62)[a]
Education level (Completed High school and above)	14% *	21%*	26%*

The results complement the definition of the farm typology presented earlier. We found extensive farms were larger and usually had fewer, but bigger ponds. They were operated by farmers engaged in farming for a longer period (a mean of 17 years), but with a lower level of education than those operating other farm types. Compared to semi-intensive and intensive, less extensive farmers surveyed belonged to a cooperative or had contracted a loan. Semi-intensive farmers had the least experience farming shrimp; they belonged to a cooperative, thus to a larger network with access to aquaculture knowledge, and had an average level of education compared to other farmer types. They also reported the highest rates of contracted loans to finance their crops. Intensive farms had the largest number of ponds, albeit with smaller individual areas than extensive farms. Intensive farmers had higher educational levels; some of them had contracted a loan and/or belonged to a cooperative.

3.3. Farm types and stocking behaviors

The survey included seven practices related to different stocking density of the two shrimp species. The practices included three levels of stocking density of *P. monodon* (low, medium and high) and four levels of stocking density of *P. vannamei* (low, medium, high and very high), which correspond to the practices found locally.

3.3.1. Stocking behavior differences across farm types

Not surprisingly, the various types of farms surveyed differed significantly in the type of species raised and in the level of intensity of the farming strategy they implemented (Table 3). At low stocking density, *P. monodon* was adopted more frequently than *P. vannamei*. Average farming intensity showed similar patterns for both species, with higher likelihood of adoption by semi-intensive farmers. Extensive farmers were reluctant to test such production system, which translated into limited adoption. High stocking density of *P.monodon* was not common even among intensive farmers; they were more likely to adopt intensive and very intensive practices with *P. vannamei*.

Adoption level corresponds to a five point scale ranging from 1: not at all to 5: always. Values in same row in superscript fonts are significantly different ($p < .05$). Standard deviations in parentheses.

Table 3
Adoption of different species and stocking intensity among the different farm types.

Practices	Extensive	Semi-intensive	Intensive
Stocking P. monodon			
Low intensity (10 < PL/m^2)	3.97 (1.47)^a	1.92 (1.46)^b	1.05 (0.21)^c
Average intensity (10–20 PL/m^2)	1.08 (0.52)^a	2.64 (1.64)^c	1.71 (1.31)^b
High intensity (> 20 PL/m^2)	1.00 (0.00)^a	1.05 (0.53)^a	1.43 (1.09)^b
Stocking P. vannamei			
Low intensity (10 < PL/m^2)	2.24 (1.67)^a	1.47 (1.22)^b	1.00 (0.00)^b
Average intensity (10–20 PL/m^2)	1.03 (0.318)^a	2.76 (1.78)^c	1.69(1.29)^b
High intensity (30–80 PL/m^2)	1.00 (0.00)^a	1.00 (0.00)^a	3.30 (1.54)^b
Very high intensity (80–200 PL/m^2)	1.03 (0.31)^a	1.00 (0.00)^a	1.37 (1.03)^b

3.3.2. Evaluation of stocking practices

For each practice, farmers were provided with a Likert-scale ranging from one (low) to five (high) to rank their perception of cost, expected productivity, expected risk of disease and easiness to implement the practices. Perception of cost was significantly different across farm types (Table 4). Extensive farmers allocated increasing cost to intensification with their perception of the cost with regard to high stocking density being similar to that of semi-intensive farms. By contrast, intensive farmers perceived the cost of farming to be lower than other farm types, and only high intensity farming was ranked as a high cost.

Intensive farmers perceived low intensity farming as unproductive but with a limited risk of disease, which contrasts with the perception of extensive farmers who considered extensive practice as relatively productive and with an average level of risk. Extensive farmers considered *P. vannamei's* culture at low density as less productive than *P. monodon,* but this perception changed when considering medium and high stocking density. This result, together with a perception of lower disease risk and easier-to-adopt practices, can explain the higher adoption rate of *P. monodon* versus *P.vannamei* when cultured at low density. The fact that extensive farmers perceived intensification to be pricier and riskier can explain their limited adoption of average stocking density.

Expected risk of disease was lower in the case of Intensive farmers, especially in the case of low and average stocking density, which could indicate a higher confidence in controlling disease outbreaks. In the meantime, at high farming intensity, Intensive farmers preferred to raise *P. vannamei*. The species was perceived as carrying a lower risk of disease, perhaps due to its shorter growth cycle.

The easiness of applying technology increased with intensity. *P. monodon* farming was perceived, in general, as easier to implement than *P. vannamei*. Semi-intensive farmers were more likely than extensive farmers to consider the practices of average and high intensity farming difficult. This could be explained as the semi-intensive farmers having more extensive experience managing semi-intensive ponds, while extensive farmers had not yet experienced this level of intensity.

3.3.3. Associations between reasons for stocking behaviors and actual stocking densities

We conducted regression analyses in which we explored the associations between underlying reasons for stocking behaviors and stocking densities. We regressed stocking intensities on perception of cost, expected productivity, disease risk, impact on pond ecosystem, and easiness of adoption of different practices (Table 5). Results indicate that stocking low intensities of *P. monodon* was positively associated with perception of cost, expected productivity, disease risk, and easiness of adoption of different practices. Comparatively, stocking *P. vannamei* at low density was associated with easiness to implement and productivity, while the association between adoption and perception of disease risk was at a lower significant level compared with *P. monodon*. Adoption of *P. monodon* at average intensity was associated with increased perception of cost and negatively associated with the easiness of the technology, showing the technical challenges to adopting this type of practice. At higher density the adoption of *P. monodon*, was negatively associated with disease risk but positively with the easiness of practice.

With intensification, adoption of *P. vannamei* was negatively correlated with perception of high cost, lower perception of disease risk in the case of "high intensity" and with easiness of technology. Perception of cost was negatively associated with intensification of *P.vannamei* but not with *P. monodon,* indicating that adopters of high intensity type of culture perceived that *P. vannamei* was a more affordable practice than *P. monodon.* Results show that adoption of intensive farming of both species was negatively associated with risk of disease, but expected productivity was not a driver for adoption. For adopters of high intensity practices, both species were associated with low perception of disease risk and easiness of practice. The later perception also applied to very high intensity culture of *P. vannamei.*

3.4. Farm type and risk management strategies

3.4.1. Risk management strategies according to farm type

Some considerable differences between risk management strategies currently implemented by different types of farmers were noted (Table 6). Adoption of the "*input way*", with use of high quality inputs and a technical response to risk, was significantly different across all farm types, with a higher adoption rate for intensive farms. Similar differences were found for the type of risk management strategy ("*training vs risk spreading*"). Intensive and semi–intensive farm types provided a more informed response based on training and adherence to collective norms, when compared to extensive farms in which risk is

Table 4
Perception of cost, expected productivity and disease occurrence and easiness to adopt different practices by extensive (Ext), semi-intensive (SI) and intensive (Int) farmers. Perception level corresponds to a five point scale ranging from 1: low to 5: high. For each variable tested, values in same row in superscript fonts are significantly different ($p < .05$).

	Cost			Productivity			Disease			Easiness		
Practices	Ext	SI	Int	Ext	SI	Int	Ext	SI	Int	Ext	SI	Int
P. monodon												
Low intensity	2.99^a	2.47^b	2.01^c	3.65^a	2.49^b	1.49^c	3.29^a	2.46^b	2.54^b	4.54^a	4.17^b	4.47^a
Average intensity	3.13^a	3.19^a	1.86^b	3.62^a	3.27^a	2.49^b	3.48^a	3.27^a	2.81^b	4.54^a	3.76^b	4.30^a
High intensity	4.64^a	4.66^a	4.03^b	4.67^a	4.39^{ab}	4.07^b	4.70^a	4.51^a	4.58^a	3.13^a	2.81^b	3.11^a
P. vannamei												
Low intensity	2.97^a	2.92^a	1.79^b	2.93^a	3.05^a	1.67^b	3.76^a	3.08^b	2.80^b	4.21^a	4.02^b	4.35^a
Average intensity	4.70^a	4.10^b	3.04^c	4.55^a	3.92^b	3.17^c	4.15^a	3.39^b	3.36^b	3.38^b	3.58^b	4.06^a
High intensity	5.00^a	4.71^a	3.94^b	4.89^a	4.56^b	4.03^c	4.46^a	4.24^a	3.74^b	3.15^b	2.61^a	3.69^c
Very high intensity	5.00^a	5.00^a	4.59^b	4.72^a	3.93^b	4.41^b	4.85^a	4.24^b	4.26^b	2.53^a	1.73^b	2.58^a

Table 5
Results of regression analysis of perception of cost, expected productivity, disease control, impact on pond ecosystem, and easiness to adopt of each practice corresponding to the different stocking densities of P. monodon and P. vannamei.

	Stocking P. monodon			Stocking P. vannamei			
Predictor	Low intensity	Average intensity	High intensity	Low intensity	Average intensity	High intensity	Very high intensity
Cost	0.33***	0.23**	−0.45	0.07	0.09	−0.32***	−0.16**
Productivity	0.45***	−0.13	−0.05	0.31***	−0.12†	−0.03	−0.079
Disease risk	0.23***	0.04	−0.26***	0.14*	−0.04	−0.16**	−0.08
Easiness	0.18***	−0.25***	0.18**	0.25***	0.03	0.30***	0.35***

Note. Standardized regression weights (Betas) are reported. †$P < .10$; *$P < .05$; **$P < .01$; ***$P < .001$.

Table 6
Differences across farm types and risk management strategies. Mean and standard deviation of risk management strategies factors are in parenthesis. Values in same row in superscript fonts were significantly different ($p < .05$). Standard deviation in parenthesis.

Risk management strategies	Extensive	Semi-intensive	Intensive
Input way	−0.54 (0.88)[c]	0.11 (0.90)[b]	0.40 (0.93)[a]
Training vs risk spreading	−0.83 (0.81)[c]	0.14 (0.75)[b]	0.63 (0.71)[a]
Management and marketing strategies	−0.21 (1.13)[b]	0.27 (1.00)[a]	0.03 (0.82)[ab]
Bio-floc technology	−0.02 (0.63)[a]	−0.09 (0.86)[a]	0.07 (1.29)[a]
Local and accessible knowledge	0.09 (0.87)[a]	0.04 (1.04)[a]	−0.11 (1.07)[a]
De-intensification	−0.03 (0.93)[a]	0.06 (1.07)[a]	−0.00 (1.01)[a]
Livelihood diversification	0.12 (1.05)[a]	0.04 (1.03)[a]	−0.13 (0.92)[a]

diffused through multiple stocking and the use of cheap inputs. Finally, semi-intensive and extensive farms presented significant differences in the adoption of "*management and marketing strategies*", with semi-intensive farms being more likely than extensive farms to pursue BMP certification (VIETGap, Aquaculture Stewardship Council), join a co-operative and/or partner with processing companies. Adoption of other risk management strategies did not differ significantly between the three farm types.

3.4.2. Perception of risk severity and confidence in ability to mitigate risk

The perception of the severity of these different types of risk varied according to farm type. Extensive farmers perceived climate risk to be more severe than farmers in other farm types ($P < .01$), but no differences between semi-intensive and intensive farms emerged (Table 7). The differences in perceiving risk severity could have entailed an intrinsic characteristic of extensive farms with large ponds that are more difficult to manage when facing sudden climate shocks. Farmers with large ponds had limited knowledge and capacity to effectively maintain the pond's environment compared to farmers with more intensive systems, operating smaller ponds with better access to knowledge and inputs.

The perceived severity of market and input price fluctuation varies significantly across all farm types. Intensive farmers are highly dependent on the market's input price to be able to generate profits, and perceive the potential impact of this risk as high. Semi-intensive farmers perceive this risk as less significant while extensive farmers perceive it as being of no importance. The latter can selectively harvest the larger sized shrimp by using limited inputs and wait for a price increase in the market.

Risk of pollution from other farms, disease outbreak, and slow growth were ranked as medium to high risk by the overall sample, while risks related to changes in norms and regulations were ranked as low to very low. Severity of other risks, such as degraded water quality, disease or changes in norms and regulations were not significantly different among farm types.

From extensive to intensive farmer types a gradient of confidence in controlling farm-based disease appeared (Table 8). Confidence in ability to control disease was significantly higher among intensive farmers than semi-intensive and extensive ones ($P < .05$). The extensive farmers' confidence that they could control disease was the lowest, as they just accepted disease as "bad luck" and showed less awareness of the causes of disease than the other types of farmers.

Confidence levels also varied according to pond management and selection of adequate inputs, with a similar gradient between farm types. Intensive farms were more confident than other farm types in selecting the right inputs, maintaining water quality and managing feed. In contrast, extensive farmers were less confident in maintaining water quality, use of feed and selecting the right input. We did not find significant differences between farm types for other types of confidence.

3.4.3. Mediation analysis

The above results indicate that different farm types exhibited different patterns of risk strategies (see Table 6), and that the type of farm also predicted diverse levels of severity and confidence in risk mitigation (see Tables 7 & 8). To test whether levels of severity and confidence could indeed explain the differences in adopted risk strategies between farm types, we conducted mediation analyses. We only carried out these analyses for risk strategies that were found to differ between farm types: "*input way*", "*training vs risk spreading*", and "*management and marketing strategies*". Furthermore, we only tested the role of potential mediators in case there was a link between the mediator and the dependent variable. The results of the bootstrap analyses (Table 9)

Table 7
Perceived severity of different risk factors (mean and standard deviation of risk source factors in parenthesis) by extensive, semi-intensive and intensive farmers. For each variable tested, values in same row in superscript font are significantly different ($p < .01$).

Risk severity perception	Extensive	Semi-intensive	Intensive
Climate	0.32 (1.12)[a]	−0.20 (0.86)[b]	−0.16 (0.89)[b]
Market and input cost	−0.92 (0.81)[c]	0.28 (0.89)[b]	0.63 (0.45)[a]
Water and shrimp quality	−0.75 (1.09)[a]	0.10 (0.97)[a]	0.00 (0.93)[a]
Disease	0.12 (0.82)[a]	−0.18(1.15)[a]	−0.00 (1.03)[a]
Norms and regulations	0.00 (0.71)[a]	0.04 (0.97)[a]	−0.02 (1.21)[a]

Table 8
Confidence in mitigating different types of risk (mean and standard deviation of confidence factors in parenthesis) by extensive, semi-intensive and intensive farmers. For each variable tested, values in same row in superscript fonts are significantly different ($p < .05$).

Confidence in mitigating risk	Extensive	Semi-intensive	Intensive
Disease	−0.50 (0.98)[a]	−0.00 (1.04)[b]	0.43 (0.75)[c]
Input choice & pond management	−0.54 (1.03)[a]	0.07 (0.79)[b]	0.42 (0.85)[c]
Climate risk	−0.12 (1.18)[a]	0.13 (0.99)[a]	−0.06 (0.80)[a]
Market risk	−0.05 (0.82)[a]	0.10 (1.31)[a]	−0.01 (0.93)[a]

Table 9
Bootstrap analysis of indirect relationships.

Dependent variable	Mediator	Indirect effect	SE	95% confidence interval for indirect effect	
				Lower	Upper
Input way	Severity market	0.20	0.06	0.0747	0.3104
Training vs risk spreading	Confidence inputs	0.07	0.03	0.0193	0.1426
	Severity market	0.20	0.05	0.0904	0.3074
Management and marketing strategies	Confidence diseases	0.07	0.03	0.0189	0.1735
	Confidence inputs	0.08	0.04	0.0268	0.1655
	Severity market	0.16	0.06	0.0529	0.2993

Note: Mediation is indicated by confidence intervals that do not contain zeroes.

indicate that the perceived severity of market risk explains the differences between farm types in the risk strategy "input way". Even though farmers chose to invest in technology to control their pond environment, they perceived the risk of a drop in market prices and an increase in input prices (feed, electricity and pro-biotics) as severe. These results could be seen as antagonistic, with farmers perceiving the high risk of market and input price while at the same time intensifying their production hence increasing dependence on market prices. The results also reflect a strategic choice to invest in high quality inputs (quality feed, disease free post larvae) and technology (e.g.: pond filter, water quality monitoring) to control disease and reach high productivity. However, the strategy was dependent on input cost and market price fluctuations.

Perceived severity of market risk, and confidence in selecting the right input explain differences in risk management strategies "training vs risk spreading". Farmers adhering to a "training-based" risk management strategy were more dependent on input and market prices and thus perceived this risk as being more severe. Their access to training and extension services increased their confidence in selecting appropriate inputs. By contrast, farmers striving to use low-quality inputs and low stocking density, and spreading risk among multiple stockings had a limited confidence in their own capacity to intensify. Their limited use of inputs and multiple harvesting techniques limited how severe they perceived market risk to be. Finally, the choice of implementing best management practices, joining cooperatives or partnering with processing plants was explained by a higher degree of confidence in their ability to control disease and effectively select inputs. The farmers who followed this risk management strategy perceived the market risk as severe.

4. Discussion

4.1. Stocking behavior, species and culture intensity choices

Aquaculture literature usually analyzes farm typologies, such as farm structure and farmers' characteristics, as explaining variables to understand stocking behaviors and intensity of the production system (Joffre and Bosma, 2009; Johnson et al., 2014; Engle et al., 2017). Our analysis goes beyond structural variables to explain stocking behaviors. For each farmer type (extensive, semi-intensive and intensive), we identified specific evaluations of the seven stocking behaviors from the point of view of cost, risk of disease, productivity and easiness of implementing. Evaluation of stocking practices and species varied across farmer types, with the variations explaining adoption of stocking behavior.

Our results confirmed recent field observations, that *P. monodon* is more often adopted at low stocking density and by contrast, *P. vannamei* is preferred in more intensive systems. Stocking *P. monodon* at low density was perceived by extensive farmers as more productive, easier to operate and less risky than *P. vannamei*. The same type of farmers assessed intensification with *P. vannamei* as more technically challenging than *P. monodon*. This result could be explained by the fact that the *P. vannamei* species was only recently introduced compared to *P. monodon*, a species endemic to the Mekong Delta and traditionally farmed at low intensity.

Evaluation of the disease risk for intensive practices showed a similar trend for both species, with a negative correlation between evaluation of risk and current adoption of intensive culture. It indicated that adopters of intensive culture practices had a higher confidence in their ability to control diseases. The difference in the evaluation of different practices, and how this difference influenced adoption, implied that barriers to intensification varied with the level of intensity and the species farmed, and thus support programs for farmers should be tailored to integrate this diversity. Extension services and private sector-supported intensification processes should consider the wide range of methods used to assess the farmers' diverse practices in order to tailor their message to support the transition from extensive to more intensive farming. Understanding how farmers evaluate different stocking densities provides insight into the absence of intensification. For extensive farmers, intensification of culture, for both species, was associated with an increasing cost, disease risk and technical difficulties. These evaluations were significantly higher than those made by intensive farmers who had already adopted such intensive practices. The results suggest that barriers to intensification were not only financial but also technical, and that intensification of shrimp culture remains a significant knowledge and technical upgrade for extensive farmers.

Regression analysis showed that predictors of stocking practices vary, not only with the intensity of the practices, but also with the species. For example, for intensive systems, we found that adoption of *P. vannamei* was strongly influenced by an evaluation of the low cost and easiness of the practices. By contrast, the same predictors were less or not influential when considering the adoption of *P. monodon.* For the latter, evaluation of disease risk was more influential in the adoption decision, showing that different characteristics of the stocking practices played a role in decision making. This result also indicates that the recent introduction of *P. vannamei* did not hinder adoption of the species in intensive systems; rather, farmers rated the (lower) cost, diseases, and easiness to implement as significant in the adoption process. Farmers perceived the new species to be an alternative to the relatively costly, technically difficult and risky *P. monodon* culture; hence, possibly explaining its recent expansion in the Mekong Delta beginning in 2012 and the fact that it accounts for more than half of the volume produced in the Mekong Delta.

4.2. Risk perception and risk management

We showed that farmers' rating of disease risk related to different practices influenced stocking behavior. Other perceived sources of risk also influenced the farmers' decisions. The perceived severity of risk varied across farm and farmer types, as did the farmers' confidence in their own ability to mitigate risk and the implemented risk management strategy.

4.2.1. Difference in perception of sources of risk

Extensive farmers were more concerned with climate risk, which could be due to their systems being more closely connected to wider ecosystems, hence vulnerable to fluctuations in water salinity. In addition, their confidence in their abilities to control disease and choose the right input was low, and. Influenced their risk management strategy to prevent the risk from spreading (i.e. by adopting cheap and low quality post larvae and multiple stocking) instead of a technological response to risk based on high quality inputs and control of water quality. A risk-spreading strategy entails a limited perception of market risk and an absence of confidence in selecting the right inputs in a market characterized by numerous products and brands, where choice is difficult without proper training and a trusted source of information. This contrasted with the reality of semi-intensive and intensive farmers, who perceived market risk as more severe and implemented technical responses with more confidence. It implies that farmers' technical knowledge, and perhaps access to that knowledge, also played a defining role in risk management choices. The factor analysis can generate new factors composed of different types of risk, such as in the case of "*water and shrimp quality*". Even if the statistical process combines different type of risk, we keep the aggregation of those different types of risk within a single factor as it is derived from the statistical analysis and driven by statistical criterion.

4.2.2. Market risk and risk management strategies

Perception of disease risk in shrimp farming is usually considered to be central to risk management strategies (Ahsan, 2011; Kabir et al., 2017). However, we found that market risk was also a dominant form of risk perceived by semi-intensive and intensive farmers, and was key in selecting risk management strategies. Intensive and semi-intensive farmers who intensify are dependent on market forces, production systems relying on external inputs, the quality of these inputs, and related costs. In addition, a sudden drop in the shrimp market, or price increases for items such as of inputs or electricity, can heavily affect economic margins. For example, the market price of *P. monodon* (grade 25–30 pcs) between January 2015 and January 2016 increased by 44% from 250,000 vnd/kg to reach 360,000 vnd/kg. However, in October 2015, within the same period, the price went down to 120,000 vnd/kg. Later, in mid-February 2016, the price increased by 16% to reach 420,000 vnd/kg, only to decrease by 36% one month later in March 2016 (VASEP, 2017).

Although market risk is of primary concern for intensive farmers and considered central to intensification in aquaculture (Bergfjord, 2009; Le and Cheong, 2010; Ahsan, 2011), intensive farmers do not necessary implement risk management strategies directly related to market risk mitigation such as certification or contract farming with processing companies. In the Vietnamese shrimp industry, internalization of risk by processing companies with a hierarchical organization of the value chain is limited (Bush, 2017). Processing factories and exporters keep the production risk at the producer level, as risk is too important, or the capability of farmers to upgrade their production system remains underdeveloped. The organization of the value chain also suffers from poor enforcement of contracts, disparity between farm gate prices and market prices (Bush and Belton, 2012), limiting contract farming and limited adoption by farmers of certification (Ha et al., 2012). Only groups of farmers are reported to have contractual relationship with processing companies (Bush and Oosterveer, 2007; Tran et al., 2013). In our study, we found that membership in cooperatives, common for semi-intensive farms, facilitates implementation of management strategies that address market risk through contract farming and certification schemes. Furthermore, they provide access to technical support and preferential market access, while securing supplies of quality materials for processing companies. Our analysis shows a diverse picture of the Vietnamese shrimp value chain sector, with both market and hierarchical types of organizations. In the former type, producers shoulder production risk, while in the latter, market and production risks are shared by both producers and, to a certain degree, buyers (Bush, 2017). However, the hierarchical type of value chain organization and risk management strategy are implemented in only a certain type of farm, those which are organized as a group or well connected to the industry, indicating that it might not be accessible to all farmers. Nonetheless, this type of risk management strategy is relatively recent (less than two years for most farmers), and could be abandoned if deemed ineffective.

5. Conclusion

It is now a common (and widely accepted) expression that shrimp farming is "like gambling". Business risk is important and risk mitigation limited. However, stating that shrimp farming is "like gambling" implies that farmers have no control over their production system and make choices based on luck, with limited understanding of the risk(s) they face. Our study illustrates a complex picture. Shrimp farm management, from choosing the species, the level of farming intensity and risk management strategies, depends on the perception of different sources of risks and the evaluation of species and practices from various angles. While disease risk is widely considered a constraint for shrimp farming (Thitamadee et al., 2016), our study shows that a key predictor of risk management strategies is driven by how farmers perceive market risks. The fact that farmers did not adopt market risk mitigation strategies to complement the contract farming and certification adopted by several farmers' groups highlights the absence of a market organization able to mitigate this risk, especially for extensive farmers.

One limitation of our study deserves to be addressed. Our approach focused on perception of risk, confidence to mitigate risk and evaluation of practices by farmers. We had limited insights on value chain organization, especially contractual relationships, between farmers and buyers. We also had a limited understanding of the costs associated with different risk management strategies or access to capital needed by the different types of farms to deploy the said strategies. Our sampling framework covered a wide range of production system focusing on small farms. We did not have access to the small number of large commercial farms operating in the Mekong Delta.

Even if our study presents some limitations, using a behavioral approach allowed a different angle of analysis of aquaculture farm management. It provided new insight on diversity of behavior among shrimp farmers regarding the choice of species to farm and the level of intensity. Moreover, using such an approach yielded new insights on the diversity of perception of different risk sources and allowed for explaining – at least partially – the deployment of risk management strategies. Looking at how farmers evaluate practices and perceive different sources of risk provides new insight into how shrimp farms are managed. It also provides a new avenue to steer farm management toward more sustainable practices by identifying key predictors that have a significant influence on farmers' decisions. We limited the analysis to few predictors to explain risk management strategies. Other predictors, such as sources of knowledge, levels of trust, and farmers' networks, could be explored to better understand decision making at the farm level.

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Statement of Relevance

This study analyzes the farmers' behaviors regarding stocking and the selection of farmed species, as well as the adoption of different risk management strategies. The study investigates the underlying drivers of farmer's decision making, including farmers' evaluation of various shrimp farming practices, and their perceptions of risk and confidence in their own ability to mitigate risks. We conclude that the drivers, together with the farms' structural characteristics and the farmers' backgrounds, explain the farmers' behaviors. We identify the main underlying factors affecting intensification and the gaps in the support policy portfolio that hinder the intensification process.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aquaculture.2018.06.012.

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