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Research article

Stakeholder perceptions towards sustainable shrimp aquaculture in Vietnam

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ABSTRACT

Aquaculture is the fastest growing food production industry globally and is considered to have the greatest potential to meet the growing demand for seafood and being a solution to overfishing. Despite the benefits of aquaculture, the rapid growth and intensification of production (so-called conventional aquaculture) has raised concerns about food safety, fish welfare, and environmental and social issues stemming from a tragedy of the commons. These concerns need to be addressed to enable sustainable aquaculture development. While the negative environmental impacts of aquaculture have been evaluated using physical and chemical indicators, the social acceptance has not been fully considered when evaluating aquaculture sustainability. With this backdrop, our study investigates knowledge and beliefs towards shrimp aquaculture development among two key stakeholder groups in Vietnam: the public and producers (shrimp farmers). Our results show that stakeholders were concerned about the social and environmental impacts of conventional shrimp aquaculture, although the different stakeholder groups emphasized different aspects. The public believed biodiversity loss and the overuse of antibiotics and pesticides to be more problematic compared to producers, who believed water quality and disease outbreaks were the main problems facing the industry. Following on from this, most respondents perceived sustainable aquaculture production positively, implying social acceptability for its development. Awareness of and knowledge about sustainable aquaculture positively and significantly affected stakeholders' support for expansion, suggesting that communication and education may be effective tools for improving social acceptance of aquaculture.

1. Introduction

Aquaculture is the fastest growing food production industry in the world and is considered to have the greatest potential to meet the growing demand for sea food and be a solution to overfishing (FAO, 2020). In 2017, aquatic products provided 3.3 billion people with almost 20% of their animal protein intake. Of the 156 million tons of aquatic product produced for human consumption in 2018, aquaculture accounted for 52% (FAO, 2020). A lot of production is small scale coastal aquaculture, which provides livelihood, employment, and local economic development for millions of people in developing countries; and in 2018 about 20.53 million people were employed in aquaculture (including full-time, part-time and occasional work), most were in Asia with 95% of the world total (FAO, 2020).

Shrimp accounted for 15% of the total global trade of seafood in 2018, and farmed shrimp accounted for over 80% of the supply by volume (FAO, 2020). Shrimp aquaculture takes place in more than 60 countries worldwide with more than 80% of total production taking place in Asia (FAO, 2020; Yap, 1999). Most farmed shrimp are produced for export targeting the large markets in the EU, USA and Japan (FAO, 2020). In 2018, Vietnam was the world's fourth largest producer of aquatic product with 7.5 million tons produced, of which 4.1 million (54.6%) was from aquaculture (FAO, 2020). Farmed shrimp was the second most important aquaculture product by volume after catfish and accounted for 0.8 million tons of total production in 2018; making Vietnam the third largest shrimp producer and the fourth largest exporter in the world (FAO, 2020).

Despite the economic benefits of aquaculture, it is argued that the rapid growth and intensification of production has led to a range of issues related to the environment (e.g. water pollution, biodiversity loss,

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disease outbreaks and habitat destruction) and social issues (e.g. violation of labor standards and social conflicts stemming from a tragedy of commons) (Ahmed and Thompson, 2019; Klinger and Naylor, 2012; Schlag, 2010). Ultimately, the former resulted in large losses to national income due to crop failures (Shinn et al., 2018) and has led governments and non-governmental actors worldwide to push for stricter food safety, social and environmental certification standards (Tran et al., 2013). The same criticisms regarding the lack of social and environmental sustainability has been levied against aquaculture production in Vietnam (Anh et al., 2010; Bui et al., 2012; Nguyen et al., 2007; Pham et al., 2018; Veettil et al., 2019). Concerns about consumer health-related issues associated with the high use of antibiotics and chemical contamination have been raised (Tran et al., 2013). To develop sustainable aquaculture, the above-mentioned concerns need to be addressed (Ahmed and Thompson, 2019; Valenti et al., 2018). The current national plan for aquaculture in Vietnam aims to increase investment and expansion of the shrimp aquaculture industry and develop it into a key economic sector while at the same time protecting the environment (Decision 79/QD-TTg). This plan for Vietnamese aquaculture is in line with the global trend of sustainable intensification where the goals is to 'produce more using less' given the scarcity of some aquaculture inputs such as land, freshwater and energy, and to have a social license to operate that requires social acceptance (Henriksson et al., 2018; Mather and Fanning, 2019). While aquaculture environmental impacts have been evaluated using physical and chemical indicators, the social acceptance has not been fully considered when evaluating aquaculture sustainability (Hynes et al., 2018).

A few studies focused on the public's attitudes towards aquaculture and showed that people are generally aware of aquaculture's contribution to employment, food security and reduced pressure on capture fisheries, however people are also concerned about the negative environmental effects and potential conflicts of interests (Bjørkan and Eilertsen, 2020; Freeman et al., 2012; Hynes et al., 2018; Krøvel et al., 2019; Mazur and Curtis, 2008; Whitmarsh and Wattage, 2006). Consequently, the public's support for aquaculture expansion likely depends on how they perceive the economic benefits and environmental harm (Chu et al., 2012; Freeman et al., 2012; Krøvel et al., 2019; Whitmarsh and Palmieri, 2009). Studies exploring producers' attitudes towards aquaculture focused mostly on risk perceptions and management strategies (Ahsan, 2011; Ahsan and Roth, 2010; Alam and Guttormsen, 2019; Bergfjord, 2009; Le and Cheong, 2010) and their willingness to adopt sustainable aquaculture practices (Ngoc et al., 2016, 2021; Obiero et al., 2019). Studies investigating multiple stakeholders' perceptions and attitudes towards aquaculture production indicates that the perceptions of aquaculture vary among stakeholders, and so does their support for aquaculture development (see e.g., Alexander et al., 2016; Bacher et al., 2014; Chu et al., 2012; Whitmarsh and Palmieri, 2009).

With this backdrop, our study investigates the public's and farmers' (producers) beliefs about aquaculture development in Vietnam using the white-legged shrimp aquaculture industry as a case study. The inclusion of producers and public groups simultaneously in a perceptional analysis of aquaculture represents both the supply and demand aspects of its development in a non-monetary form, which may provide new insights to understand better the variations in viewpoints towards shrimp aquaculture and priority of issues that needs to be resolved. Our study differs somewhat compared with those listed above. First, we investigate the public and producers' beliefs about conventional shrimp aquaculture. In particular, respondents were asked to state their beliefs about the negative impacts of current conventional shrimp aquaculture practices in Vietnam. Here, conventional shrimp aquaculture is defined as intensive and super-intensive production methods that often pollute and degrade the surrounding environment. At the same time, these methods rely on a healthy state of the same environment for successful production. Second, we explore their beliefs about the development of sustainable aquaculture (e.g. using high-tech production methods). Specifically, how high-tech aquaculture methods relate to economic benefits and the need to apply and expand the use of these methods. Third, the analysis of stakeholders' beliefs about both conventional and sustainable shrimp aquaculture is performed in connection with their knowledge and awareness of shrimp aquaculture. The findings reported in this paper provide useful information to policymakers regarding how policies, education, and communication can change stakeholders' perceptions of aquaculture and so does their support for the future of sustainable aquaculture development in Vietnam.

2. Methodology

2.1. Data collection

The data was collected in March and April of 2019 using face-to-face interviews. In this study, we focus on two stakeholder groups: the public (n = 754) and producers (n = 235). Our producer sample comprises shrimp farmers that were randomly selected based on the lists of shrimp farmers provided by the Aquaculture Department in the four Vietnamese provinces of Khanh Hoa, Ninh Thuan, Soc Trang and Bac Lieu. These four provinces cover 49% of the area used for white-legged shrimp farming in Vietnam (MARD, 2017). The public sample is a combination of two face-to-face interview surveys targeting the public and consumers with 370 and 384 respondents, respectively, in the Khanh Hoa province and Ho Chi Minh city (HCMC).[1] Khanh Hoa was selected because it is a representative province in south-central Vietnam given that it is a typical shrimp aquaculture location. HCMC is a large city and representative of southern Vietnam due to its high population density. The main shrimp farming regions are found south of HCMC. To get a representative sample of the public and consumers in the two regions, we used a two-stage random walk and quota sampling procedure. First, we randomly selected the districts, wards, and villages of Khanh Hoa province and HCMC where we would conduct the random walk sampling. Second, we used a random-walk procedure with quota sampling. The interviews took the form of household surveys.

The surveys were developed in multiple stages. First, draft surveys were presented and discussed with colleagues at Nha Trang University and updated based on these discussions. Second, the updated versions of the surveys were discussed with stakeholder focus groups. The producer survey was discussed with three shrimp farmers and two representatives from the Aquaculture Department of the Ninh Thuan province. The consumer and public surveys were discussed with a group of 10 people from each stakeholder group. Third, following updates based on the stakeholder discussions, the surveys were tested in small scale pilots. This allowed us to further refine the survey instrument before full scale implementation. Each survey comprised six parts: 1) A brief introduction explaining the purpose of the survey; 2) a stakeholder specific section seeking to elicit either consumption behavior of farmed shrimp, knowledge and awareness of aquaculture, or farmers' current production methods; 3) a section common to all surveys eliciting respondents' concerns and beliefs related to shrimp aquaculture production; 4) an introduction to the stakeholder specific discrete choice experiments (DCEs)[2]; 5) DCE related debriefing questions and questions related to knowledge of high-tech production methods; and 6) socio-demographic questions. Details of survey design and sampling are in Appendix S1.

[1] The original sampling of consumers, public and producers were driven by different discrete choice experiments targeted at the different stakeholder groups (see Xuan and Sandorf, 2020; Xuan, 2020). We grouped the datasets targeting consumers and the general public into one category named the public because consumers can be considered as sub-sample of the public. In fact, we could only identify seven respondents stating they have never eaten farmed shrimp.

[2] The responses to the DCE questions are not analysed in this paper as we just concentrate on the stakeholder attitudes to aquaculture. The DCE analysis is reported in Xuan and Sandorf (2020), Xuan (2020) and Ngoc et al. (2021).

2.2. Sample composition and key demographic variables

The summary statistics of the socio-demographic variables for the two samples are reported in Table 1. There were relatively more men in the producer sample (95%) but more women in the public samples (62%) compared with the national average of 49% men and 51% women. This is because in Vietnam, men take more responsibility in the aquaculture industry while women take more responsibility at home and for household shopping. The majority of respondents were married, and their average age were higher than the officially reported figure 31 years. While our public sample was skewed towards higher education, i. e. 72% of respondents had tertiary education level compared to the average of 22% in the population, only 15% of respondents in the producer sample had the same. It is not surprising that few shrimp farmers have higher education because shrimp farming in Vietnam is small scale, spontaneous and mainly distributed in rural coastal areas where education levels are lower. Household composition was comparable across samples. The average household income recorded in the two samples was higher than the officially reported figures 13.6 million VND of Statistics Vietnam.

3. Results

3.1. Knowledge and awareness of aquaculture

The distribution of self-reported knowledge among respondents in the public sample (Fig. 1a) shows that most members of the public considered their prior knowledge about shrimp aquaculture to be limited with 80% of respondents stating that they knew nothing or little about shrimp aquaculture. Furthermore, from Fig. 1b, we see that about 50% of respondents in our public sample were aware of sustainable aquaculture and only 12% stated that they understood what sustainable aquaculture is. Given that producers are familiar with and knowledgeable about conventional shrimp aquaculture, we only asked them questions about sustainable aquaculture. We classified producers' knowledge about sustainable aquaculture as: low, medium, and high based on responses to two questions associated with training and application of high-tech aquaculture methods (see Table 2).

Table 1
Descriptive statistics of the stakeholder samples.

	Public		Producer	
	Mean	SD	Mean	SD
Gender				
Male	0.39	0.49	0.95	0.22
Age	36.79	12.89	49.47	9.76
Marital status				
Married	0.66	0.47	0.94	0.24
NGO (member of environmental organization)	0.01	0.11	0.02	0.15
Education				
Less than secondary school education	0.12	0.32	0.62	0.49
Secondary/high school education	0.16	0.37	0.23	0.42
Professional education	0.07	0.25	0.03	0.16
Under-graduate education	0.52	0.50	0.12	0.33
Graduate education	0.13	0.34	–	–
Occupation				
Part-time employed	0.11	0.32	–	–
Full-time employed	0.57	0.49	–	–
Student	0.16	0.36	–	–
Retired	0.05	0.21	–	–
Unemployed	0.11	0.32	–	–
Household income (million VND/month)	21.57	41.17	23.72	23.41
Household members (persons)	4.39	1.55	4.61	1.44
Sample size	754		235	
Khanh Hoa	446		80	
HCMC	308			
Soc Trang			50	
Ninh Thuan			55	
Bac Lieu			50	

Interestingly, and in contrast to the general public, the majority of producers stated they have prior knowledge of sustainable aquaculture methods, i.e. about 73% of respondents attended government training courses related to the use of high-tech aquaculture methods, and two-thirds indicated that they have been applying these methods after receiving training (see Table 2 & Fig. 1c).[3]

Given the ordinal nature of responses to prior knowledge and awareness, we used ordered logistic regressions to identify how responses differ across respondents. The odds ratios from the ordered logit models are reported in Table 3. Using odds ratios makes the interpretation of the ordered logit model easier because we can interpret the coefficients as the odds (likelihood) of stating a one category higher response for a unit change in any of the independent variables. Standard errors are calculated using the Delta method and all significance tests are against 1. On prior knowledge of shrimp aquaculture, we did not identify any significant differences between marital status, being member of environmental organization, and household composition in relation to public respondents. However, men, older, and higher educated respondents appeared to have more perceived prior knowledge. Regarding public awareness of sustainable aquaculture, no significant differences existed for gender, marital status, and household composition, although age and education had a significantly positive effect on awareness. It seems that producers with higher education levels were more likely to be interested in high-tech aquaculture methods, i.e. attending government training courses related to the use of high-tech aquaculture methods as well as applying these methods on their farms afterwards. However, we could not find any significant differences for gender, age, marital status, being member of environmental organization, and household composition in the producer sample.

3.2. Perception for risk sources in shrimp aquaculture production

It has been shown that price and demand uncertainty, disease, low quality feed and fingerlings, climate change, risks related to production, finances, and institutions were perceived to be the most important sources of risk associated with aquaculture (Ahsan and Roth, 2010; Ahsan, 2011; Alam and Guttormsen, 2019; Le and Cheong, 2010). Shrimp aquaculture in Vietnam is faced with most of these (MARD, 2017); shrimp farmers were most concerned about disease outbreaks (65%), followed by water source pollution (13%) and quality of seeds and fingerlings (9%) (see Fig. 2). As recorded, in 2015 and 2016, the share of total shrimp aquaculture area affected by disease and climate change was 8% and 10%, respectively (DAH, 2017).

3.3. Beliefs about conventional shrimp aquaculture production

In this section, we focus on respondents' beliefs about the negative impacts of conventional shrimp aquaculture and how knowledge relates to these beliefs (see Appendix S1 for a detail of belief statements). The distribution of responses to the belief statements broken down by stakeholder groups are shown in Fig. 3. Producers tended to agree or strongly agree with the belief statements relating to water quality, disease outbreaks and to a certain extent labor rights and stakeholder conflicts, while they were more likely to disagree with the belief

[3] In fact, producers have improved their farms after receiving government training in the use of high-tech aquaculture methods, but in a simpler manner with the purpose of increasing production and reduce environmental impact. Water exchange during the production cycle is taken from settling ponds to reduce the risks of introducing diseases and contaminated water from the rivers into the ponds, however, wastewater is still directly discharged into the surrounding environment. The rate of high-tech method adoption, such as recirculating aquaculture or biofloc systems, is very low due to high knowledge requirement of the system operation and high cost of investment and operation (Xuan and Sandorf, 2020).

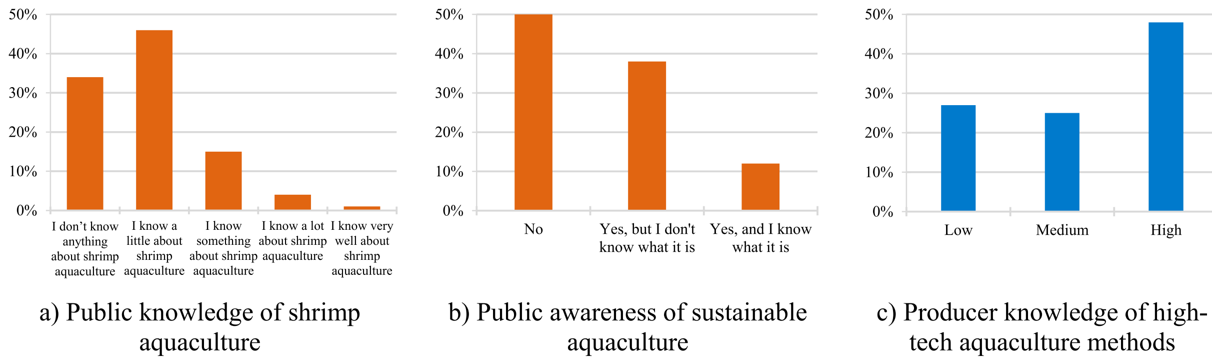


Fig. 1. Distribution of stated knowledge and awareness of aquaculture.

Table 2
Producers' knowledge of sustainable aquaculture grouped according to answers to the questions.

Level of knowledge	Low	Medium	High
Question: "Have you received government training in the use of high-tech aquaculture methods?"	"No"	"Yes"	"Yes"
Question: "After receiving training, did you apply high-tech aquaculture practices into your farm?"	–	"No"	"Yes"
Number of respondents	63	58	114
Percentage of sample	26.81	24.68	48.51

statements regarding biodiversity loss, and antibiotics and pesticide use. This is arguably a reflection of circumstance. We know from Fig. 2 that 65% of producers in our sample viewed disease outbreaks as the greatest risk factor. Furthermore, as stated above, water source pollution and disease outbreaks are the two main reasons for high crop failure rates in Vietnam in recent years (DAH, 2017), and the two are closely linked. Untreated wastewater from shrimp farms are discharged directly into adjacent water bodies, which are also used as source water for new crops. This means that "dirty" water is used for new crops and heightens the risk of disease outbreaks. To combat this, and the resulting high rates of crop failure, Vietnamese shrimp farmers must use more pesticides and antibiotics in production (Anh et al., 2010). Ironically, the measures taken to reduce crop failures are themselves contributing factors to the high crop failure rate that has been recorded during the recent years (DAH, 2017). This result is in line with what was found in Xuan and Sandorf (2020), where farmers tend to focus solely on factors leading to successful crops when deciding whether or not to invest in high-tech shrimp aquaculture production practices.

The public, on the other hand, was more likely to agree or strongly agree with the statements relating to food safety, i.e. antibiotic and pesticide use, and to some extent biodiversity loss. These beliefs can be linked to the issue of perceived human health risks, which is among the most important concerns raised by the public and consumers when eating farmed fish (Alexander et al., 2016; Schlag, 2010). As indicated by Hinkes and Schulze-Ehlers (2018), among German consumers, for example, there is a persistent negative view of farmed fish produced in Vietnam and Bangladesh for this very reason. In Australia, the public also showed strong concern about the environment and rated environmental impacts as the most important problem in aquaculture, followed by the industry's economic contribution and social issues such as stakeholder conflicts (Mazur and Curtis, 2008).

To ascertain the relationships between respondents' characteristics and their pro-environmental concern reflecting beliefs toward the negative impacts of conventional shrimp aquaculture, we used the Multiple Indicators Multiple Causes (MIMIC) model based on a generalized structural equation model given the generalized responses of an ordinal scale. The model was run using either a pooled dataset with dummies for whether a respondent is a producer relative to the public,

Table 3
Determinants of prior knowledge and awareness.

	Public				Producer	
	Knowledge		Awareness		Knowledge	
Male	1.43**	(0.22)	1.14	(0.17)	0.34	(0.26)
Age	1.03***	(0.01)	1.03***	(0.01)	1.02	(0.02)
Married	1.11	(0.23)	1.18	(0.23)	0.66	(0.53)
NGO	1.78	(1.67)	2.07	(1.34)	0.44	(0.49)
Education						
secondary/high school	1.30	(0.36)	1.26	(0.34)	2.50**	(1.09)
professional	0.89	(0.33)	1.40	(0.51)	13.44*	(20.49)
undergraduate	2.59***	(0.71)	2.29***	(0.61)	3.25**	(1.84)
graduate	10.07***	(3.30)	8.04***	(2.57)	–	
Household income	1.00**	(0.00)	1.00	(0.00)	1.02*	(0.01)
Household members	1.10	(0.07)	1.01	(0.05)	1.14	(0.12)
Location						
HCMC	1.48***	(0.22)	1.31*	(0.20)	–	
Soc Trang	–		–		0.30**	(0.15)
Ninh Thuan	–		–		0.47**	(0.18)
Bac Lieu	–		–		0.17***	(0.09)
Model statistics						
Observations	728		729		219	
Wald Chi-square	84.68***		66.27***		44.10***	
Pseudo R-square	0.06		0.06		0.10	

Note: Tests of significance of the odds-ratio is against unity. Robust standard errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level, respectively.

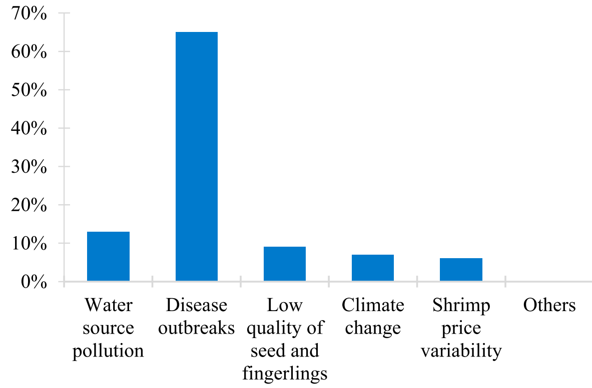


Fig. 2. Distribution of perception of risk sources in shrimp aquaculture.

exploratory factor analysis where the estimated Kaiser-Meyer-Olkin (KMO) measures were 0.78 using the pooled data (item range of 0.71–0.86) and 0.83 using the public data (item range of 0.79–0.92), which indicates sufficient correlation between items.[4] Furthermore, the Cronbach Alpha of the internal consistency were 0.82 (item range of 0.77–0.81) and 0.86 (item range of 0.83–0.85) using the pooled and public data respectively.[5] Please see Appendix S2 for more details on the modeling approach.

In Table 4, we present the odds-ratios from the MIMIC model. The measurement model for pro-environmental concern shows the factor loadings and all items were significantly loaded on to the latent variable at the 1% significant level. The first item (water quality) had the factor loading coefficient constrained to unity that reported in an exponential value. The structural model shows the relationship between pro-environmental concern and respondent's characteristics. We did not identify any significant differences between producers and the public in

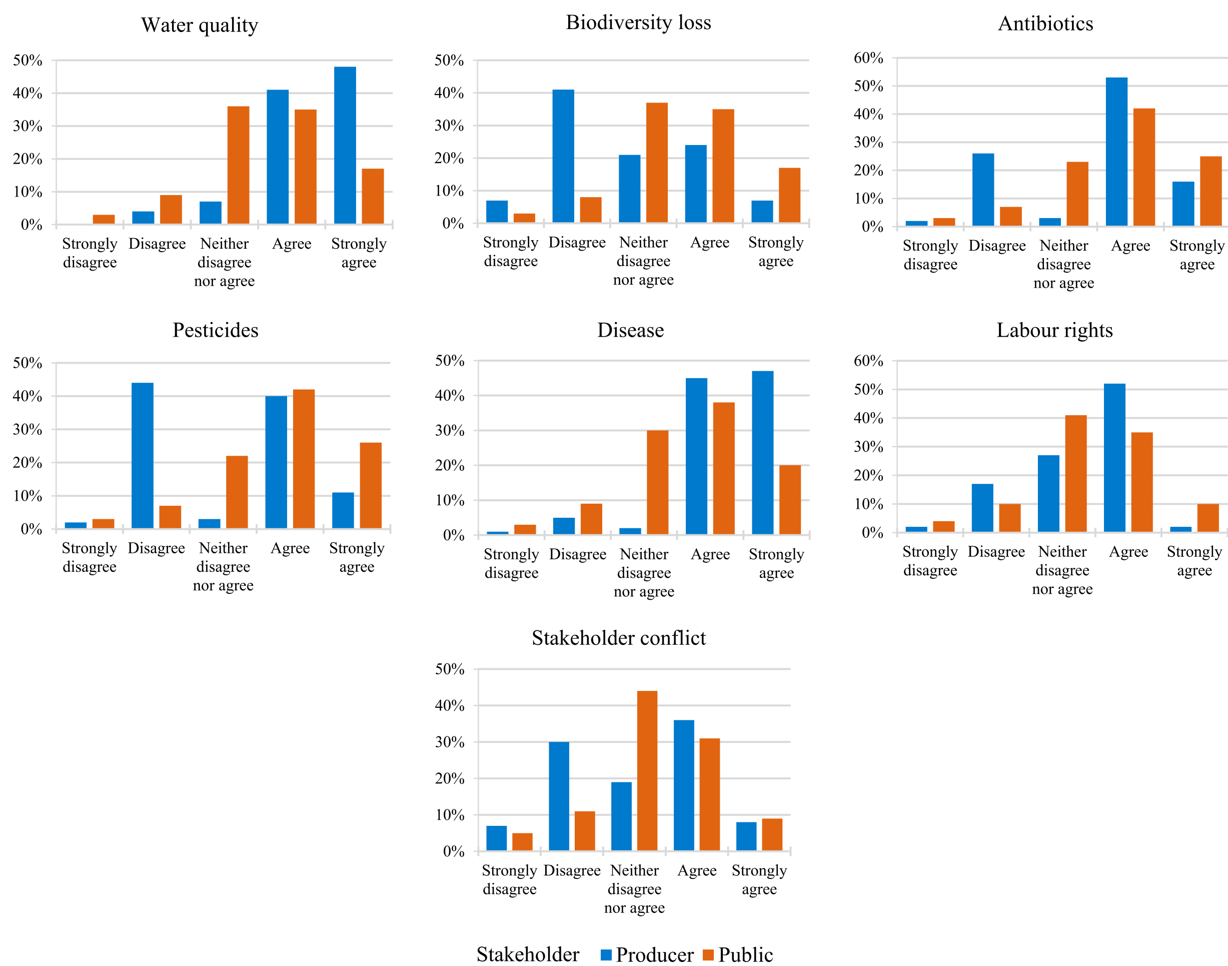


Fig. 3. Distribution of belief statements of conventional shrimp aquaculture (INDICATORS).

or the public data only to ascertain the effect of knowledge about shrimp aquaculture on the public's beliefs about the negative impacts of conventional shrimp aquaculture (see Table 4). Given that producers are familiar with, and knowledgeable about, conventional shrimp aquaculture it is not necessary to run a separate model for producers.

To estimate a MIMIC model, we assumed that the 7 belief indicators shown above form a unidimensional latent variable underlying the respondents' beliefs about the negative impacts of conventional shrimp aquaculture and that this can be explained by their characteristics. To test the validity of this assumption, we conducted a single latent relation to pro-environmental concern, while age had a significant and positive influence. Respondents with tertiary education were more likely to be pro-environmental, however there were no significant effects of gender, whether a respondent was married or a member of an

[4] Kaiser (1974) threshold values of 0.70–0.79, 0.80–0.89, and 0.90–1.00 indicate "middling", "meritorious", and "marvellous" correlations, respectively.

[5] A value of 0.6 is considered as acceptable and 0.8 or higher is regarded as satisfactory (Hair et al., 2011).

Table 4
Determinants of pro-environmental concerns.

Structural	Pooled data		Public data	
Producer	0.82	(0.15)	–	
Knowledge of shrimp aquaculture				
low	–		1.44**	(0.23)
medium	–		3.35***	(0.91)
high	–		8.37***	(4.02)
Male	0.96	(0.09)	0.83	(0.13)
Age	1.01***	(0.01)	1.02*	(0.01)
Married	1.17	(0.14)	1.25	(0.26)
NGO	1.02	(0.25)	0.69	(0.45)
Education				
secondary and high school	1.20	(0.14)	1.40	(0.33)
professional	0.98	(0.19)	0.78	(0.25)
undergraduate	1.54***	(0.23)	1.77**	(0.45)
graduate	2.04***	(0.38)	1.78*	(0.54)
Household income	1.00***	(0.00)	1.00***	(0.00)
Household members	1.00	(0.02)	0.98	(0.04)
Location				
HCMC	1.15	(0.11)	1.16	(0.17)
Soc Trang	0.66*	(0.15)	–	
Ninh Thuan	2.00***	(0.34)	–	
Bac Lieu	0.81	(0.19)	–	
Measurement* **				
Water quality	2.72 (constrained)		2.72 (constrained)	
Biodiversity loss	4.15	(0.69)	2.51	(0.18)
Antibiotics	36.39	(22.58)	5.41	(1.34)
Pesticides	13.50	(5.75)	4.77	(1.12)
Disease	3.64	(0.40)	3.30	(0.42)
Labour rights	2.72	(0.34)	2.09	(0.18)
Stakeholder conflicts	2.90	(0.37)	2.25	(0.19)
Model statistics				
Observations	949		728	
Log-likelihood	−8074.30		−5820.85	

Note: Tests of significance of the odds-ratio is against unity. Robust standard errors are in parentheses. ***, **, and * indicate 1%, 5%, and 10% significance level, respectively. The two categories of knowledge of shrimp aquaculture including "I know a lot" and "I know very well" were grouped into "high" knowledge because of few respondents in either category.

environmental organization. Results from the MIMIC model using the public data (see the last two columns in Table 4) shows that pro-environmental concern was strongly determined by prior knowledge of shrimp aquaculture. For example, respondents with a high knowledge of shrimp aquaculture were 737% more likely to be pro-environmental while respondents with medium and low levels of knowledge were 235% and 44% more likely to be pro-environmental compared with respondents having no knowledge. Age and levels of education significantly positive influenced respondents' pro-environmental concern regarding the negative impacts of conventional shrimp aquaculture.

3.4. *Perceptions of sustainable shrimp aquaculture*

To ascertain different stakeholders' perceptions of sustainable aquaculture, respondents were asked to state their agreement or disagreement with two statements related to the economic benefits and expansion of high-tech shrimp aquaculture practices. The results from these statements are showed in Fig. 4 and sorted by producer's knowledge and public awareness of sustainable shrimp aquaculture. The public with higher awareness of sustainable aquaculture were more likely to state stronger agreement with the statements. Interestingly, we observe the opposite result for producers. Producers with a medium level of knowledge had the largest proportion strongly agreeing with the two belief statements, followed by the high-knowledge group and the low-knowledge group. Higher support for high-tech aquaculture practices among producers with medium levels of knowledge compared with producers with high levels of knowledge may be because of their lack of experiences applying these production methods. Research suggests that the economic incentive (i.e. increased productivity) is a key driver for adopting high-tech methods in shrimp farming, rather than environmental benefits of these methods (Ngoc et al., 2021). However, the investment and operating costs for high-tech aquaculture methods are significant and that represents a major barrier for small-scale household farmers to adopt these methods. In addition, there are potential risks related to the high-tech production investment such as negative outcomes resulting from technological complexities, the uncertainty of price premium attached to sustainable products, and lack of access to capital (Xuan and Sandorf, 2020).

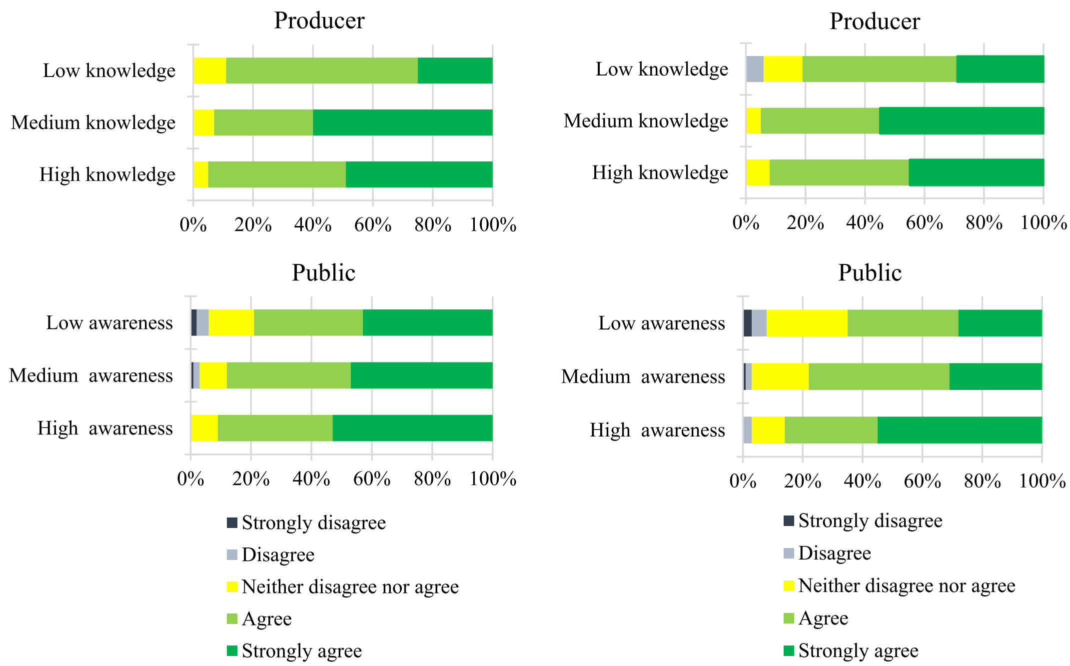
To ascertain the effects of knowledge and awareness of sustainable aquaculture, as well as the individual characteristics on the odds that respondents more strongly agree with a given statement related to the support for expanding high-tech shrimp aquaculture production we ran separate models for public and producers (see Table 5). The public with higher levels of awareness of sustainable aquaculture were more likely to state a higher level of agreement with the statement concerning expansion. No significant difference existed for age, being a member of environmental organization, and household composition in the public. While men were less likely to support sustainable aquaculture expansion, married respondents were more likely to support this. Education, however, had a negative effect on the likelihood of stating support for sustainable aquaculture expansion. This may be because of low levels of perceived awareness among the public (see Fig. 1b). In terms of producers, no significant differences existed for individual characteristics related to the support for sustainable aquaculture expansion. However, producer's knowledge about high-tech aquaculture methods had a significant and positive influence on the likelihood of stating support for expansion.

4. Discussion and conclusion

The study of multiple stakeholders' perceptions, knowledge, awareness, and attitudes towards the environmental impacts of aquaculture intensification and the transition to sustainable aquaculture production is critical to successfully manage and develop aquaculture sustainably (Bacher et al., 2014). In this paper, we showed that both the public and producers were concerned about the social and environmental impacts of conventional shrimp aquaculture, although the different stakeholder groups emphasized different aspects. The public believed that biodiversity loss and the overuse of antibiotics and pesticides were larger problems compared to producers, who believed that water quality and disease outbreaks were the most serious issues with current aquaculture practices.

It is showed that the public's beliefs towards food safety was strongly associated with the trust they placed in the industry and government institutions tasked with ensuring food safety (Schlag, 2010; Wilcock et al., 2004). Many national governments worldwide have introduced stricter safety regulations and certification schemes to establish trust in food safety as well as other sustainability aspects (Bergleiter and Meisch, 2015). Certificates have been found to increase the level of consumer confidence in the safety of the available food products in the market (Nawi and Nasir, 2014) and consumers in Vietnam are found to be willing to pay a premium for farmed shrimp products labeled with eco-certification (Xuan, 2020). The latter may provide incentives for Vietnamese producers to apply for a sustainability certification and label their products in order to meet the market demand.

However, shrimp farmers were more concerned about water source pollution and disease outbreaks that leads to high rates of crop failure. A key factor in disease spread is that untreated wastewater is discharged directly into the water bodies that also serve as source water for new crops (Xuan and Sandorf, 2020). Promising abatement strategies include minimizing point source pollution and water treatment that can be utilized through adoption of high-tech aquaculture methods, though a key obstacle for small-scale shrimp farmers adopting this method is high investment cost (Anh et al., 2010). Xuan and Sandorf (2020) suggest that a credit subsidy scheme could provide a good incentive to encourage



a) Statement: “I believe that sustainable shrimp aquaculture methods should be applied and expanded”

b) Statement: “I believe that promoting sustainable shrimp aquaculture practices facilitates long-term economic benefits to farmers and society through increased food security”

Fig. 4. Distribution of stated knowledge and awareness of sustainable shrimp aquaculture.

Table 5
Determinants of perceived sustainable shrimp aquaculture expansion.

Variable	Public		Producer	
Awareness of sustainable aquaculture				
medium	1.34*	(0.21)	–	
high	1.94***	(0.49)	–	
Knowledge of high-tech aquaculture methods				
medium	–		1.63	(0.91)
high	–		2.12**	(0.80)
Male	0.66***	(0.10)	0.81	(0.61)
Age	1.00	(0.01)	0.99	(0.02)
Married	1.69**	(0.35)	0.68	(0.60)
NGO	0.83	(0.53)	1.71	(1.10)
Education				
secondary and high school	0.71	(0.12)	0.99	(0.39)
professional	0.31***	(0.11)	1.89	(1.97)
undergraduate	0.62*	(0.17)	1.29	(0.76)
graduate	0.42***	(0.14)	–	
Household income	0.99***	(0.00)	0.99***	(0.00)
Household members	1.07	(0.05)	1.07	(0.10)
Location				
HCMC	1.22	(0.18)	–	
Soc Trang	–		0.28**	(0.12)
Ninh Thuan	–		1.63	(0.87)
Bac Lieu	–		0.39**	(0.17)
Model statistics				
Observations	729		219	
Wald Chi-square	78.68***		36.42***	
Pseudo R-square	0.04		0.09	

Note: Tests of significance of the odds-ratio is against unity. Robust standard errors are in parenthesis. ***, **, and * indicate 1%, 5%, and 10% significance level, respectively.

shrimp farmers to invest in high-tech production.

Most respondents recognized the economic benefits of sustainable shrimp aquaculture and had positive perceptions towards the expansion of sustainable shrimp aquaculture practices. This implies that stakeholders are willing to accept aquaculture development. Social acceptance (or social license to operate) is defined as the community’s perceptions of the acceptability of an industry and its operations (Weitzman and Bailey, 2018). It plays an important role in sustainable resource management, yet has been a continuing challenge for aquaculture, and has become a priority in many countries considering the development of sustainable aquaculture (Alexander et al., 2016; Bacher et al., 2014; Bjørkan and Eilertsen, 2020; Hynes et al., 2018; Ruiz-Chico et al., 2020; Thomas et al., 2018; Weitzman and Bailey, 2018; Whitmarsh and Palmieri, 2009).

Overall, the variations in viewpoints attached to the environmental and socio-economic impacts of conventional and sustainable shrimp aquaculture among stakeholder groups (i.e. producer versus the public) provide useful information to policymakers on how to shape effective aquaculture strategies and to improve social acceptability of aquaculture. Respondents’ perceptions, however, are driven by their knowledge and awareness of aquaculture. That said, members of the public with higher knowledge of shrimp aquaculture were more concerned about the negative impacts of the industry, whereas the awareness of sustainable aquaculture positively influenced the support for its expansion. These findings differ from Thomas et al. (2018) who indicated that the public awareness level was not a significant influence on their general opinion of aquaculture, even though people who stated that they had high levels of awareness also held more favorable perceptions towards aquaculture. Therefore, designing programs of effective communication and education in order to increase public’ awareness on the benefits of sustainable aquaculture coupled with watchful monitoring of aquaculture’s social and environmental impacts are necessary to improve social acceptance of aquaculture which has not been integrated fully into aquaculture sustainability evaluation (Hynes et al., 2018). Furthermore, producers with medium and high levels of knowledge of high-tech aquaculture methods were more likely to support its expansion compared with those who are low knowledge. This suggests that training and education are important to fill the technical-knowledge gap associated with high-tech aquaculture methods. In addition, the interactive learning between farmers, researchers, technology providers, extension services, and policymakers is necessary to reduce the negative outcomes resulting from technological complexities (Kumar et al., 2018).

To conclude, stakeholders' positive attitudes towards sustainable shrimp aquaculture expansion, combined with producers' willingness to adopt high-tech shrimp farming methods (Ngoc et al., 2021), and consumers' willingness to pay a premium for sustainable shrimp products (Xuan, 2020) may contribute to the success of sustainable aquaculture development in Vietnam and globally. Because Vietnam is one of world's five largest producers of aquaculture products (FAO, 2020), the success of Vietnam in developing sustainable aquaculture would make a significant contribution to the global sustainable aquaculture development goal. Although, the results in this study may not reflect the opinions in other parts of Vietnam, the aquaculture sector has generally been facing the same challenges and consequences of rapid and unsustainable growth, therefore, the sustainable development of aquaculture has become a prominent issue in Vietnam as well as globally.

Author contributions

Bui Bich Xuan and Erlend Dancke Sandorf contributed conceptualization and performed statistical analysis. Bui Bich Xuan wrote the first draft of the manuscript. Quach Thi Khanh Ngoc contributed conceptualization and collected data. All authors reviewed and edited the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

Ahmed, N., Thompson, S., 2019. The blue dimensions of aquaculture: a global synthesis. Sci. Total Environ. 652, 851–861. https://doi.org/10.1016/j.scitotenv.2018.10.163.

Ahsan, D.A., 2011. Farmers' motivations, risk perceptions and risk management strategies in a developing economy: Bangladesh experience. J. Risk Res. 14 (3), 325–349. https://doi.org/10.1080/13669877.2010.541558.

Ahsan, D.A., Roth, E., 2010. Farmers' perceived risks and risk management strategies in an emerging mussel aquaculture industry in Denmark. Mar. Resour. Econ. 25 (3), 309–323. https://doi.org/10.5950/0738-1360-25.3.309.

Alam, M.A., Guttormsen, A.G., 2019. Risk in aquaculture: farmers' perceptions and management strategies in Bangladesh. Aquacult. Econ. Manag. 23 (4), 359–381. https://doi.org/10.1080/13657305.2019.1641568.

Alexander, K.A., Angel, D., Freeman, S., Israel, D., Johansen, J., Kletou, D., Meland, M., Pecorino, D., Rebours, C., Rousou, M., Shorten, M., Potts, T., 2016. Improving sustainability of aquaculture in Europe: stakeholder dialogues on integrated multi-trophic aquaculture (IMTA). Environ. Sci. Pol. 55, 96–106. https://doi.org/10.1016/j.envsci.2015.09.006.

Anh, P.T., Kroeze, C., Bush, S.R., Mol, A.P.J., 2010. Water pollution by intensive brackish shrimp farming in south-east Vietnam: Causes and options for control. Agric. Water Manag. 97 (6), 872–882. https://doi.org/10.1016/j.agwat.2010.01.018.

Bacher, K., Gordoa, A., Mikkelsen, E., 2014. Stakeholders' perceptions of marine fish farming in Catalonia (Spain): a Q-methodology approach. Aquaculture 424, 78–85. https://doi.org/10.1016/j.aquaculture.2013.12.028.

Bergfjord, O.J., 2009. Risk perception and risk management in Norwegian aquaculture. J. Risk Res. 12 (1), 91–104. https://doi.org/10.1080/13669870802488941.

Bergleiter, S., Meisch, S., 2015. Certification standards for aquaculture products: bringing together the values of producers and consumers in globalised organic food markets. J. Agric. Environ. Ethics 28 (3), 553–569. https://doi.org/10.1007/s10806-015-9531-5.

Bjørkan, M., Eilertsen, S.M., 2020. Local perceptions of aquaculture: a case study on legitimacy from northern Norway. Ocean Coast Manag. 195, 105276. https://doi.org/10.1016/j.ocecoaman.2020.105276.

Bui, T.D., Luong-Van, J., Austin, C.M., 2012. Impact of shrimp farm effluent on water quality in coastal areas of the world heritage-listed Ha Long Bay. Am. J. Environ. Sci. 8 (2), 104–116. https://doi.org/10.3844/ajessp.2012.104.116.

Chu, J., Anderson, J.L., Asche, F., Tudur, L., 2012. Stakeholders' Perceptions of Aquaculture and Implications for its Future: A Comparison of the U.S.A. and Norway. Mar. Resour. Econ. 25 (1), 61–76. https://doi.org/10.5950/0738-1360-25.1.61.

DAH, 2017. Report on disease status of brackish water shrimp in 2016 and plan for disease prevention in 2017. In: Vietnamese: Tình hình dịch bệnh trên tôm nước lợ năm 2016 và kế hoạch phòng chống dịch bệnh năm 2017. Meeting of the Development of Shrimp Industry in Vietnam. Department of Animal Health (DAH) - Ministry of Agriculture and Rural Development (MARD), Ca Mau City.

FAO, 2020. The State of World Fisheries and Aquaculture 2020. Sustainability in Action. Rome https://doi.org/https://doi.org/10.4060/ca9229en.

Freeman, S., Vigoda-gadot, E., Sterr, H., Schultz, M., Korchenkov, I., Krost, P., Angel, D., 2012. Public attitudes towards marine aquaculture: A comparative analysis of Germany and Israel. Environ. Sci. Pol. 2, 60–72. https://doi.org/10.1016/j.envsci.2012.05.004.

Hair, J.F., Ringle, C.M., Sarstedt, M., 2011. PLS-SEM: Indeed a silver bullet. J. Market. Theor. Pract. 19 (2), 139–152.

Henriksson, P.J.G., Belton, B., Murshed-e-Jahan, K., Rico, A., 2018. Measuring the potential for sustainable intensification of aquaculture in Bangladesh using life cycle assessment. Proc. Natl. Acad. Sci. Unit. States Am. 115 (12), 2958–2963.

Hinkes, C., Schulze-Ehlers, B., 2018. Consumer attitudes and preferences towards pangasius and tilapia: The role of sustainability certification and the country of origin. Appetite 127, 171–181. https://doi.org/10.1016/j.appet.2018.05.001.

Hynes, S., Skoland, K., Ravagnan, E., Gjerstad, B., Krøvel, A.V., 2018. Public attitudes toward aquaculture: An Irish and Norwegian comparative study. Mar. Pol. 96, 1–8. https://doi.org/10.1016/j.marpol.2018.07.011.

Kaiser, H.F., 1974. An index of factorial simplicity. Psychometrika 39 (1), 31–36.

Klinger, D., Naylor, R., 2012. Searching for solutions in aquaculture: charting a sustainable course. Annu. Rev. Environ. Resour. 37, 247–276.

Krøvel, A.V., Gjerstad, B., Skoland, K., Lindland, K.M., Hynes, S., Ravagnan, E., 2019. Exploring attitudes toward aquaculture in Norway – Is there a difference between the Norwegian general public and local communities where the industry is established? Mar. Pol. 108, 103648. https://doi.org/10.1016/j.marpol.2019.103648.

Kumar, G., Engle, C., Tucker, C., 2018. Factors driving aquaculture technology adoption. J. World Aquacult. Soc. 49 (3), 447–476.

Le, T.C., Cheong, F., 2010. Perceptions of risk and risk management in vietnamese catfish farming: An empirical study. Aquacult. Econ. Manag. 14 (4), 282–314. https://doi.org/10.1080/13657305.2010.526019.

MARD, 2017. Current status and solutions for developing shrimp industry in Vietnam. In: Vietnamese: Hiện trạng và giải pháp phát triển ngành tôm Việt Nam. Meeting of the Development of Shrimp Industry in Vietnam. Ministry of Agriculture and Rural Development (MARD), Ca Mau City.

Mather, C., Fanning, L., 2019. Social licence and aquaculture: Towards a research agenda. Mar. Pol. 99, 275–282. https://doi.org/10.1016/j.marpol.2018.10.049.

Mazur, N.A., Curtis, A.L., 2008. Understanding community perceptions of aquaculture: Lessons from Australia. Aquacult. Int. 16 (6), 601–621. https://doi.org/10.1007/s10499-008-9171-0.

Nawi, N.M., Nasir, N.I.M., 2014. Consumers' Attitude Toward the Food Safety Certificate (FSC) in Malaysia. J. Food Prod. Market. 20 (S1), 140–150. https://doi.org/10.1080/10454446.2014.921879.

Ngoc, P.T.A., Meuwissen, M.P.M., Le, T.C., Bosma, R.H., Verreth, J., Lansink, A.O., 2016. Adoption of recirculating aquaculture systems in large pangasius farms: A choice experiment. Aquaculture 460, 90–97. https://doi.org/10.1016/j.aquaculture.2016.03.055.

Ngoc, Q.T.K., Xuan, B.B., Sandorf, E.D., Phong, T.N., Trung, L.C., Hien, T.T., 2021. Willingness to Adopt Improved Shrimp Aquaculture Practices in Vietnam. Aquacult. Econ. Manag. 1–24. https://doi.org/10.1080/13657305.2021.1880492.

Nguyen, V.T., Momtaz, S., Zimmerman, K., 2007. Water pollution concerns in shrimp farming in Vietnam: A case study of Can Gio, Ho Chi Minh city. Int. J. Environ. Cult. Econ. Soc. Sustain. 3 (2), 9.

Obiero, K.O., Waidbacher, H., Nyawanda, B.O., Munguti, J.M., Manyala, J.O., Kaunda-Arara, B., 2019. Predicting uptake of aquaculture technologies among smallholder fish farmers in Kenya. Aquacult. Int. 27 (6), 1689–1707. https://doi.org/10.1007/s10499-019-00423-0.

Pham, T.T.H., Rossi, P., Dinh, H.D.K., Pham, N.T.A., Tran, P.A., Ho, T.T.K.M., Dinh, Q.T., De Alencastro, L.F., 2018. Analysis of antibiotic multi-resistant bacteria and resistance genes in the effluent of an intensive shrimp farm (Long An, Vietnam). J. Environ. Manag. 214, 149–156. https://doi.org/10.1016/j.jenvman.2018.02.089.

Ruiz-Chico, J., Biedma-Ferrer, J.M., Peña-Sánchez, A.R., Jiménez-García, M., 2020. Acceptance of aquaculture as compared with traditional fishing in the province of Cadiz (Spain): an empirical study from the standpoint of social carrying capacity. Rev. Aquacult. 12 (4), 1–17. https://doi.org/10.1111/raq.12442.

Schlag, A.K., 2010. Aquaculture: An emerging issue for public concern. J. Risk Res. 13 (7), 829–844. https://doi.org/10.1080/13669871003660742.

Shinn, A.P., Pratoomyot, J., Griffiths, D., Trong, T.Q., Vu, N.T., Jiravanichpaisal, P., Briggs, M., 2018. Asian shrimp production and the economic costs of disease. Asian Fish Sci. 31, 30–58.

Thomas, J.B.E., Nordström, J., Risén, E., Malmström, M.E., Gröndahl, F., 2018. The perception of aquaculture on the Swedish West Coast. Ambio 47 (4), 398–409. https://doi.org/10.1007/s13280-017-0945-3.

Tran, N., Bailey, C., Wilson, N., Phillips, M., 2013. Governance of Global Value Chains in Response to Food Safety and Certification Standards: The Case of Shrimp from Vietnam. World Dev. 45 (202374), 325–336. https://doi.org/10.1016/j.worlddev.2013.01.025.

Valenti, W.C., Kimpara, J.M., Preto, B.D.L., Moraes-Valenti, P., 2018. Indicators of sustainability to assess aquaculture systems. Ecol. Indicat. 88, 402–413. https://doi.org/10.1016/j.ecolind.2017.12.068.

Veettil, B.K., Quang, N.X., Trang, N.T.T., 2019. Changes in mangrove vegetation, aquaculture and paddy cultivation in the Mekong Delta: A study from Ben Tre Province, southern Vietnam. Estuar. Coast Shelf Sci. 226, 106273. https://doi.org/10.1016/j.ecss.2019.106273.

Weitzman, J., Bailey, M., 2018. Perceptions of aquaculture ecolabels: A multi-stakeholder approach in Nova Scotia, Canada. Mar. Pol. 87, 12–22. https://doi.org/10.1016/j.marpol.2017.09.037.

Whitmarsh, D., Palmieri, M.G., 2009. Social acceptability of marine aquaculture: The use of survey-based methods for eliciting public and stakeholder preferences. Mar. Pol. 33 (3), 452–457. https://doi.org/10.1016/j.marpol.2008.10.003.

Whitmarsh, D., Wattage, P., 2006. Public Attitudes Towards the Environmental Impact of Salmon Aquaculture in Scotland. Eur. Environ. 121 (16), 108–121. https://doi.org/10.1002/eet.406.

Wilcock, A., Pun, M., Khanona, J., Aung, M., 2004. Consumer attitudes, knowledge and behaviour: A review of food safety issues. Trends Food Sci. Technol. 15 (2), 56–66. https://doi.org/10.1016/j.tifs.2003.08.004.

Xuan, B.B., 2020. Consumer Preference for Eco-Labelled Aquaculture Products in Vietnam. Aquaculture, p. 736111. https://doi.org/10.1016/j.aquaculture.2020.736111.

Xuan, B.B., Sandorf, E.D., 2020. Potential for Sustainable Aquaculture: Insights from Discrete Choice Experiments. Environ. Resour. Econ. 77 (2), 401–421. https://doi.org/10.1007/s10640-020-00500-6.

Yap, W.G., 1999. Shrimp culture: a global overview. SEAFDEC Asian Aquaculture 21 (4), 18–21.