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Involving stakeholders to support sustainable development of the marine lobster aquaculture sector in Vietnam

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ABSTRACT

This paper used a combination of the strengths, weaknesses, opportunities and threats analysis and analytical hierarchy process to analyze the challenges and prospects for the sustainable development of marine lobster aquaculture in Vietnam. This analysis was based on the participation of four stakeholder groups including representatives at the provincial level, district level, and commune level and lobster farmers. The results show that stakeholders have a relatively positive perception about the sustainable development of marine lobster aquaculture in Vietnam because they believe the strengths and opportunities outweigh the weaknesses and threats. The suitable natural conditions in Vietnam were considered as the most important strength, while the many untapped markets and the support of the government for the sector are key opportunities for further developing marine lobster aquaculture. The increased lobster mortality and frequency of disease outbreaks were considered as the main weaknesses. In addition, the complex development of disease pressure and the reliance on the Chinese market were considered the most crucial threats. The findings of this study can be used by policy-makers in Vietnam to further develop the marine lobster aquaculture sector.

1. Introduction

Thanks to the abundant settlement of lobster seed and the availability of suitable sites with protection against wind and waves, Vietnam has a well-developed lobster aquaculture industry [1]. Lobster farming was established here in the 1990s with production of less than 100 tonnes. However, demand grew rapidly and lobster fisheries were soon over-exploited [1,2]. The lobster aquaculture industry in Vietnam responded by expanding significantly and became more intensive over the past two decades [3]. The number of lobster farming cages has increased from around 17,600 in 2000 to more than 83,000 in 2017 [4,5]. This development has made a major contribution to Vietnam's economy and to poverty alleviation in its coastal communities [3,4,6]. However, the industry's uncontrolled and spontaneous growth has also increased pollution, and spread diseases and in recent years, decreases in productivity have been observed [7,8].

To support this industry, the local authorities and Vietnamese government do not only rely on general aquaculture policies; they have also issued specific policies for lobster farming. For examples, a number of temporary national regulations were issued in 2008 [9]; a more detailed national technical regulation on culture area, food safety, veterinary hygiene and environmental protection was updated in 2014 [10]; and another national technical regulation to ensure veterinary hygiene and aquatic resource conservation for shrimp and lobster seeds was issued in 2017 [11]. These regulations mainly focus on technical and environmental conditions for lobster farming and cover aspects such as farm site selection, water quality standards, infrastructure, quality of lobster seed, stocking density and feeding practice. A zoning plan for lobster aquaculture was approved by the Ministry of Agriculture and Rural Development in 2016 [12]. It covers farming practices, permitted sites, total area for lobster farming and lobster production targets for each locality based on province. These policies, however, do not seem to have been fully implemented [3]. In some cases, there appears to be a lack of support among lobster farmers [3]. Based on these observations, it seems appropriate to question whether the policies were based on sufficient information on the development of lobster farming and whether they took into account the realities and stakeholder needs. An assessment of the sector's strengths, weaknesses, opportunities and threats (SWOT) may therefore be useful for better policy-making. In addition, stakeholder participation would increase support for these policies.

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A number of previous studies and reports have examined the opportunities and challenges for lobster farming in Vietnam [2–4]. However, these studies have tended to address the issue from the perspective of academic experts or provincial officials and overlooked the – equally important – opinions and experiences of farmers and local experts working at the commune and district levels. Moreover, in the existing studies no attempt is made to rank opportunities and challenges according to their importance, even though this information is of great relevance for policy development. With limited budgets, resources, and time, it is clearly difficult to take all opportunities and challenges into account when building strategies for the sector's development. It is also difficult to develop strategies based on experts' SWOT evaluations if opinions differ. To overcome this disadvantage and fill the gap, this paper uses a SWOT-AHP analysis to (1) identify the strengths, weaknesses, opportunities, and threats relating to the sustainable development of lobster farming in Vietnam; and (2) rank these strengths, weaknesses, opportunities, and threats according to their importance within and across categories. All stakeholder groups were considered in this process.

2. Methodology

Strengths, weaknesses, opportunities, and threats (SWOT) analysis is a qualitative method typically used to support strategic planning and decision-making [13,14]. The tool is commonly used to analyze internal and external environments. A SWOT analysis classifies a sector's internal aspects as strengths and weaknesses and defines external situational factors as opportunities and threats. Strengths can serve as a foundation for building a competitive advantage, and weaknesses may hinder this. By identifying these factors, a strategy can be built on the strengths, avoiding the weaknesses, taking advantage of the opportunities, and reducing the threats [13]. SWOT analysis is therefore regarded as simple and useful in strategic planning for development [13]. However, it appears to be inadequate for prioritizing and facilitating decision-making [15] because it merely identifies the strengths, weaknesses, opportunities and threats but does not categorize them in terms of their importance [14]. Kurttila et al. [14] therefore suggest combining SWOT with an analytical hierarchy process (AHP) analysis which allows the importance of the factors in SWOT groups to be measured. The SWOT-AHP approach has been applied in many different fields [15–17]. Applications in aquaculture, however, have been limited to the scenarios described in Henríquez-Antipa and Cárcamo [18].

2.1. Data collection

2.1.1. Identification of stakeholders

The sustainable development of marine lobster aquaculture depends on several factors including the availability of inputs, markets, profits, availability of technology, access to extension services and credit, relevant policies and their implementation, the environment and so on. This implies that it is important to obtain information not only from decision-makers, managers and officials but also from lobster farmers. This study therefore collects data on the opinions of four types of stakeholders: officials working at provincial level, district level and commune level, and lobster farmers from the most important lobster farming areas in Vietnam.

Following the advice of Schmoldt and Peterson [19] about the optimal number of participants in decision making workshops, 20 respondents were involved. Participants included leaders, deputy leaders and experts working in the departments, sub-departments and centers of aquaculture and fisheries, agricultural extension workers and lobster farmers in the study areas. Most of these respondents have many years of experience. For example, the five representatives of the provincial level have between two and 14 years of experience advising the Director of the Department of Agriculture and Rural Development on long-term development policies, strategies, and plans for aquaculture, fisheries and agriculture; they're also responsible for the content of extension materials and organize workshops and training courses for farmers. The three district-level participants have between nine and 21 years of experience in proposing and advancing the national regulations and new technologies and disseminating them to the lower levels. They are also involved in training, guidance, consulting and provision of extension services to farmers, based on the national regulations. The five representatives at the commune level have between two and 20 years of experience in assisting farmers to implement the regulations and collecting feedbacks from farmers to forward to the district level. The study also collected information from seven lobster farmers with 10–25 years of working-experience.

2.1.2. Identification and evaluation of factors

Firstly, factors influencing the sustainable development of marine lobster aquaculture in Vietnam were identified, based on a literature review and field visit. A draft list of influential factors and an outline agenda were sent to stakeholders before the focus group discussions (FGDs). In the workshop, a short presentation was given to explain to participants the purpose of the FGDs and what was required of them. The list of identified SWOT factors was then discussed and edited, with factors added or removed on the basis of consensus among all participants. A new final list of SWOT factors was drawn up following the discussion and with agreement of all stakeholders. In order to allow manageable pair-wise comparisons, the number of factors in each SWOT category was limited to 5. The research framework in Fig. 1 gives an overview of how the study was conducted.

Based on the new list, each SWOT factor was compared to another within each category using the pair-wise comparison scale developed by Saaty and Vargas [20]. For each pair participants were asked whether they were equally important or not. If not, they were asked which one was more important, and how much more important than the other. Based on this information, the local priority for each factor within each SWOT group was calculated using the eigenvalue method (which is discussed in Section 2.2). The local priority score shows the relative importance of each strength/weakness/opportunity/threat within a SWOT category.

Economic and environmental perspectives were considered as the two most important angles of sustainability in this case. The participants were therefore also asked to compare the economic and environmental perspectives to identify which one was more important for lobster aquaculture development; this was performed using the Saaty and Vargas [20] scale.

Participants were then asked to rate the overall importance of each SWOT category from an economic and environmental point of view using a five level intensity rating scale ranging from very low (1) to very high (5) importance. The scale parameters obtained from these results were used to measure the overall priority score for each factor. This overall priority score reflects how important each factor is across all SWOT categories.

2.2. Data analysis

The results of the pair-wise comparisons used to measure the priorities are shown in the matrix below:

$$A = (a_{ij}) = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \vdots & \vdots & \vdots\vdots\vdots & \vdots \\ \cdot & \cdot & \dots & \cdot \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix}$$

where a_{ij} shows the relative preference of factor i compared to factor j. $a_{ij} = 1$ when $i = j$. This creates the diagonal of the matrix with the reciprocal $1/a_{ij}$ on the opposite side.

Using the eigenvalue averaging technique [21], the relative weight

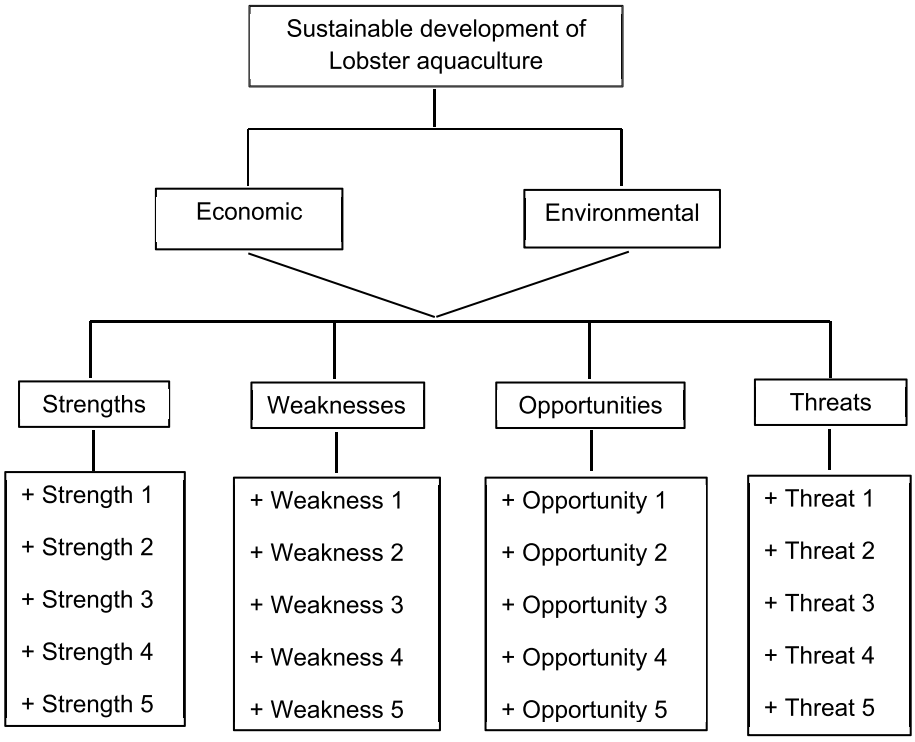

Fig. 1. Research framework for SWOT-AHP analysis.

in each of the three hierarchical levels was computed. The eigenvector was then normalized to obtain local priority scores for each factor in each SWOT category. The sum of the local priority for each SWOT category is equal to 1. The overall priority scores were measured by multiplying their local priority scores with the scaling parameters. Therefore, 1 is also the value of summing the overall priority scores across all SWOT categories. Higher priority values represent greater importance.

In order to be certain of providing a valid approximation to the overall weights, the consistency in the comparison matrix was checked using the following formula:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$CR = CI/_{RI}$$

where CI is the consistency index, CR is the consistency ratio, RI is the consistency index of a random-like matrix (see Ref. [21]), λ_{max} is the largest eigenvalue, and n is the number of pair-wise comparison. The consistency of pair-wise comparison is acceptable if $CR \leq 10\%$ [22].

In order to assess the robustness of the results, a sensitivity analysis was carried out. A Monte Carlo simulation was used to randomly generate pairwise evaluations from the distributions specified by participants in the AHP analysis [23,24]. Moreover, a non-parametric Kruskal-Wallis test was conducted to determine whether the overall priority scores of each SWOT category differed between stakeholder groups and whether the overall priority scores of each stakeholder group differed between SWOT categories.

3. Results and discussion

3.1. Key SWOT factors influencing the sustainable development of marine lobster aquaculture in Vietnam

The internal and external factors influencing the sustainable development of marine lobster aquaculture are shown in Table 1. The results in this table show that most of the factors identified by the stakeholders are in line with other studies and reports such as Thao [4], Tuan [2], and Minh et al. [3].

3.1.1. Strengths

All participants consider the suitable natural conditions in Vietnam, especially in the central region, including the long coastline and the many bays and islands offering wind and wave protection, to be one of the key strengths for developing lobster aquaculture. The natural availability of seeds, one of the important inputs for the lobster aquaculture industry, is also regarded as one of the strengths. In Vietnam, especially in the central sea, lobster seeds occur naturally in abundance and can easily be caught [2,3,25]. However the supply of wild-caught seed from local areas has not kept pace with the continuous increase in demand from the industry. Because hatchery technology has not been developed, it is necessary to import seeds from other countries in order to cover the shortfall. According to the participants, lobster pueruli are readily available as imports from Indonesia, Philippines, and Malaysia.

With more than 3200 km of coastline and about 2000 fish species, Vietnam's fishery industry is highly developed. Although there is no

Table 1
Key SWOT factors influencing the sustainable development of marine lobster aquaculture in Vietnam.

Strengths	Weaknesses
Suitable natural condition	Unstable seeds
Availability of seeds	Unstable feed
Availability of feed	Recent frequent disease
Availability of experienced labors	and increased mortality
High return	Underdeveloped farming technology
Opportunities	**Threats**
Many untapped markets	Decrease coastal resource
High and increase demand	Rely on China market
Government support	Less accessible to credit
Availability of relevant services	Lack of sanctions
	Complex development of disease

special fishery for trash fish, by-catch is the most important product of this industry in terms of both weight and value [26]. Trash fish is an important input for aquaculture, including lobster farming. According to all stakeholders, the availability of trash fish is relatively good in Vietnam. Moreover, the availability of labor with high skills and many years of experience in working in lobster aquaculture is one of the strengths in developing this industry. In addition, the experts agreed that the high returns have been an important strength of lobster farming up to now.

3.1.2. Weaknesses

Although seeds and trash fish for lobster aquaculture are available in the study area, all participants are concerned about their stability in terms of quality, quantity, and price. An increasing supply of trash fish from the local fisheries and naturally settling seed provide a strong foundation on which to expand lobster farming. However, many farms in Vietnam face a shortage of both lobster seeds and high-quality trash fish for feeding lobster [3]. The prices of seed and trash fish have also increased significantly [2,25]. In addition, there are concerns about the increase in frequency of disease outbreaks and the rising in mortality in this industry. The underdeveloped farming technology is also assumed to be one of the weaknesses for the sustainable development of lobster aquaculture.

3.1.3. Opportunities

All stakeholders agree that the demand for lobster is high and increasing, both domestically and on the international market [27–29]. At the same time, wild-caught production is over-exploited [2,28,30]. According to all participants, this is a very good opportunity for the lobster farming industry to identify available markets and fill this unmet demand. Moreover, there are still many markets around the world with high demand for lobster products, which the Vietnamese lobster aquaculture sector has not yet explored. These untapped markets could be opportunities for Vietnam's lobster aquaculture to expand its exports.

In the opinion of the respondents, unlike other marine aquaculture production, the lobster sector receives a high level of attention and is a priority for the Vietnamese government. Moreover, one of the key opportunities for the sustainable development of lobster aquaculture is the availability of relevant services in the study areas. Currently, the sectors that manufacture cages and supply trash fish for feed, and seeds are well-developed in Vietnam, especially in the southern central sea areas.

3.1.4. Threats

All participants agree that despite feed being available from fisheries, the coastal resource appears to be overexploited. This implies that there will be less trash fish available for feeding lobsters and/or that the feed price might increase in the future. This threatens the sustainable development of lobster aquaculture. Moreover, over-reliance on the Chinese market is recognized as a threat for the sustainable development of this industry in Vietnam. In the participants' opinion, one of the most serious threats is the current "complex development of the disease problem".[1]

Although the Vietnamese government is supportive and has adopted relevant policies, the lack of sanctions in implementing these policies is identified as a threat by all stakeholders. Moreover, many studies mention that lobster aquaculture requires substantial capital inputs for the purchase of cages, seeds and feed [3]. However, the respondents stated that due to the high risk, lobster farmers find it difficult to obtain loans from banks or credit institutions. They all agreed that limited access to credit is therefore likely to be a barrier to the development of lobster aquaculture in the future.

[1] This was named by all participants, who stated that disease in lobster production is not only increasing in frequency but is also unpredictable due to miscellaneous factors.

3.2. The local and overall priority scores of SWOT factors (AHP analysis)

Generally, the result of all pair-wise comparisons in Table 2 was acceptable because all consistency ratios were less than or equal to 10%.

3.2.1. The local priority scores

The analysis within the strengths category in Table 2 and Fig. 2 shows that according to all groups of stakeholders, *suitable natural conditions* are the most important strength supporting the development of marine lobster aquaculture in Vietnam, with a score ranging from 0.524 to 0.578 on average. This is understandable because suitable natural conditions are the most indispensable factor for lobster aquaculture. Vietnam has not only a long coastline but also more than 4000 islands and bays protected from wind and waves. These characteristics create suitable habitats and ecological conditions, not only as an ideal nursing ground for juvenile lobsters but also for developing a growing-out industry. As the second most important strength, *high return* was identified by district-level stakeholders (0.260) and lobster farmers (0.203), who reported that lobster farming is more profitable than other types of marine aquaculture in the area. This is a good incentive for developing lobster grow-out farming in Vietnam. The stakeholders from the provincial (0.205) and commune level (0.156) ranked the *availability of seeds* in second place. This implies that for further development of marine lobster aquaculture, representatives from provincial and commune level believe the sector can rely on the suitable natural conditions and availability of seeds. Moreover, according to farmers and district-level representatives, this industry has scope for development and therefore for generation of higher returns and profits.

In terms of opportunities, most of the stakeholders viewed the many untapped markets as a major opportunity, with an average score ranging from 0.530 to 0.574. Up to now, Vietnamese lobster has mainly been exported to China [2,3,28]. The US, Canada and Japan are also important importers of lobster [3,27]. According to all participants, diversification of the current export markets should be explored. Only the stakeholders at the district level believed that government support (0.493) is more important than the untapped markets (0.390). This factor was also ranked second by the other participants.

Looking at the weaknesses, the analysis shows that the *recently increased frequency of disease outbreaks and increased mortality* is the most crucial weakness, with an average score ranging from 0.472 to 0.710. In the past, very few farms encountered problems with diseases, but recently, most of the farms in the study areas have experienced disease outbreaks. As a result total lobster production has decreased. Mortality has increased from 30% in the past to approximately 50% in recent years. An annual loss of USD 30 million has been reported since 2007 [2,31]. The weakness ranked second is the *underdeveloped farming technology,* with an average score ranging from 0.118 to 0.224. Stakeholders at the provincial (0.215) and commune (0.111) level ranked the *unstable supply of seeds* in third place; however, the *unstable feed* supply was ranked third by participants from district level (0.093) and farmers (0.099). A possible explanation is that stakeholders working at a higher level, i.e. at provincial and commune levels, may be concerned about the reliability of the seed supply as they have a better overview of over-exploitation and environmental degradation. Between 40 and 98% of farms in Vietnam were reported to be experiencing a shortage of seed [3]. Local development of hatchery technology is still at an early stage [3,32]. Australia and New Zealand are successful in producing lobster pueruli but this is not commercialized yet [3,30]. Although the shortage of supply of wild caught seeds can be filled by importing from other countries, these imported lobster seeds are also wild-caught. Not only are the quantity and the price uncertain, the quality should also be considered, especially after a long transportation period. Nevertheless, for those cultivating lobster, the supply and quality of the feed appear to be a larger problem. This is in line with Minh et al. [3] who report that 62%–82% of lobster farms in Vietnam are experiencing a shortage of high-quality feed. In the study area, most farms rely heavily on trash

Table 2
Priority scores of SWOT-AHP analysis.

	Local priority scores				Overall priority scores				
	Province	District	Commune	Farmer	Province	District	Commune	Farmer	Average
Strengths					0.233	0.236	0.244	0.278	0.238
Suitable natural condition	0.574	0.536	0.578	0.524	0.134	0.127	0.141	0.146	0.132
Available seeds	0.205	0.042	0.156	0.076	0.048	0.011	0.038	0.021	0.029
Available feed	0.096	0.035	0.095	0.119	0.022	0.008	0.023	0.033	0.021
Available experienced labors	0.060	0.124	0.136	0.078	0.014	0.029	0.033	0.022	0.024
High return	0.065	0.26	0.035	0.203	0.015	0.061	0.009	0.057	0.033
Weaknesses					0.279	0.228	0.234	0.222	0.2444
Unstable seeds	0.215	0.082	0.111	0.08	0.060	0.019	0.026	0.018	0.030
Unstable feed	0.089	0.093	0.063	0.099	0.025	0.021	0.015	0.022	0.021
Recent frequent disease and increased mortality	0.472	0.707	0.609	0.697	0.132	0.161	0.143	0.155	0.152
Underdeveloped farming technology	0.224	0.118	0.206	0.124	0.062	0.027	0.048	0.027	0.041
Opportunities					0.209	0.319	0.298	0.250	0.277
Many untapped markets	0.530	0.39	0.559	0.574	0.111	0.125	0.167	0.144	0.142
High and increase demand	0.170	0.053	0.079	0.101	0.036	0.017	0.024	0.025	0.028
Government support	0.215	0.493	0.261	0.220	0.045	0.157	0.078	0.055	0.082
Available relevant services	0.085	0.064	0.101	0.105	0.018	0.020	0.030	0.026	0.025
Threats					0.279	0.217	0.223	0.250	0.241
Decrease coastal resource	0.074	0.051	0.084	0.052	0.021	0.011	0.019	0.013	0.016
Rely on China market	0.324	0.195	0.374	0.304	0.090	0.042	0.084	0.076	0.072
Less accessible to credit	0.084	0.053	0.099	0.082	0.023	0.011	0.022	0.021	0.019
Lack of sanctions	0.114	0.116	0.054	0.08	0.032	0.025	0.012	0.020	0.022
Complex development of disease	0.404	0.585	0.389	0.482	0.113	0.127	0.087	0.121	0.112

fish, but its quantity and price depend on the season, catch-ability and availability of stock. In addition, the quality of trash fish is regarded as poor due to inadequate preservation techniques and the long transportation route from capture to farming [26]. Manufactured feed, however, is perceived to be expensive and to lead to a slower growth rate [3,33]. These results imply that if this sector is to be developed sustainably, the lobster disease problem has to be dealt with first. Lobster disease is attributed to environmental stress caused by organic pollution from feeding practice [33]. Therefore, a further study on environmental performance and related factors should be undertaken to identify solutions. Furthermore, attention should focus on exploring stable sources of seed and feed in terms of quantity, quality and price. In relation to seeds, it is necessary to continue the research on lobster hatchery technology. This could be speeded up through cooperation with, and/or transfer of hatchery technology from, New Zealand and Australia. As regards feed, frozen trash fish can be a good alternative to ensure quantity, quality and price [3]. Manufactured feed should also be considered with recirculating aquaculture systems if land-based culture is developed [3]. Moreover, provisions on how to use such inputs sparingly [7,8] in the current situation could usefully be included in the national technical regulations.

According to almost all stakeholder groups, the most serious threat for marine lobster aquaculture development in Vietnam, with a factor priority score ranging from 0.389 to 0.585, is the *complex development of disease*. This is an expected result because in recent years disease outbreaks have become not only more frequent but also more complex and unpredictable [2–4,28,34,35]. In the opinion of all stakeholders, disease outbreaks are related not only to pathogenic agents but also to unusual and unfavorable weather, the degradation of the marine environment and combinations of these factors. The *reliance on the Chinese market* was rated as the second most important threat by all other stakeholders, with a score ranging from 0.195 to 0.374, reflecting the fact that at present, 90% of lobster export got to China [3,28]. Although the demand for lobster and hence the price of imports into China are increasing [27], it is really a high-risk strategy for the lobster farming industry to supply only this market. Overall results show that disease trajectories in this area should be studied closely to reduce the threats to the industry's sustainable development. Moreover, the export markets for lobster products should be diversified to reduce the risks associated with overreliance on the Chinese market.

3.2.2. *The overall priority scores*

On average, the across-group analysis indicates that key stakeholders have a positive perception of the sustainable development of marine lobster aquaculture in Vietnam because the strengths and opportunities (with the sum score of 0.515) appear to slightly outweigh the threats and weaknesses (with the sum score of 0.48.5). The results in Table 2 show that although there is not much difference among the four categories, the most important one is opportunity, with an average priority score of 0.277 (27.7%). It is followed by weakness, threat, and strength, with average priority scores of 0.244 (24.4%), 0.241 (24.1%), and 0.241 (23.8%) respectively.

The different evaluations among stakeholder groups for different SWOT categories are visualized in Fig. 3. This figure shows that the opinion of the stakeholders from the provincial level was quite opposite to that of the other stakeholder groups. Most of the stakeholder groups, except those from the provincial level, regarded the opportunities and strengths as most important. The representatives from the provincial level, however, thought that the threats and weaknesses had a higher weight than the opportunities and strengths. Generally, this difference in evaluation can be explained by the difference in working level among stakeholders. Working at a higher level, the participants from the provincial level might have a broader view of the current problem, whereas the rest of the participants had more opportunity to work directly with farmers. Some participants from the district and commune level were lobster farmers themselves or used to be lobster farmers in the past. They were therefore well aware of the advantages offered the natural conditions in the study area. They also had opportunities to directly experience or to work with other types of marine aquaculture. The higher returns and suitability for lobster farming might be the reasons why they evaluated the strengths as high or very high from an economic point of view. Moreover, they might still believe in the self-cleaning ability of the marine environment. They also recognized and appreciated the encouragement and support from the government. Furthermore, they were very optimistic about the opportunities to explore new export markets. Therefore, the participants from the district and commune

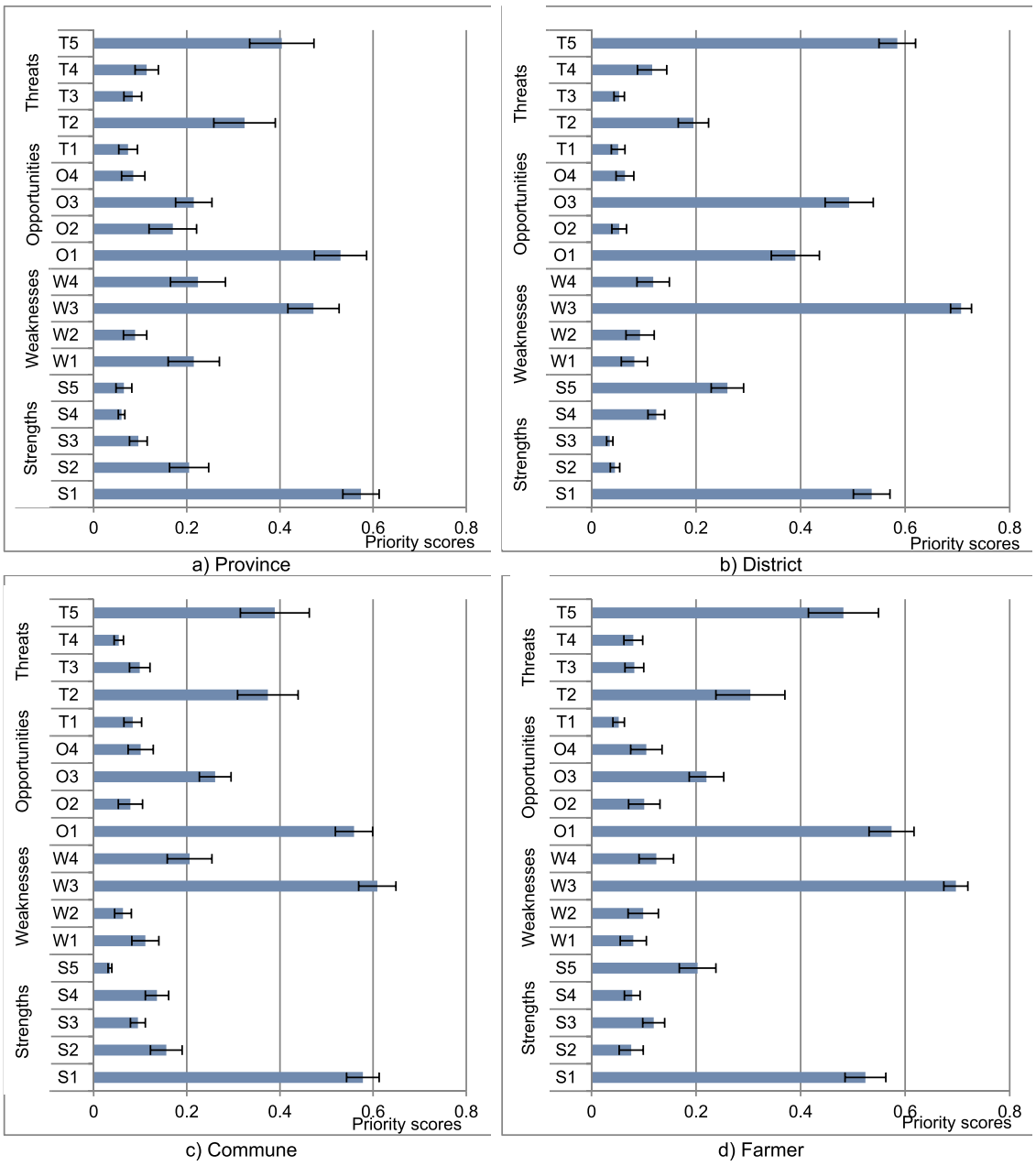

Fig. 2. Local priority score of each factor for each stakeholder group.

levels and the farmers evaluated opportunities as high and very high from an economic point of view, and medium and high from an environmental perspective (Appendix A). The differences in priority scores between each SWOT category within each stakeholder group are statistically significant for all groups (Appendix C). The evaluations of each strength, weakness, opportunity and threat category between groups also differ significantly (Appendix B).

Based on these evaluations, the scale parameters were obtained. The overall priority score for each factor was calculated using the local priority score and the scale parameters. The findings are presented in Table 2 and visualized in Fig. 4. Although the order varies for different stakeholder groups, the result shows that on average, *recent frequent disease and increased mortality* has the highest score of 0.152. The next four factors are the *many untapped markets* (0.142), the *suitable natural conditions* (0.132), the *complex development of disease* (0.112) and *government* support (0.082). These results imply that in order to sustainably develop the marine lobster aquaculture in Vietnam, besides taking advantage of the available natural conditions and support from the

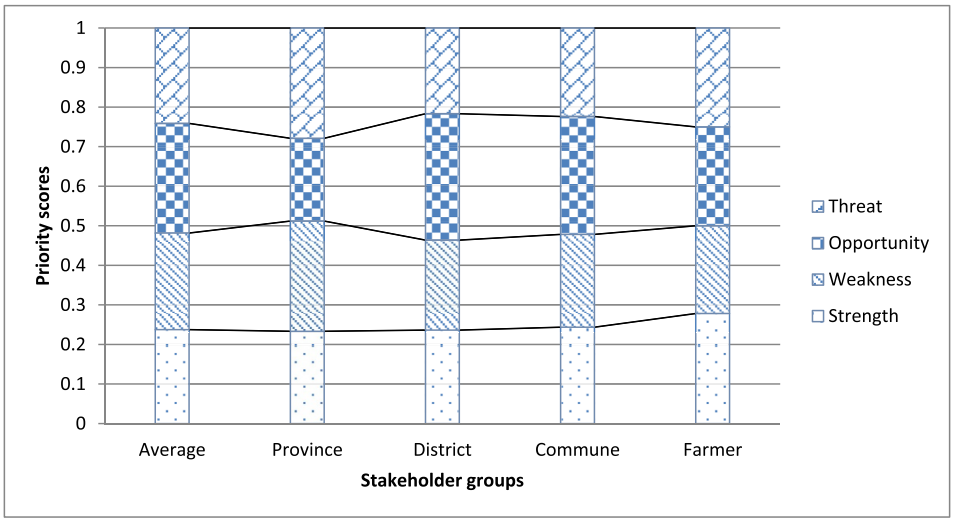

Fig. 3. Overall priority of Strength, Weakness, Opportunity, and Threat.

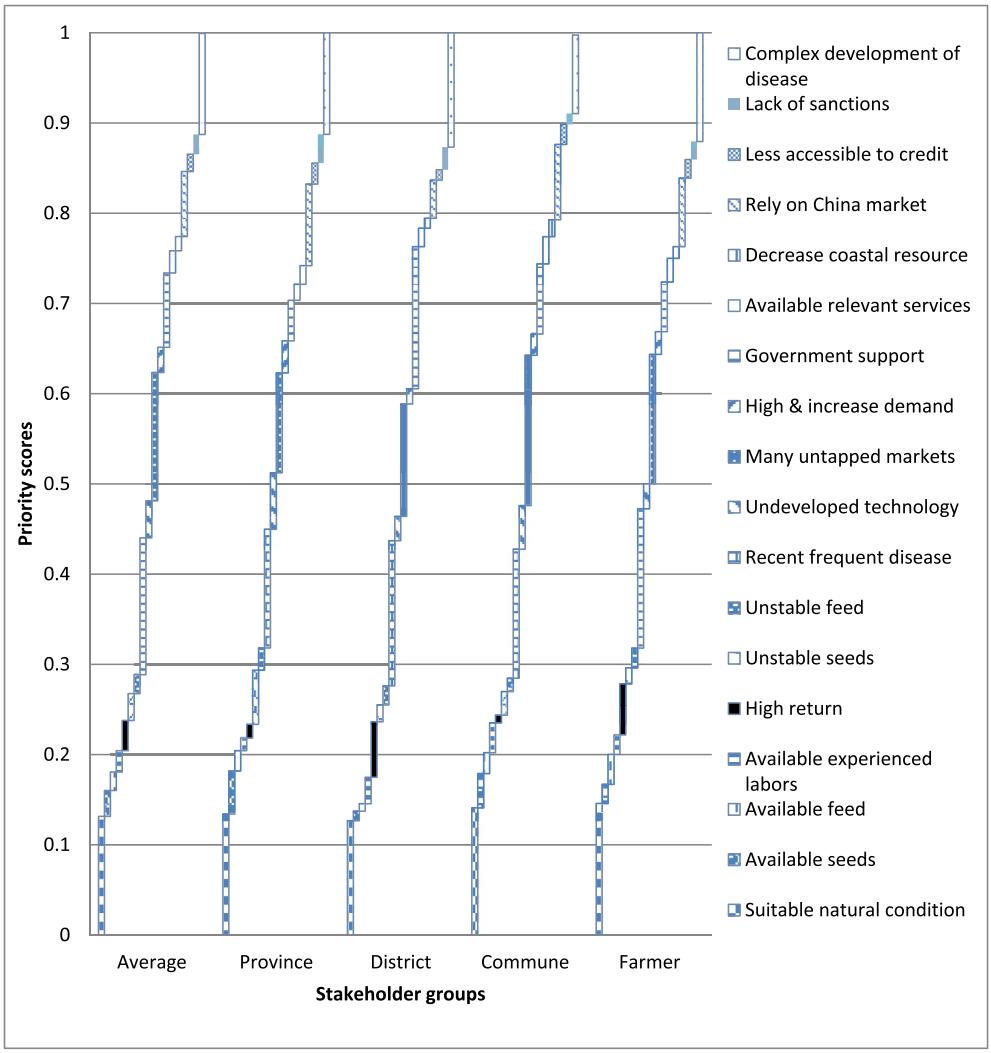

Fig. 4. Overall priority score of each factor in SWOT analysis.

government, it is essential to give serious consideration to the issue of marine water quality and address the problem of pollution. That is because stress is identified as the primary cause of disease and increasing mortality [36] and lobster stress in this area might be caused by pollution. The development and progression of lobster diseases in this area should be studied in depth. Moreover, the untapped markets should

be explored as soon as possible.

4. Conclusion

This study is the first application of a SWOT-AHP analysis in evaluating the challenges and prospects for the sustainable development of marine lobster aquaculture in Vietnam. Representatives from provincial level, district level and commune level and lobster farmers, who are involved in making decisions, guiding, managing and implementing relevant policies and are engaged in lobster aquaculture were identified as the key stakeholders for the analysis. The findings showed the relatively positive perception among most of the stakeholders about the sustainable development of marine lobster aquaculture in Vietnam. Only at the provincial level was there a negative perception about this prospect.

In summary, the results show that the suitable natural conditions, the presence of many untapped markets and the availability of government support are the main opportunities for marine lobster aquaculture. However, the recently increased frequency of disease outbreaks and mortality, the complex development of disease and the reliance on the Chinese market are the main challenges for the sustainable development of this industry in Vietnam. These factors should be taken into account in designing interventions and in policy-making. For example, based on stakeholders' most important concerns, provisions relating to reductions in nutrient inputs to decrease pollution in the marine environment should be included in the national technical regulations. This could also reduce the lobster disease problem and mortality due to stress. There is also a need for more detailed studies on the complex development of diseases in this sector as a basis for devising solutions. Moreover, with government support, solutions to halt environmental degradation and address the disease problem can more easily be incorporated into extension service. It might be useful to assess government support in order to establish an aquaculture management area [37]. A final recommendation is to identify and diversify new export markets as soon as possible instead of relying solely on China as an export market for lobster products.

Declaration of competing interest

None.

CRediT authorship contribution statement

Au Ton Nu Hai: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Visualization. **Stijn Speelman:** Writing - review & editing, Supervision.

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Appendix A. Ranking results of each SWOT category in economic and environmental perspective

		Strengths	Weaknesses	Opportunities	Threats
Province	Economic	High (4.07)	Medium (3.76)	Low (2.89)	High (4.32)
	Environmental	Medium (3.13)	High (4.13)	Medium (3.31)	High (4.32)
District	Economic	Very high (5.00)	Low (2.00)	Very high (5.00)	Medium (3.00)
	Environmental	Low (2.00)	High (4.00)	High (4.00)	Medium (3.00)
Commune	Economic	High (4.78)	Low (2.40)	High (4.18)	Medium (3.18)
	Environmental	Low (2.40)	High (4.18)	Medium (3.78)	Medium (3.18)
Farmers	Economic	High (4.54)	Low (2.48)	High (4.26)	Medium (3.62)
	Environmental	Very low (1.51)	High (4.09)	Medium (3.28)	Low (2.94)

Appendix B. Kruskal-Wallis test for the difference in overall priority of SWOT category between stakeholders

	Hypothesis	P-value of Kruskal test
Strengths	H_0: $S_P = S_D = S_C = S_F$ H_1: $S_P \neq S_D \neq S_C \neq S_F$	1.364e-05***
Weaknesses	H_0: $W_P = W_D = W_C = W_F$ H_1: $W_P \neq W_D \neq W_C \neq W_F$	<2.2e-16***
Opportunities	H_0: $O_P = O_D = O_C = O_F$ H_1: $O_P \neq O_D \neq O_C \neq O_F$	<2.2e-16***
Threats	H_0: $T_P = T_D = T_C = T_F$ H_1: $T_P \neq T_D \neq T_C \neq T_F$	3.831e-09***

P = Province, D = District, C = Commune, and F = Farmers.
S = Strengths, W = Weaknesses, O = Opportunities, and T = Threats.
***H_0 is rejected at 1%.

Appendix C. Kruskal-Wallis test for the difference in overall priority of each stakeholder between SWOT categories

	Hypothesis	P-value of Kruskal test
Province	H_0: $P_S = P_W = P_O = P_T$ H_1: $P_S \neq P_W \neq P_O \neq P_T$	<2.2e-16***
District	H_0: $D_S = D_W = D_O = D_T$ H_1: $D_S \neq D_W \neq D_O \neq D_T$	<2.2e-16***
Commune	H_0: $C_S = C_W = C_O = C_T$ H_1: $C_S \neq C_W \neq C_O \neq C_T$	<2.2e-16***
Farmer	H_0: $F_S = F_W = F_O = F_T$ H_1: $F_S \neq F_W \neq F_O \neq F_T$	<2.2e-16***

P = Province, D = District, C = Commune, and F = Farmers.
S = Strengths, W = Weaknesses, O = Opportunities, and T = Threats.
***H0 is rejected at 1%.

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