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Sustainable Innovation Management in the Shrimp Sector of the Municipality of Guasave, State of Sinaloa, Mexico

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Abstract: Aquaculture is one of the fastest growing productive sectors in recent years, so much so that it has surpassed traditional fishing. The aim is to make its production processes sustainable, mainly economically and environmentally, through continuous innovation. Hence, the objective is to determine the relevance of sustainable innovation management in the shrimp sector in the municipality of Guasave, state of Sinaloa, Mexico, as a determining factor in the search for social and environmental well-being in this region of the Mexican Pacific. With this in mind, the present research was designed as an exploratory–explanatory study, under a qualitative approach with a multiple case study strategy using the Likert scale. To this purpose, 24 surveys were applied to the owners and managers of six farms specializing in shrimp production, with a continuous production of 10 years and a minimum of 100 hectares cultivated in recent years. Each survey consisted of seven themes and a total of 37 items to analyze eight indicators which influence the sustainable innovative management of the shrimp sector. The survey results indicate that the perception of entrepreneurs toward the relevance of sustainable innovation management is favorable, with 96% agreeing to encourage innovation, 83% agreeing to invest in new equipment and methods, and 83% in favor of their participation in markets. Moreover, the correlation between the indicators to determine the influence of sustainable innovation management is significant at 0.69 and 0.86.

Keywords: sustainable aquaculture; competitiveness; disruptive technologies

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1. Introduction

Aquaculture represents one of the fastest-growing productive sectors, contributing to global food security and to the economic well-being of rural and coastal regions [1]. Currently, the global aquaculture industry is performing the function of the fishing industry, enabling economic and sustainability goals to be achieved [2].

According to statistics recorded by the Food and Agriculture Organization of the United Nations (FAO), for 2017, the global fish consumption reached approximately 171 million tons, of which 47% came from aquaculture [3]. The state of Sinaloa, Mexico, ranks second in aquaculture and fishery products at the national level [4], representing 22.77% of the national aquaculture and fisheries production, with crustacean production accounting for 74% of the total value of the state's production [5] (Table 1).

Specifically, the shrimp production was worth more than MXN 16 billion [6], with an annual per capita consumption of 1.7 kg. The state of Sinaloa stands out as the leader in shrimp production in Mexico, with two thirds of the volume generated by the state's aquaculture units [4].

Table 1. Main aquaculture species produced in the state of Sinaloa.

Species	Proportion of the Production
Fish	23%
Crustaceans	74%
Mollusks	2%
Other species	1%

Prepared by the author based on data from SENASICA [5].

It is important to note that since 2001, aquaculture in Mexico has become one of the fastest-growing sectors in Mexico, despite the fact that the activity has lacked financing for its operation, as well as the infrastructure required for its expansion [7], in addition to being a productive activity vulnerable to negative external influences on production processes associated with diseases, survival risks, operational management, and high production costs [8].

As shown in Figure 1, aquaculture has experienced exponential growth, where continuous innovation has played a relevant role, but has faced criticism regarding its ecological practices, social sustainability practices, and innovation processes [9]. Some of these criticisms are the negative external influences on the environment, such as pollution, habitat use, and impacts on small-scale artisanal fisheries, which have challenged the industry and led to numerous regulations [10,11]. These negative effects have forced the construction of more sustainable societies, in which governments have taken an interest in responding to the UN sustainable development goals [12].

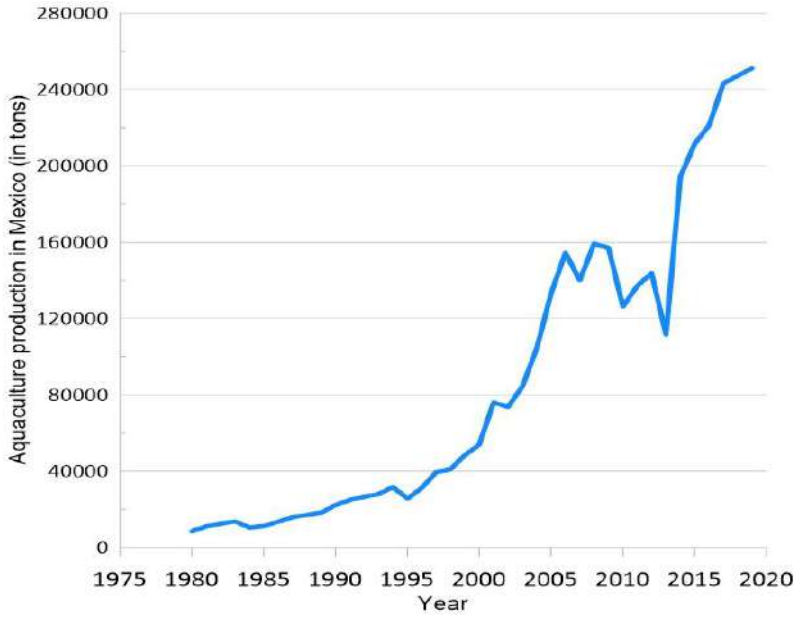

Figure 1. The total aquaculture production in Mexico from 1980 to 2019. Prepared by the authors with information from FAO [7].

Prepared by the authors with information from FAO [7].

Sustainability is a long-term project, a process that, to become a reality and not just a utopia, needs radical change in business mentality, i.e., a responsible culture; it is a stimulus for technological innovation and an important factor in explaining the new regulatory framework, such as the use of a wide range of environmental indicators to assess the aquaculture production systems [13].

In terms of innovation and sustainability, both have gained significant importance in recent decades, not only in the business and entrepreneur sphere, but in all branches and sectors of a country's production. In this way, and as far as the interest of this study is concerned, innovations have the potential to help plan and overcome many of the

challenges facing aquaculture today. However, if not carried out a sustainable way, they can create new problems, even catastrophes [14]. Hence, addressing innovation in a sustainable way requires an understanding of all of the components that influence innovation processes.

Today's markets make it necessary for companies to make permanent and constant adjustments to their activities and to develop sustainable innovation capabilities, due to factors such as high competition, globalization, and digitalization [15].

Considering several authors that address the issue of sustainable innovation in the aquaculture sector [9,16–21], sustainable innovation in the aquaculture sector is understood as the implementation of state-of-the-art technological practices that help to improve supply, production processes (sowing, cultivation, harvesting, among other activities), and administrative, monitoring, feeding, and supply mechanisms, in addition to the fact that such implementation contributes to reducing the negative impact on the environment and achieving economic development in which environmental protection, feeding, and supply mechanisms are coordinated. The implementation of these practices should also contribute to reducing negative environmental impacts and achieving economic development in which environmental protection, social welfare, and business competitiveness are coordinated via investing in emerging technologies, being at the forefront of market changes, fostering innovation, allocating resources to social and environmental issues, and having defined environmental strategy.

Thus, the concept describes each of the indicators used to determine the influence of sustainable innovation in the shrimp sector, which are presented in Table 2, which are supported by Quiroga Martínez, Mendoza, Ting et al., and Valenti et al. [22–25].

Table 2. Indicators to determine the influence of innovation on sustainable management in the shrimp sector in the municipality of Guasave. Source: elaborated by the author with data from Quiroga Martínez, Moyeda and Arteaga, Ting et al., and Valenti at al.

Indicator	Author
1. Continuous improvement	Quiroga Martínez [22]; Moyeda y Arteaga [23]
2. Investment in disruptive technologies	Quiroga Martínez [22]; Moyeda y Arteaga [23]
3. Fostering innovation	Quiroga Martínez [22]; Ting et al. [24]; Valenti [25]
4. Social and environmental commitments	Quiroga Martínez [22]; Ting et al. [24]
5. Volunteer work actions	Quiroga Martínez [22]; Ting et al. [24]
6. Prevention of conflicts with the community	Quiroga Martínez [22]; Ting et al. [24]
7. Monitoring of community issues	Valenti [25]; Quiroga Martínez [22]
8. Defined environmental strategy	Valenti [25]; Quiroga Martínez [22]; Ting et al. [24]

In this way, innovation-oriented management therefore improves the performance of companies worldwide [26]; thus, innovation in the aquaculture sector adds to economic growth without harmful effects on the environment in pursuit of social welfare.

Innovation systems can play a critical role in globally coordinated efforts to create a sustainable future. However, research linking innovation systems and sustainability is scarce [27,28]. Sustainability-oriented innovation requires different circumstances, such as a focus on individual culture and practices within organizations revealed by traditional innovation research [29].

Sustainable innovation has been recognized as an important driver of social transitions towards sustainability [30]. Sustainability-oriented innovation (SOI) indicates that, to achieve this type of innovation, intentional changes need to be made to an organization's values, philosophy, products, processes, and practices to achieve the specific purpose of creating and achieving social and environmental values as well as economic benefits [16].

According to Rodríguez-Espíndola et al. [31], the circular economy promotes sustainability-oriented innovation, which aims to maintain the value of products, materials, and resources for as long as possible and minimize waste generation, creating a positive impact on financial, environmental, and social performance. On the other hand, it should be mentioned

that sustainable innovations and company development are influenced by both the internal management and external economic policy uncertainty [32].

In turn, Bush et al. [17] highlight that the use of technology and innovation reinforce their potential to address a range of short-term production risks, and long-term objectives of intensifying sustainability in aquaculture. Continuing this, Raftowicz and Gallic [18] point out the importance of innovation along the aquaculture value-chain, stating that market-oriented innovations appear to be the most promising.

Sampson et al. [33] argue that radical systems may be necessary to achieve ecological and social sustainability in aquaculture, through the generation of new processes, new production techniques, and organizational changes, leading to new markets and potential applications. However, in the literature concerning the aquaculture sector, there is limited systemic knowledge on how innovation has been approached, understood, and managed, as well as the scope of the innovation processes [9].

Therefore, for the aquaculture sector to remain as a globally relevant, the continuous sustainable innovation of its production systems is necessary to respond to the key issues, such as those related to environmental and social sustainability.

In this sense, the objective of this research was to determine the relevance of sustainable innovation management in the shrimp farming sector in the municipality of Guasave, state of Sinaloa, Mexico, as a determining factor in the search for social and environmental well-being.

2. Materials and Methods

This research was designed with a qualitative approach [34], using the multiple case study strategy [35], covering the shrimp sector in the municipality of Guasave, state of Sinaloa, Mexico. The study was conducted in 2020, in six enterprises in the shrimp sector in this municipality. The objective was to analyze the perception of management staff on sustainable innovation and the practices used in the industry. For this purpose, a survey was designed in which the administrative staff answered the constructs containing the indicators needed to determine the influence of innovation on sustainable management. For the choice and development of the indicators used, the main initiatives for the development and implementation of environmental and sustainable development indicators in the world were reviewed. The indicators developed specifically for the relevant users represented a system that allowed companies in the shrimp sector to assess their progress towards sustainable innovation management (Table 2).

Indicators, whether of environmental sustainability or sustainable development, are constructs (concepts) that make it possible to evaluate progress or setbacks in sustainable development [22]. They are necessary and useful in decision making, in establishing development perspectives, and in understanding the state or situation in which a region finds itself due to certain activities or the impact of certain public policies applied or to be applied, as well as in public management.

Indicators incorporate dimensions such as economic, social, environmental, or institutional dimensions. In this paper, we considered the indicators in Table 2, which correspond to the environmental (4,5,8), social (5,6,7), and economic (1,2,3) dimensions. The indicators were collected from the authors listed in Table 2. These indicators were determined qualitatively by means of 37 items incorporated in the survey and applied to the owners or managers of the farms studied. The Likert-scale survey items were divided into seven categories according to the qualitative assessment criteria, in order to visualize the dimensions of indicators, innovation, and processes in management in the survey.

2.1. Study Area

The study area comprised the coastal zone of the municipality of Guasave, state of Sinaloa, Mexico, where more than 152 shrimp farms operate [36] (Figure 2).

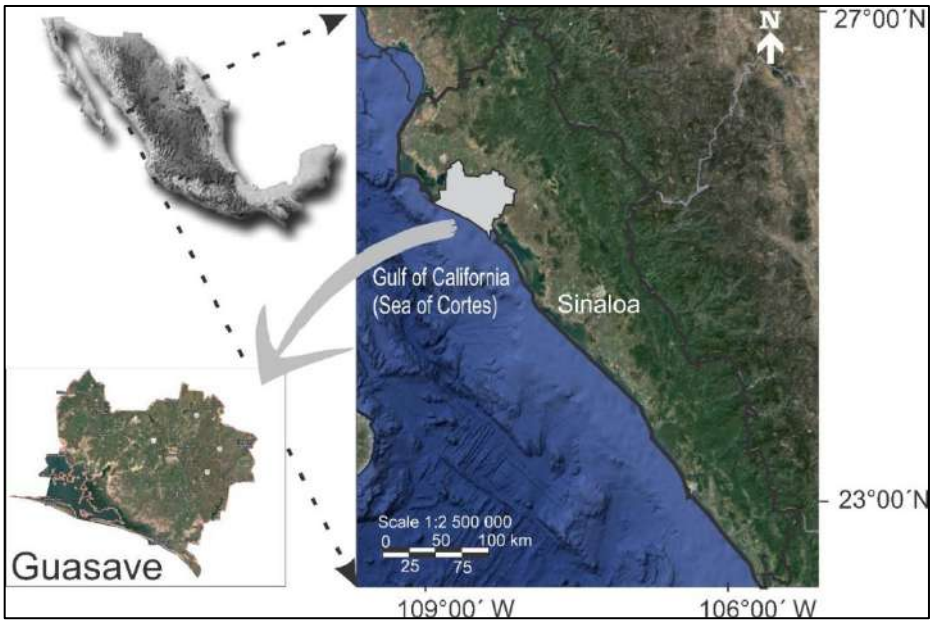

Figure 2. Map of Guasave, Sinaloa. Source: elaborated by the author with data from INEGI [37], supplemented with satellite images from Google Earth Engine (GEE) and Google Maps.

The habitat in the study area is formed of mangroves, which provide a positive environmental service to the aquaculture farms by protecting them from the effects of erosion and sediment accumulation generated during the annual storm periods, and if the mangroves did not exist, the sediments dragged by cyclonic currents would modify the conditions of the farms. On the other hand, mangroves generate a particular ecosystem that provides food for predatory species of aquaculture products, especially shrimp [38].

The scope of the present study was exploratory–explanatory, because there are not many studies focused on the analysis of sustainable management for the shrimp sector, and the study covered not only the description of concepts but aimed at pointing out the relevance of managing sustainable innovation in the shrimp sector of Guasave, Sinaloa [34].

2.2. Study Population and Sampling

To determine the number of case study companies to be studied in Guasave, qualitative sampling was performed using the multi-case strategy [35]. It is pertinent to mention that, in the case study, data could be obtained from a variety of sources, both qualitative and quantitative, i.e., documents, records, direct interviews, cross interviews, direct observation, participant observation, and physical facilities or objects [39].

For the selection of the six case study companies, the following criteria were considered: (a) having more than 10 years in the market, (b) having a cultivation area of more than 100 hectares (247.105 acres) of shrimp production, and (c) being environmentally recognized and certified in terms of their productive work (according to SENASICA criteria in force in 2020). The selection of six case studies was justified under criteria of homogeneity and representativeness, since the history of aquaculture in the region is irregular (it deviates from the three criteria mentioned above), so that the indicators applied through the surveys would not be biased by the heterogeneity. In order to determine the sample size corresponding to the number of administrative staff in the six shrimp companies under study, probability sampling was carried out, which allowed us to obtain a small part of the population that was representative and sufficient. In this research, the working population was finite, and the procedure indicated by Aguilar [40] was followed, assigning a confidence level of 90% and an error margin of ±10%. The following equation was applied:

$$n = \frac{NZ^2\ pq}{d^2(N-1) + Z^2\ pq}$$

where:

- N—36 administrative personnel
- Z—1.645 (90% confidence interval)
- p—50%
- q—50%
- d—10%
- Substituting values:

$$n = \frac{(36)(1.645)^2(0.5)(0.5)}{(0.1)^2(36-1)+(1.645)^2(0.5)(0.5)}$$

$$n = \frac{24.35}{1.0265} = 23.7 \approx 24$$

- $n = 24$

According to this calculation, the number of administrative staff to be surveyed was 24.

Opinion and purposive sampling were applied [41]. The instrument used in this research was an interview measured on a six-point Likert scale, as defined by Harpe [42]. Each survey consisted of 37 items, divided into 8 categories. Each item was quantified numerically, as the Likert scale allows them to take a value out of a possible six. In this way, each item behaved as a variable that took the value assigned by each respondent, allowing various statistical operations to be carried out among the items (variables).

2.3. Reliability Analysis

The Statistical Package for the Social Sciences 25.0 (SPSS) was used to analyze the results. This tool is capable of processing large volumes of data through a user-friendly interface [43]. This tool was used to find the relationship between the categorical items of the surveys applied to the owners and managers of the shrimp enterprises of Guasave, as well as a validation to determine the reliability of the tool according to Quero Virla [44] for the responses to the categorical items, which were process management (5), sustainability management (5), social dimension (6), environmental dimension (9), economic dimension (4), innovation management (3), and relation with stakeholders (5). The number in brackets corresponds to the number of items of each category.

Specifically, the instrument was used to analyze the validity and reliability properties of the eight indicators related to the influence of innovation on sustainable management (Table 2).

Sánchez Escobedo [45] points out that, for the reliability analysis, indices such as McDonald's Omega (ω) should be used, stating that a minimum of 0.65 points is required to determine validity and, according to Table 3, the result for the present investigation was 0.929; similar values were found in investigations carried out by Ortiz et al. [46] (ω = 0.903), Matar-Khalil et al. [47] (ω = 0.929), and Muñetón and Alarcón-Vásquez [48] (ω = 0.933).

Table 3. Reliability statistics of the scales.

	McDonald's ω
Scale	0.929

Source: elaborated by the author.

3. Results and Discussion

The survey applied to the shrimp farm owners and managers revealed that 100% of them were men, aged between 40 and 70 years, all having undertaken university studies.

Regarding the indicators used to determine the influence of innovation in sustainable management, 96% of the respondents said they were in favor of promoting innovation, giving economic incentives to workers; 83% commented to agree about investing in disruptive technologies for the acquisition of new equipment and methods; and 83% agreed with continuous improvement being at the forefront of market changes (Figure 3).

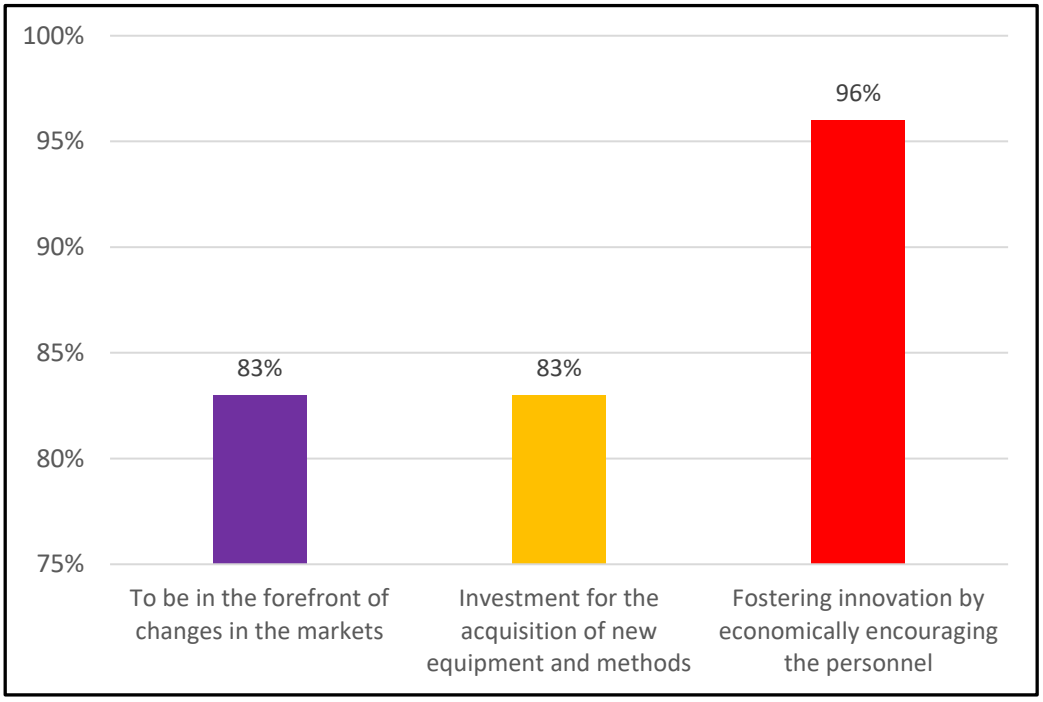

Figure 3. Favorable opinions according to the variables of the sustainable management of innovation. Source: elaborated by the author.

Despite the lack of public or private funding at affordable rates, respondents were in favor of investing in the acquisition of new equipment, methods, and continuous improvement to be at the forefront of changes in the markets, which shows that there is willingness and interest, and that they are aware of the need for technological innovations towards more sustainable production processes, as proposed by Shahzad et al. [49] in their research performed in Pakistan. In their findings, they argue that investing in and adopting the latest sustainable technology and practices is not only valuable for long-term success, but that aspects such as organizational knowledge management are also vital in today's knowledge-based economy. It is worth noting that Hu et al. [50], in their work in Bangladesh, mention that fish farmers implementing innovations such as new technologies and new products often require collaborative innovation across segments of other sectors or in other segments of the value-chain, such as wholesalers implementing new product innovations such as the commercial supply of fish feed and chemicals. Hence, it can be argued that clustering value-chain segments in a local area will stimulate innovation in this important sector.

As for the indicator of social and environmental commitments, 79.17% favored a variable intensity as shown in Figure 4. In turn, Troise et al. [51] point out the relevance of the sustainability pillars such as the environmental ones, because they constitute a substantial competitive advantage, and consumers are increasingly demanding that companies focus on the three pillars of sustainability: economic, social, and environmental factors. Similarly, Nilsson and Göransson [52], from Sweden, point out that most of the existing research on sustainable innovations has been conducted at the company level. This encourages short-term thinking and profit maximization. The latter can translate into a strong incentive to continue investing in the aquaculture sector, despite constraints due to a lack of funding.

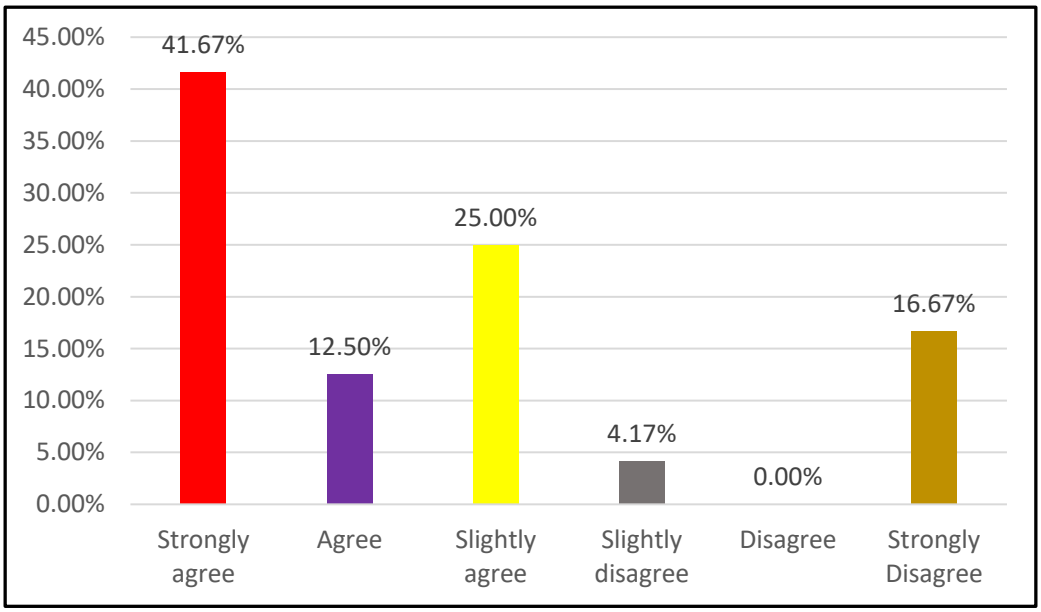

Figure 4. Allocation of resources to social and environmental commitments. Source: elaborated by the author.

With regard to the average value of indicators, volunteering actions, prevention of conflicts in the community, and monitoring of community affairs were 54.20%, 58.3%, and 70.8%, respectively, that is, above 50%, which indicates that there is a willingness to adopt more sustainable production processes (Figure 5). In relation to these values, Appolloni et al. [53] found that the multidimensionality of industrial organizations should encourage companies to include social and environmental attributes in their products, such as the circular green premium and sustainability certification. This contrasts with a focus solely on customer needs from a price point of view.

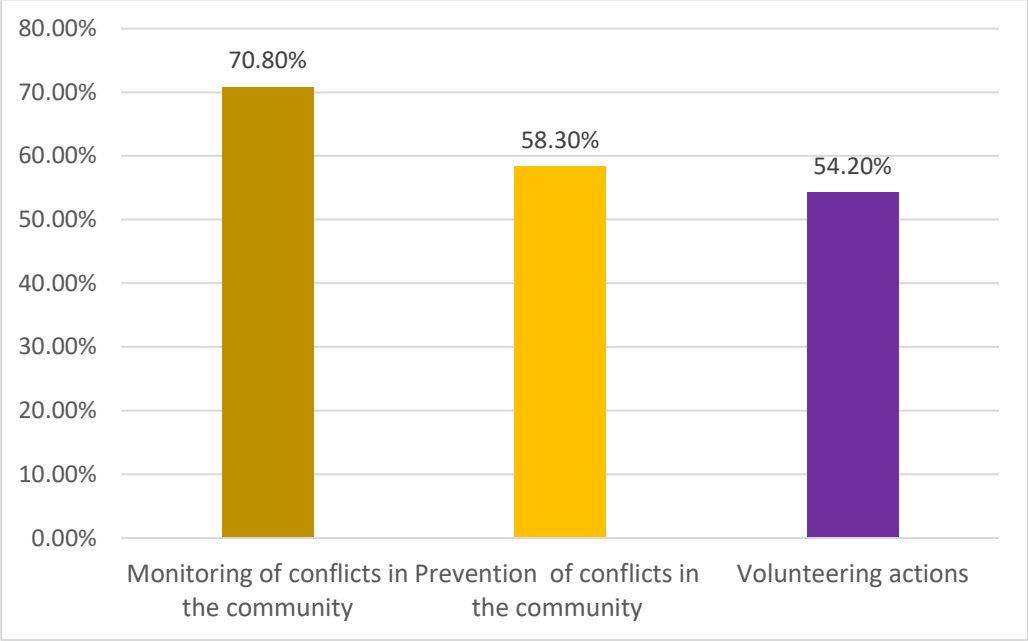

Figure 5. Favorable opinions, according to the variables of the organization's relationship with the community in which it operates. Source: elaborated by the author.

In Ireland, O'Neill et al. [54] state that sustainable research and innovation, as well as global disruptive innovation, in aquaculture are relevant because they pose global chal-

lenges and opportunities, emphasizing the need for international agreement on resilient indicators that encompass ecological, social, economic, and cultural linkages. This represents a complex challenge that implies widespread change in the aquaculture sector, its management, and industry policies.

In relation to the defined environmental strategy indicator, the responses varied among the respondents: 13% agreed completely, 33% agreed, 38% agreed slightly, and 16% had an unfavorable response (Figure 6). In other words, 84% maintained a favorable response with varying shades of variation. Nowadays, companies have to develop environmental awareness; so, fish farmers seek to improve the productive processes in favor of the environment, as proposed by Boyd [55] in the USA, avoiding the use of antibiotics and products that pollute the culture water. Song [56] and Yao [57], in China, agree in the field of encouraging the use of novel feeds to replace fishmeal, which will help to decrease organic matter, increase production, and decrease costs.

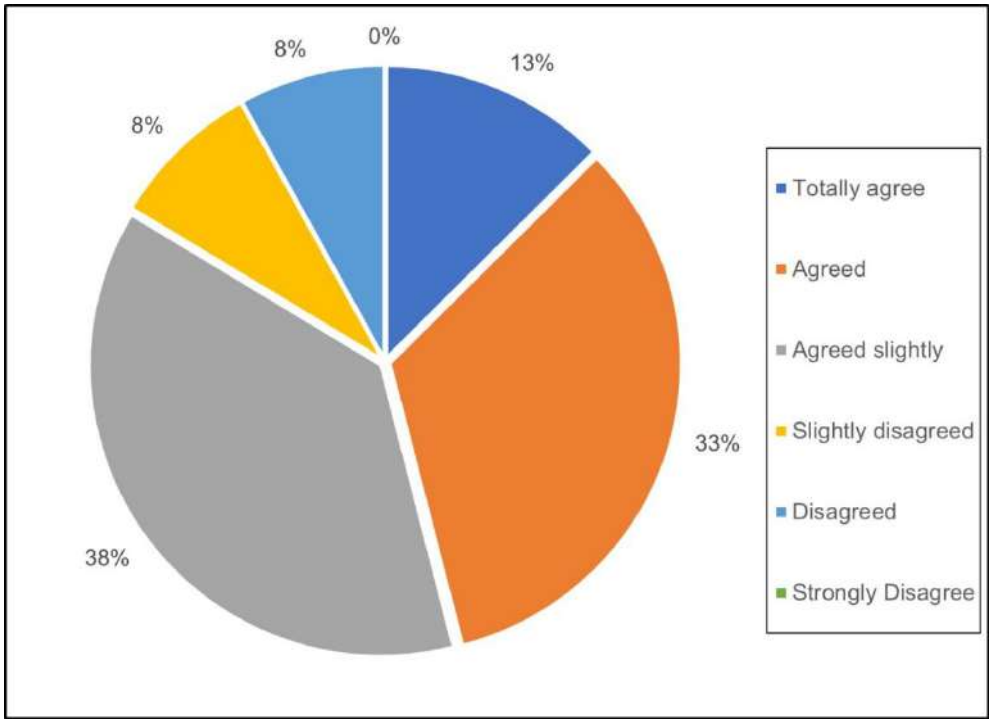

Figure 6. Favorable opinions, according to the defined environmental strategy. Source: elaborated by the author.

Zhou et al. [58] studied the relationship between business innovation and green management and revealed how companies pursue sustainability and prosperity under specific environmental conditions, while at the same time promote new product development.

A cross-tabulation between the variables of investments for the acquisition of new equipment and methods and the promotion of innovation by financially supporting personnel reveals that all those who responded that they very fully agreed with the investment for the acquisition of new equipment and methods were also in favor of promotion and innovation, because in addition to impacting production, the ecological context is preserved (Table 4). As Bremer et al. [59] point out in northern Europe, where rapid growth of the aquaculture sector has occurred in the last 40 years, this is related to innovation and advances in science and technology. Similarly, Bustos [60], in Chile, agrees that innovation may be necessary to achieve ecological and social sustainability in this important sector.

Table 4. Cross-referenced information between investments for the acquisition of new equipment and methods and the promotion of innovation by providing economic incentives for personnel.

		Investment for the Acquisition of New Equipment and Methods (in %)				
		T.D.	SD.	S.A.	A.	T.A.
Fostering innovation and economically encouraging personnel	S.D.	100.0				
	S.A.		27.3	54.5	18.2	
	A.				57.1	42.9
	T.A.					100.0
Total		4.2	12.5	25.0	25.0	33.3

D. Disagreement. SD. Slight disagreement. S.A. Slight agreement. A. Agreement. T.A. Total agreement. Source: elaborated by the author.

Pearson's correlation (determined using SPSS software) of the indicators to determine the influence of innovation on sustainable management showed a positive correlation of 0.696 between the indicator of investment in acquiring and improving new equipment and methods, and the indicator of being at the forefront of market changes (Table 5).

Table 5. Innovation management correlations.

	To Be in the Forefront of Market Changes	Investment for Acquisition and Improvement of New Equipment and Methods	Fostering Innovation, Economically Encouraging Personnel
• To be in the forefront of market changes	1		
• Investment for the acquisition and improvement of new equipment and methods	0.696 **	1	
• Fostering innovation and economically encouraging personnel	0.564 **	0.865 **	1

** The correlation is significant at the 0.01 level (bilateral). Source: elaborated by the author.

The correlation between encouraging innovation by providing financial incentives to staff and investment in the acquisition and improvement of equipment and methods was 0.865. Therefore, if the favorable opinion on the variable of encouraging innovation by financially incentivizing staff increases, the favorable opinions on investments for the acquisition and improvement of equipment and methods will also increase (Table 5).

Similarly, Asche and Smith [61], in their research conducted in the USA, stated that Malthus, the economist, predicted that scarcity would undermine the world and that it is of utmost importance to design policy responses to encourage innovation, while recognizing the physical limitations of natural resources. In this context, the shrimp sector under the action of sustainable innovation is an asset for the sector.

Moons et al. [62], in their study performed in Flanders and the Netherlands, but in another food sector, such as nursery horticulture, showed a clear motivation and willingness of producers to adopt sustainable innovations.

In the same line of thinking, Yue and Shen [63], in China and Singapore, state that the use of technological, policy, and market innovations allows seafood products to grow, and investments represent a viable option. Aquaculture is an alternative to ensure sufficient seafood products for the world; however, it needs innovative and disruptive technologies to increase its production.

In continuation, Hermundsdottir and Aspelund [64], in their study in Norway, stated that sustainability innovations have a positive effect on the competitiveness of companies. Similarly, Rezende et al. [65], in Brazil, agree that the competitiveness results of innovations in sustainability translate into higher value creation and cost reduction. As for green innovation, its effect is time-dependent, i.e., in the short or long term, and is seen as a way

to meet regulatory pressures and costumer demands. There is no consensus on the impact on returns.

In addition, Kuncoro and Suriani [66] analyzed the relationship between product innovation and sustainable competitive advantage in the Ngablak Magelang district, and found a significant positive relationship. On the other hand, Le and Ikram [67] studied the nexus between sustainable innovation and business performance of small and medium enterprises in Vietnam, exploring the mediating role of business competitiveness in the context of an emerging market. They found that there is a strong positive relationship between sustainable innovation and competitiveness of companies, with the latter having a positive and significant relationship with financial, environmental, and operational performance.

Moe Føre et al. [68] analyzed proposals of technology concepts contained in applications for development licenses granted in Norway. These provided an alternative to the challenges caused by the negative environmental externalities of aquaculture.

Raftowicz and Le Gallic [18] studied the role of innovation along the value-chain of aquaculture in Poland. Their research was based on innovation theory; according to which, the entrepreneur improves economic processes through innovations. They also confirmed that public funding plays a key role in facilitating the diffusion and adoption of innovate processes.

Finally, Osmundsen [69], in Norway, stated that it is important to note that sustainable innovation and business development can be influenced both by efficient internal management and by political and economic issues that support the aquaculture industry, with incentives for the adoption of disruptive technologies for cleaner production.

The international experiences mentioned above reveal that sustainable innovation management in various production processes is relevant and desirable, resulting in a context where the managers or owners of the aquaculture farms of this study perceive that innovation management is desirable, and set the basis for development in shrimp farming.

4. Conclusions

Respondents expressed their support for innovation management in the shrimp farming sector, with 96% in favor of encouraging innovation, 83% in favor of investing in new equipment and methods, and 83% in favor of entering the markets.

The correlation among indicators to determine the influence of innovation on sustainable management was positive and significant at 0.696.

The correlation between encouraging innovation by providing financial incentives to staff and investing in the acquisition and improvement of new equipment and methods was 0.865.

These percentages and correlation values reveal that the owners and managers accept that innovation is an important element in sustainable management; it also responds to regulatory pressures and helps with gaining a competitive advantage. Both elements combined foster sustainable value creation in the shrimp companies, as these rates of acceptance of innovation in the aquaculture sector represent a valuable alternative to seafood scarcity, fostering and increasing the quality of production through processes and strategies oriented towards the goal of sustainability. Therefore, for the aquaculture sector in the study area and in other regions of the world to remain an important sector worldwide, the continuous innovation of systems is necessary to solve key problems, such as those posed by environmental and social sustainability.

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