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Review

Environmental and Socioeconomic Impacts of Shrimp Farming in the Philippines: A Critical Analysis Using PRISMA

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Abstract: Shrimp aquaculture is under pressure to increase its production to meet the growing demand for food from a growing population. In the Philippines, aquaculture has experienced the shift from milkfish to prawn, with its attractive marketable price. This intensification has led to negative and positive impacts, which have raised a range of environmental and socioeconomic problems. This paper reviews the environmental and socioeconomic challenges that the shrimp aquaculture industry faces using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method. We examine the gaps and the changes that are required to revitalize the industry. We examine and assess the impacts of shrimp culture on the environment, e.g., shrimp farm management, marine pollution, disease outbreaks, and the social, economic, and climate change impacts. The presence of viral diseases, such as White Spot Syndrome Virus (WSSV), Monodon Baculovirus (MBV), Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV), Hepatopancreatic Parvovirus (HPV), and Yellow Head Virus (YHV), have caused approximate losses in the industry of 40,080 mt in 1997, and 51,000 mt in 2014. Recommended strategies and policy changes are considered for the improvement of shrimp aquaculture, including disease management, the adoption of good aquaculture practices, proper environmental monitoring, sustainable practices at the farm level, and priorities for cooperation among the concerned government agencies and local governments, as well as the involvement of state universities and colleges, for better management practices.

Keywords: aquaculture; environmental impacts; PRISMA; shrimp aquaculture; shrimp diseases; socioeconomic impacts

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1. Introduction

Aquaculture serves the employment and food security needs of most Asian coastal countries, such as Bangladesh, China, India, Indonesia, the Philippines, Thailand, and Vietnam, which are all aquaculture-reliant countries with large aquaculture sectors [1–5]. Aquaculture is a major driver of socioeconomic development in poor rural and coastal communities, particularly in Asia, and it relieves the pressure on, and helps to maintain the sustainability of, wild-caught species from rivers, lakes, and oceans, as it provides for the shortfalls of capture fisheries [6]. The rise of aquaculture has been one of the most profound changes in global food production over the past 100 years [7]. This industry has become a major source of food protein and it is predicted that it will support our seafood production as a sustainable alternative to wild-caught fish [3,8]. There is a prediction that the per capita seafood consumption will continue to increase by 1.5 kg per year by 2025 [9]. Population growth and increased individual consumption indicate that farmed seafood products will be gradually more important as an additional food source, and that aquaculture will play a vital role as natural fish stocks continue to decline [9,10].

Crustaceans contribute to a significant portion of the production and value of aquaculture among the aquatic species that are developed for it [11]. Penaeid shrimps are the most preferred crustaceans in aquaculture, as is shown by the vast expansion of the land area that is being devoted to shrimp farming [12,13]. Globally, about 9.4 million metric tons (mt) of farmed crustaceans were produced in 2020. Of this, 5.7 million mt were from *Penaeus vannamei* (Pacific white shrimp) and *Penaeus monodon* (black tiger shrimp) production [14]. In the most recent years, shrimp has become the world's most valuable aquaculture species, and its production has increased from less than 75,000 mt in 1980, to over 5.7 million mt in 2020 [14]. In the Philippines, shrimp production remains a valuable export commodity, with a total production in 2019 of 66,252 mt; it ranks fourth in value, at USD 42.36 million; and it is exported to Japan, South Korea, and the United States [15].

Penaeus vannamei is one of the most popular shrimp species for culture [16]. This species became well-known in tropical countries for its desirable characteristics, such as its short culture period and fast growth, and it has made inroads in the global market [17]. Its production has grown tremendously in past years because of its high economic returns, although it has also been ravaged by diseases [18].

In the Philippines, shrimp production has been mainly located in Negros and the Panay Islands in Central and Western Visayas. Recently, this has changed, and shrimp production has been growing and increasing in other areas, such as in Central Luzon, in other parts of Central Visayas, in SOCCSKSARGEN, in Northern Mindanao, and in the Caraga and Davao regions [19,20]. Thus, *P. vannamei* production has spread in various parts of the country, whether it is cultured alone, or in combination with other finfish species [6,21]. There are new cultivation techniques being applied and new cultivation areas that were previously nonexistent, which means that farmers have been encouraged to adapt because of the high economic returns [17,22]. Despite what happened because of the *P. monodon* crises in the mid-to-late 1990s, shrimp farmers and investors have high hopes and expectations for better market demands in local and overseas markets [17,19,23,24].

Before the importation of *P. vannamei*, *P. monodon* was the only species being exported abroad [17]. *P. monodon* is indigenous to the Philippines and can be grown in freshwater, brackish water, and marine water [24], and throughout northern Luzon to the southernmost parts of Mindanao [17]. During the continuous growth and expansion of shrimp culture in the Philippines, the shrimp industry reached its highest peak in 1992, when it produced about 120,000 mt [25].

Below is the development history of the shrimp industry in the Philippines (Table 1). Beyond the year 2000 shows the lack of a clear industry roadmap for reinvigorating the shrimp industry in the Philippines, despite the availability of all the relevant technologies to expand and to increase its existing capacity. While Republic Act 8550, which is otherwise known as the "Philippine Fisheries Code of 1998", was enacted to law, it contained vague references on incentivizing the fisheries and the aquaculture industry. For instance, Section Two (2), Objective three (3), argues for the *"Improvement of productivity of aquaculture within ecological limits"*. This law only argues for increasing the aquaculture production; it does not specify how to protect the ecosystem; for example, the mangrove ecosystem during forest clearing and pond construction, and protection against the release of wastewater in the case of milkfish and shrimp production. It also does not state nor specify whether the state can solely decide the terms for putting up ecological limits on the basis of the best available scientific expertise. Even the more specific provisions contained in Article Three (3), Section Eight (8) of the same law, which provides for incentives and disincentives for the proper cultivation or culture of species, do not properly discuss the process for attaining the proper method of culturing species in all the stages, such that it reduces the possible environmental impacts. Furthermore, the implementation of the rules and regulations of RA 8550, the act of the reforestation of bays, shores and dikes, and the building of structures to minimize water pollution by the fishpond lessee are all stated (Rule 46.2), including good aquaculture practices (Rule 47.1), which are crafted by the Bureau of Fisheries and Aquatic Resources (BFAR). Yet, a cursory visit to fishpond farms (small-scale and commercial operators) show that these are not being followed most of the time, or that shrimp farmers are minimally fulfilling these guidelines of the law. Despite these failures to adopt sustainability practices, except for compliance certifications, when exporting shrimps and finfish to premium markets, such as Europe, Japan, and the United States, which require adherence to traceability and other food safety rules and protocols, the required compliance certificates become external motivating factors in accessing those premium markets.

Table 1. Milestones of shrimp industry in the Philippines.

Year	Milestone	References
1960s	• The Philippines is one of the pioneers in shrimp farming; • An extensive method of production is introduced; • Shrimp farming is dependent on fries collected from the wild; • Annual production is far below 5000 mt.	[17,24]
1970s	• The first culture systems are extensive; • *Penaeus monodon* become popular in Japan; • Export of first trial shipment to Japan.	[17,24]
1980s	• Southeast Asian Fisheries Development Center (SEAFDEC) and the Aquaculture Department (AQD) promote breakthroughs on hatchery production; • Shrimp farming becomes a significant industry; • Semi-intensive and intensive farming is introduced; • Large-scale shrimp production is established; • Japanese market absorbs 80% of shrimp produced in Asia; • First trial of polyculture with milkfish and shrimp.	[17,26,27]
1990s	• Japanese market collapses; • Rapid increase in production due to expansion of pond areas; • Government support and financing is no longer a problem; • The "boom and bust" period; • Industry peak production and decline due to disease outbreak; • Shrimp production continues to decrease;	[17,23,24,28]
2000s	• Verification runs on environmentally friendly shrimp culture conducted by the SEAFDEC and the AQD; • The SEAFDEC and the AQD start to respond to the requests of the private sectors for on-farm techno-transfer demos; • Shrimp production increases from 34,627 mt in 1999 to 42,390 mt in 2001; • First investigations on biocontrol of shrimp diseases;	[17,29]
2010s	• Current production hits 60,000 mt in 2019; • Exports of shrimp to South Korea, Japan, and the United States; • The inadequate supply of shrimp fries is still an issue; • Sustainable production using IMTA (Integrated Multi-Trophic Aquaculture), polyculture, and greenwater technology is tested.	[15,21,22,30]

In this study, we used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), which is a published approach that helps to facilitate a processoriented flow for researchers to broadly evaluate and review resources [31], and which has been utilized by researchers [32–34]. The PRISMA approach requires four stages: (1) Identification; (2) Screening; (3) An eligibility assessment; and (4) Inclusion. This paper reviews the possible environmental and socioeconomic impacts, challenges, and disease outbreaks that have affected the Philippines' shrimp industry over the years, and it examines the gaps and the possible strategies that are required in order to revitalize the industry for future resilience.

2. Materials and Methods

This paper applies the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to review the interaction between shrimp farming and the natural environment, to assess the impacts of shrimp farming, and to suggest solutions for the gaps that the government may need to fill in. The systematic review was carried out using the scheme presented in Figure 1. The literature search encompassed the period from 1990 to 2021. The inclusion criteria were based on ISI/Scopus publications in the WoS (Web of Science) and Scopus databases. The records were first identified through data searching, which was followed by the removal of duplicates. Next, screening and data extraction were performed, which meant removing the articles that did not meet the eligibility criteria. The eligibility criteria required evaluating the remaining articles if they were related to the subject of interest by browsing their abstracts or contents. The last step was the selection of the studies to be included in the review on the basis of the articles that passed the eligibility assessment [32]. The search for the papers to be included in this review made use of key terms, such as ″shrimp farming in the Philippines", "environmental and socioeconomic impacts", "climate change impacts on shrimp fisheries", "viral diseases on shrimps", and it also included published papers by authors on the Philippines' shrimp fisheries.

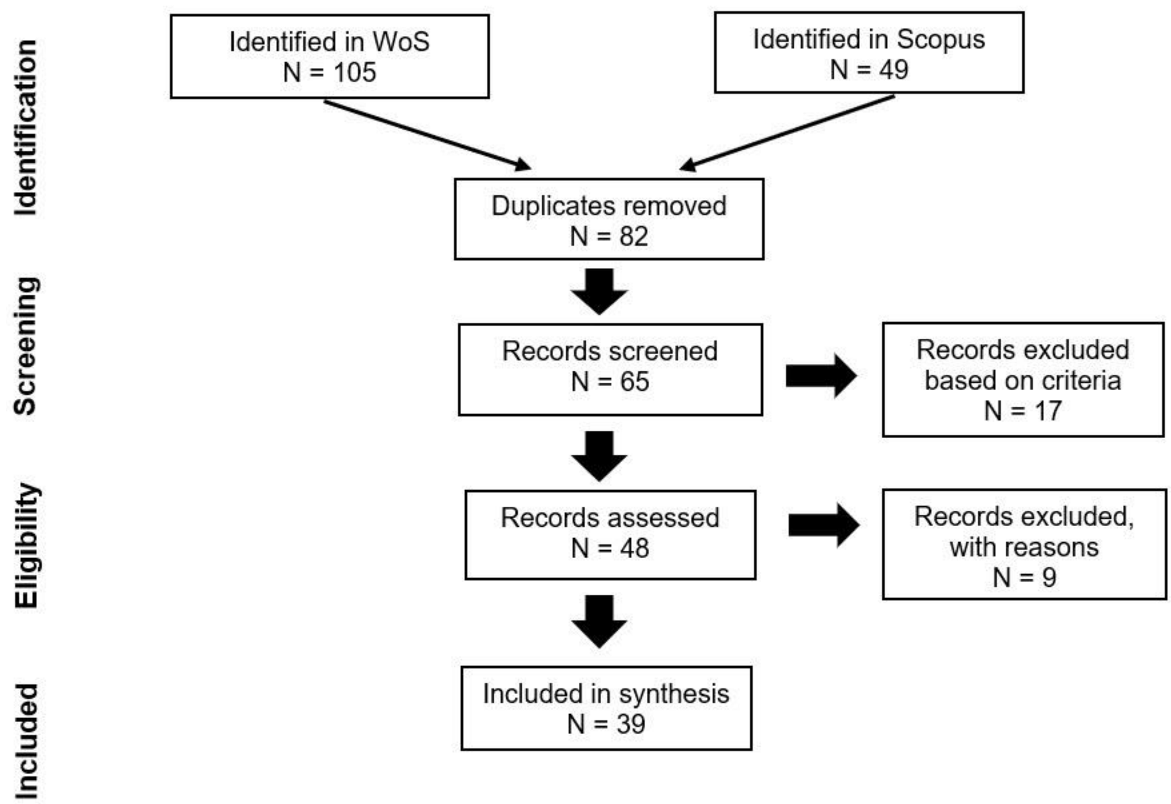

Figure 1. Flow of information through the different phases of a systematic review (adapted from Moher et al. [31]).

All of the papers that were included were then identified from the Web of Science (WoS) and Scopus databases from the literature that was downloaded. These two databases were chosen because of the comprehensiveness and quality of the publications that they host and curate. This means that we especially excluded reports coming from agencies such as the DENR (the Department of Environment and Natural Resources), the DA (the Department of Agriculture), the BFAR (the Bureau of Fisheries and Aquatic Resources), and the SEAFDEC (the Southeast Asian Fisheries Development Center) that were unpublished, and that were not found in the two databases. We still think that this did not have an impact on the generated insights provided by this method. For this investigation, we limited our coverage to studies on Philippine shrimp aquaculture from 1990 to 2021, and we considered only full-text journal articles in English, mainly because there have been almost three decades since the time that shrimp production hit its highest peak and then declined, and it continues to keep pace with what is considered to be environmentally acceptable and sustainable culture practices.

A VOSviewer bibliometric analysis [35] was then conducted to visualize the co-occurrences of the authors' keywords and indexes, and to analyze the textual data (titles and abstracts). A co-occurrence analysis allows one to identify the most frequently used and most highly networked terms. The qualitative thematic analysis of the selected literature (n = 39) followed a synthesis approach that utilized narratives and summaries [36,37].

3. Results and Discussion

Figures 2 and 3 below show the co-occurrence map that is based on the keywords and the text data from the various study abstracts and titles from 1990 to 2021. A total of 120 authors and index keywords were identified, and a filtering of the keywords was carried out in order to visualize the most relevant ones. Table 2 presents the occurrence classification by the author and index keywords. The keyword, "shrimp culture", takes the first position in terms of the total link strength and occurrences, and it is followed by "Philippines", "decapoda", "shrimp farming", and "aquaculture". The cluster analysis of the author/index keywords shows that the most commonly used keywords (Figure 2) are divided into three clusters: Cluster 1 (in red color) includes "aquaculture", "socioeconomic effects", "ecological effects", "pollution", "*Penaeus monodon*", and "mangroves"; Cluster 2 (in green color) includes "fishery production", "Philippines", and "decapoda"; and Cluster 3 (in blue color) includes "shrimp farming/culture" and "economics".

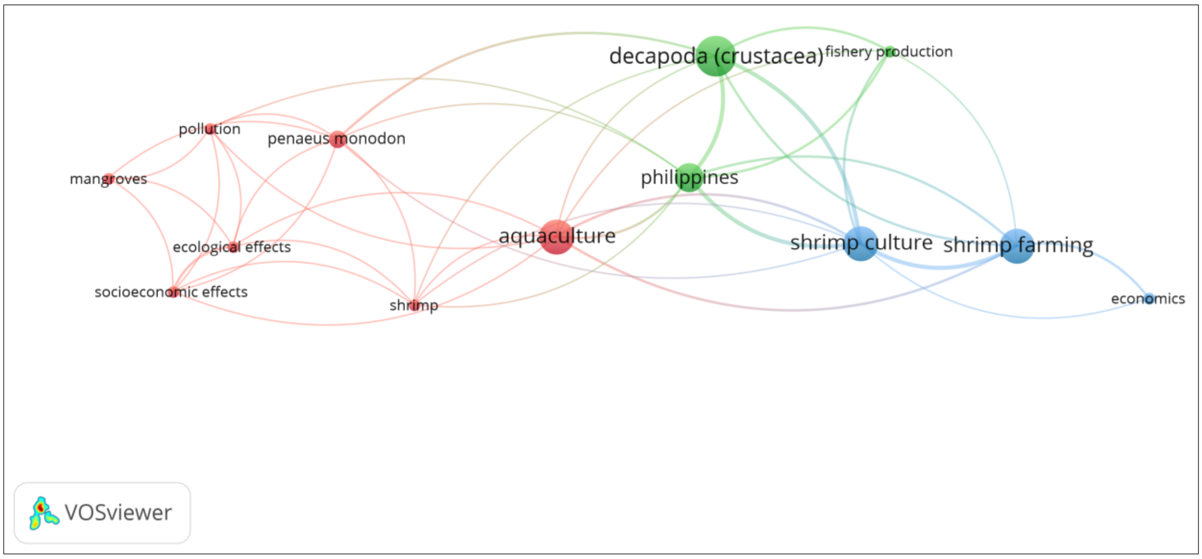

Figure 2. Co-occurrence map based on keywords.

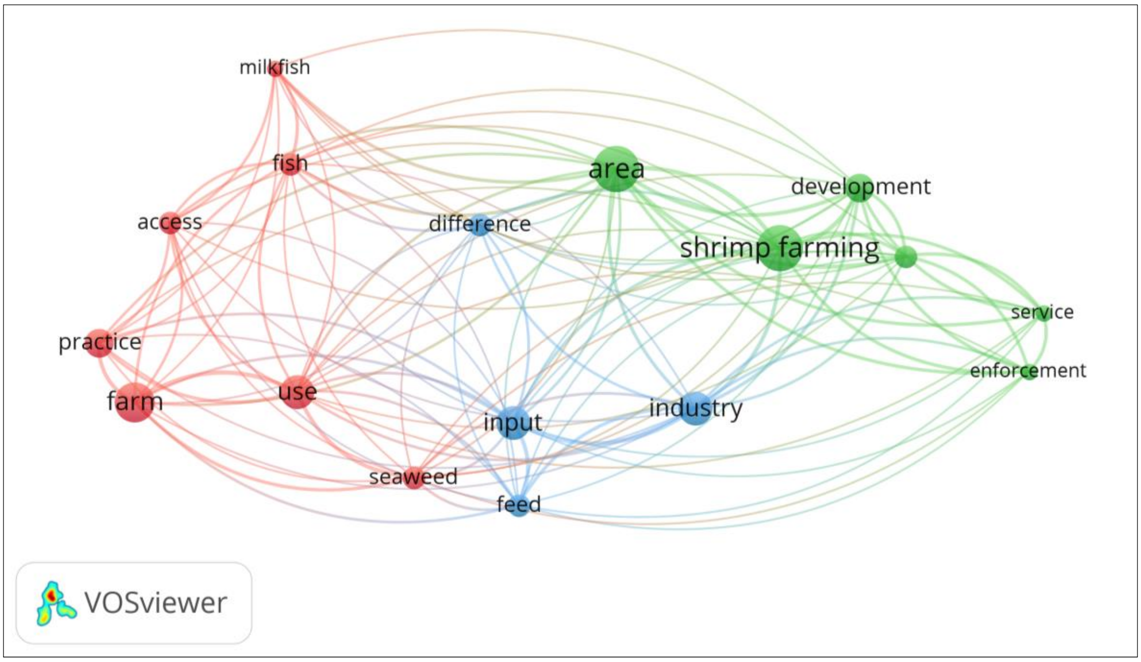

Figure 3. Co-occurrence map based on text data.

Table 2. Occurrence classification by author/index keywords.

Keywords	Occurrences	Links	Total Link Strength
Cluster 1			
Aquaculture	6	9	12
Ecological effects	2	6	7
Mangroves	2	4	4
Penaeus monodon	3	8	9
Pollution	2	6	6
Shrimp	2	7	7
Socioeconomic effects	2	6	7
Cluster 2			
Decapoda (crustacean)	7	7	16
Fishery production	2	5	8
Philippines	5	8	17
Cluster 3			
Economics	2	2	3
Shrimp culture	6	8	19
Shrimp farming	6	6	13

Source: the authors' own elaboration.

The most common words from the text data (Figure 3) were also categorized into three clusters: Cluster 1 (in red color) includes "farm", "practice", "use", "access", "seaweed", "fish", and "milkfish"; Cluster Two (in green color) includes "shrimp farming", "development", "area", "service", "enforcement"; and Cluster Three (in blue color) includes "input", "industry", "difference", and "feed". The terms in the larger circles (i.e., "aquaculture", "Philippines", "decapoda") indicate a higher number of publications in which these occur together. The clusters in the same colors suggest a similar topic among the publications. Table 3 presents the classification by occurrence of the most commonly used terms from the abstract. In terms of the number of occurrences, "shrimp farming" and "area' take the first position, while "area" has the highest link strength, followed by "shrimp farming".

Table 3. Occurrence classifications of texts from abstracts.

Abstract	Occurrences	Links	Total Link Strength
Cluster 1			
Access	4	12	18
Farm	7	11	25
Fish	4	14	22
Milkfish	3	10	15
Practice	5	11	19
Seaweed	4	15	23
Use	6	16	31
Cluster 2			
Area	8	16	41
Development	5	14	29
Enforcement	3	10	21
Mangrove	4	13	25
Service	3	10	21
Shrimp farming	8	15	35
Cluster 3			
Difference	4	12	16
Feed	4	15	23
Industry	6	15	23
Input	6	15	29

Source: the authors' own elaborations.

Moreover, Figures 4 and 5 present an overlay visualization of the frequently used terms from 1990 to 2021, thereby showing the recent study trends on shrimp farming in the Philippines. The studies in recent years have focused on pollution, access, and practices.

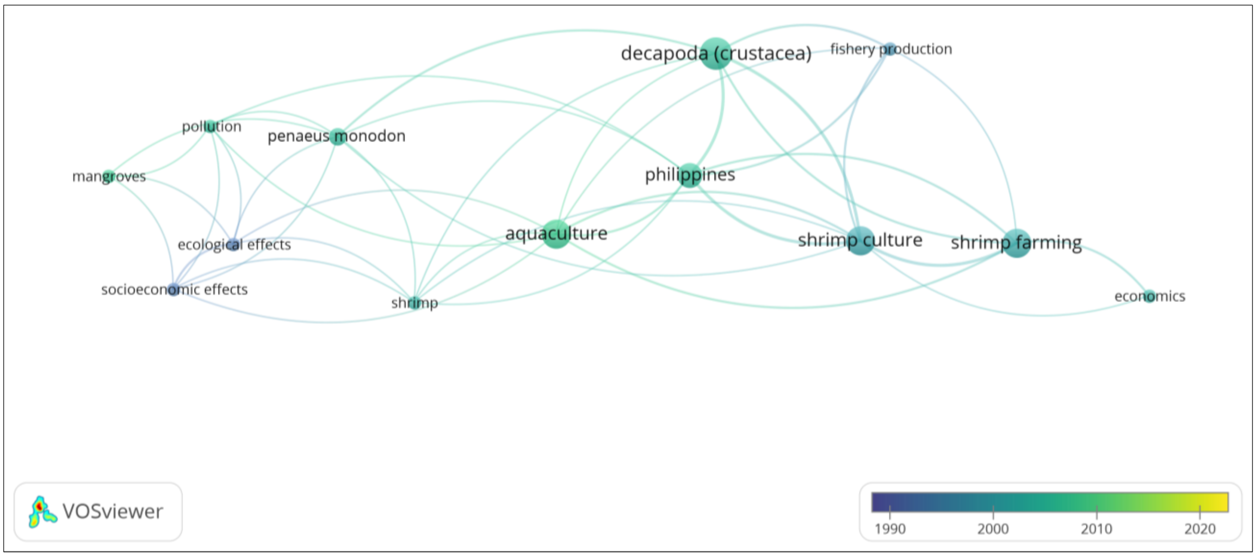

Figure 4. Overlay visualization of most frequently used terms in Philippines from 1990–2021.

Table 4 presents the studies conducted in the years 2007 (18%) and 2011 (10%), which reflect the predominant publications that came out during that time, with studies conducted in the fisheries and aquaculture sectors that are specifically related to the environmental impacts and the socioeconomic factors.

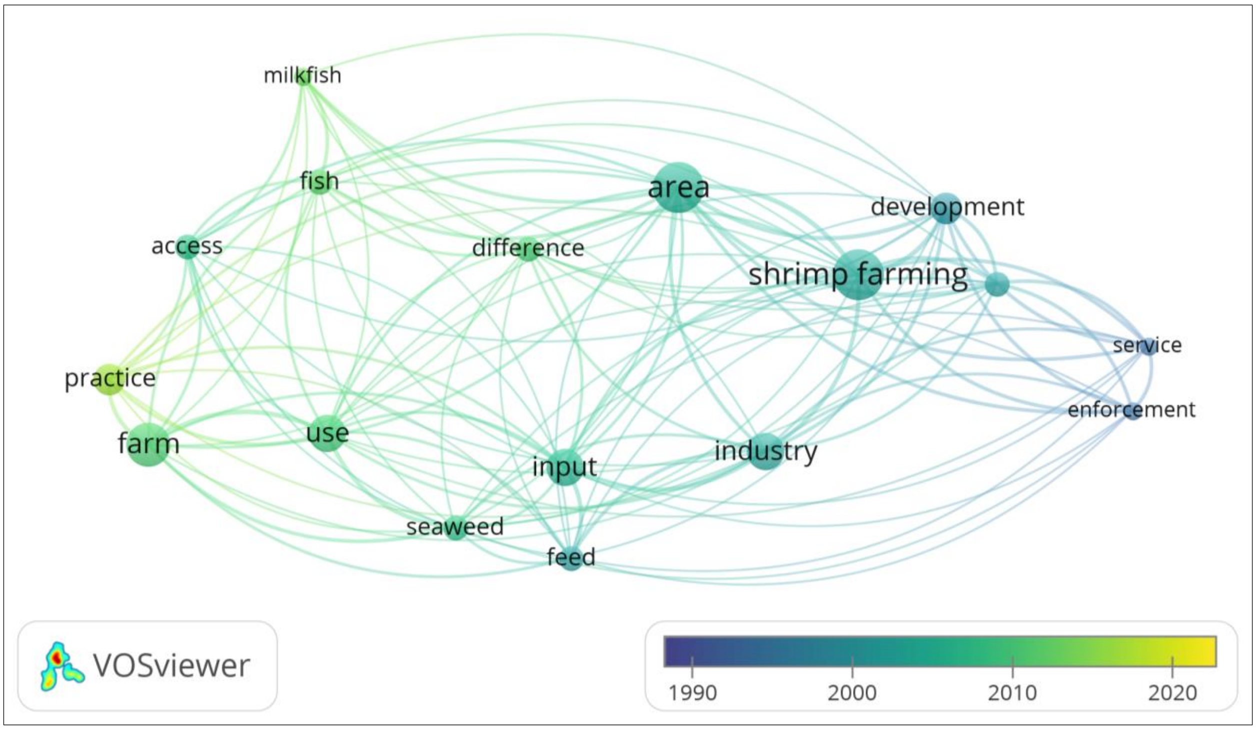

Figure 5. Common study areas in recent years in the Philippines regarding shrimp farming.

Table 4. Literature profiles by year of publication.

Year	No. of Studies	%	Journal Name
1993	1	2.56	
1995	2	5.13	
1997	2	5.13	
1998	2	5.13	
1999	1	2.56	*Philippine Journal of Science*
2000	1	2.56	*Philippine Agricultural Scientist*
2001	2	5.13	*Fisheries Science*
2002	1	2.56	*Estuarine Coastal and Shelf Science*
2003	2	5.13	*Journal of General and Applied*
2004	1	2.56	*Microbiology*
2005	1	2.56	*Aquaculture Research*
2006	1	2.56	*Journal of Social, Political, And*
2007	7	17.95	*Economic Studies*
2008	2	5.13	*Diseases of Aquatic Organisms*
2009	1	2.56	*Bulletin of Marine Science*
2011	4	10.26	*Environmental Management*
2012	1	2.56	*Fish Pathology*
2014	1	2.56	*Hydrobiologia*
2015	1	2.56	*Journal of General and Applied*
2017	1	2.56	*Microbiology*
2018	1	2.56	
2020	1	2.56	
2021	2	5.13	
Total	**39**	**100.00**	

The papers that were reviewed using the method of identifying, analyzing, and reporting the patterns (themes) within the data were categorized into five broad categories on the basis of their keywords, titles, and frequently used terms: farm management (12 studies, or 31%); diseases (9 studies, or 23%); marine pollution (8 studies, or 21%); socioeconomic impacts (8 studies, or 21%); and climate change (2 studies, or 5%), as is shown in Table 5. These broad categorizations also conform to the earlier clustering of the keywords and the text data that were mainly related to marine pollution or the ecological impacts, the socioeconomic impacts, shrimp farming and practices, development and inputs, and fishery production.

Table 5. Literature categorized according to the keywords.

Themes	No. of Studies	%
Farm management	12	30.77
Disease	9	23.08
Marine pollution	8	20.51
Socioeconomic impacts	8	20.51
Climate change	2	5.13
Total	**39**	**100.00**

It has been pointed out in several studies that an impact assessment is essential in order to identify better management practices, and to reduce the impacts of diseases and marine pollution in the industry [38]. Moreover, the major issues in shrimp farming include the loss of the important ecological and socioeconomic functions of mangrove ecosystems [23,39], and the impacts of climate change on the fisheries sector, which lead to possible economic effects in the long term [40,41]. These themes are discussed in the following sections.

3.1. Farm Management

Awareness about the need to reduce the impacts of shrimp farming has been a global issue. Farm and health management practices that focus on disease prevention rather than treatment, the maintenance of hygiene and biosecurity measures, and the responsible and effective use of chemicals could be the keys to the sustainability of aquaculture [42].

3.2. Disease

On the basis of the studies that we reviewed, the presence of viral diseases, such as White Spot Syndrome Virus (WSSV), Monodon Baculovirus (MBV), Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV), Hepatopancreatic Parvovirus (HPV), and Yellow Head Virus (YHV), has been identified in several provinces in the Philippines (Table 6). They have now occurred in Pampanga, Bataan, Batangas, Bulacan, Camarines Norte, and in Mindoro Oriental and Palawan in Luzon; in Capiz, Bohol, and Negros Oriental in Visayas; and in General Santos and Sarangani Province in Mindanao [43,44]. In the 1980s, the intensive monoculture of *Penaeus monodon*, which is commonly known as "black tiger shrimp", was introduced and gained wide acceptance in the Philippines. Later, this shrimp species was affected by infectious diseases, which caused its aquaculture and economic decline. In the Philippines, intensive shrimp farmers have reduced their culture runs because of viral and bacterial disease outbreaks [43,44]. The diseases of penaeid shrimps may be caused by living agents, such as bacteria, fungi, parasites, and viruses, and nonliving factors, such as nutritional deficiencies, toxic substances, and environmental problems. *Penaeus monodon*, *Penaeus merguiensis*, and *Penaeus indicus* were the major species that are cultivated in the Philippines that were affected by diseases [45]. Diseases are the topmost issues and challenges in shrimp aquaculture worldwide [9,18]. According to Andrino-Felarca et al. (2015), the major viral pathogens that affect the Philippines' shrimp industry include White Spot Syndrome Virus (WSSV), Monodon Baculovirus (MBV), Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV), Hepatopancreatic Parvovirus (HPV), Yellow Head Virus (YHV), and Taura Syndrome Virus (TSV). The principal hosts for TSV are *Penaeus vannamei* and *Penaeus stylirostris.* However, the outbreak of virus diseases, such as the White Spot Syndrome Virus (WSSV) in the early 1990s, resulted in a significant decline in shrimp production in Asia [18,45]. Upon further investigation, WSSV was found to have originated from Chinese hatcheries, where infected hatchery-produced *Penaeus japonicus* was imported to Japan in 1993 [19,46], and was later spread to other countries, such as the

Philippines [47]. There were also other widespread diseases, such as vibriosis and luminous bacterial (Lumbac) infections. They had the same impact as WSSV, which contributed to significant economic losses among shrimp growers [17,48]. Because of the WSSV pandemic, the Philippine government decided to ban the importation of live shrimp, except for scientific or educational purposes following the attainment of the required permission. This was to prevent the spread of the diseases [17,46]. Technically, *P. vannamei* was first introduced in the Philippines in 1978, but the production was unsuccessful. Since there was a prohibition on importing live shrimp, the private sector illegally imported *P. vannamei* from Taiwan in 1997, which was labeled as "milkfish fry". Later, in 2001, because of this incidence, the government also prohibited the culture of this shrimp species with corresponding penalties [17,48]. Despite this early setback in the culture of *P. vannamei* in the Philippines, by 2006, the Philippines had become one of the main producer countries of *P. vannamei* in the FAO's fishery statistics in 2006. The illegal shipments of the shrimp remain uncontrolled, and the possibility of the contamination of TSV remains [49,50]. The viral disease appears to be more widespread during the dry season than during the wet season. The presence of TSV had also been detected in *P. monodon* adults. This disease has increased the social impacts associated with shrimp farming, which include poverty and landlessness, food insecurity, and impacts on the health and education of shrimp farmers and their families. One of the main issues in the recent expansion of shrimp culture is the social conflict with other resource users. This usually happens when coastal lands are leased or bought for the use of large multinational companies or export-led companies for cultivating various aquaculture species, such as milkfish or shrimp. Coastal communities are then displaced, and their markets and livelihoods are removed. In other cases, such as in the process of pond construction and maintenance, the former occupants of the cultivated area are given priority during the hiring of workers. Nonetheless, worldwide shrimp aquaculture production has been depressed by diseases, particularly those caused by luminous vibrio and/or viruses [18,45,51].

Table 6. Common diseases and their effects on the various life stages of shrimp.

Disease	Effects	Stage of Culture	References
White Spot Syndrome Virus (WSSV)	First described in Japan, where the initial outbreak occurred in *Penaeus japonicus* in 1993. Develops rapidly and reaches 100% mortality within 3–10 days. The white inclusion evidently represents the abnormal deposits of calcium salt.	All larval stages of *Penaeus monodon*	[51–55]
Hepatopancreatic Parvo Virus (HPV)	The hepatopancreases of affected shrimp cause abnormal metabolism and eventual death; mortalities may reach 50% within 4–8 weeks.	Juveniles and adults of *P. monodon* and *P. merguiensis*	[45]
Taura Syndrome Virus (TSV)	First recognized in shrimp farms in Ecuador in 1992 and caused catastrophic losses, with a very high cumulative mortality rate of the affected *P. vannamei;* includes reddening of the tail fan and visible necrosis in the cuticle.	Postlarvae and broodstock	[28,50,55]
Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV)	First reported in Hawaii in 1980. The presence of the virus can cause the death of the cell of the cuticle, the blood-forming tissues, and the connective tissues, which causes abnormal metabolism that leads to the mortalities of the shrimp.	All life stages of *P. monodon*	[45,48,56]
Shell Disease	Appearance of brownish-to-black erosion of the carapace, the abdominal segment, and the tail, gills, and appendages. The affected shrimp appendages show a cigarette-butt-like appearance.	All life stages of *P. monodon*, *P. merguiensis*, and *P. indicus*	[28,45]

Table 6. *Cont.*

Disease	Effects	Stage of Culture	References
Infectious Myonecrosis Virus (IMNV)	First reported in Hawaii in 1980. Viral occurrences affect the cell nucleus, from the subcuticular epithelium of the mouth appendage, to the gill, the thoracic ganglion, and the nerve fiber of the walking leg, but can also occur sparsely in the cytoplasm.	Postlarvae and broodstock	[21,28]
Filamentous Bacterial Disease	Larval shrimp are less prone to infestation than in the postlarval, juvenile, and adult stages because of the rapid succession of molts throughout the different larval stages, while infected eggs show thick mats of filaments on the surfaces that may affect the respiration or hatching.	All life stages of *P. monodon*, *P. merguiensis*, and *P. indicus*	[28,45]
Monodon Baculovirus (MBV)	The affected shrimp exhibit pale blue-gray to dark and dark blue-black colorations that cause sluggish and inactive swimming movements, loss of appetite, and retarded growth. The presence of the virus damages the organs, which weakens the shrimp and leads to gradual mortalities.	All life stages of *Penaeus monodon* and *P. merguinsis*	[28,57]
Luminous Vibriosis	One of the major diseases in grow-out cultured shrimps weakens the larvae and juveniles of the infected shrimp. The larvae become opaque-white, while the juveniles have discolored portions on the body. Systemic infection reaches to 100% of the affected population.	Postlarval stage and broodstock	[58]

3.3. Marine Pollution

More than 100 chemicals and biological products are used in aquaculture in the Philippines, from pond preparation to the culture period, and for disease prevention and control (Table 7) [42,58]. The practice of polyculture and extensive farming did not pose any major problems; however, when the farm methods shifted to semi-intensive and intensive systems, high stocking densities and formulated feeds were used. The culture intensification resulted in the production of shrimps that are susceptible to several infectious diseases, and, consequently, the use of chemical and biological products became mandatory to prevent and treat these diseases [45]. Water management became difficult as a result of the culture intensification, which led to uncontrolled feed wastes, and the release of effluents into the marine environment, which affected the diversity of the phytoplankton, the spawning grounds, and the nursery habitats, as well as of the seagrass and mangrove ecosystems [19]. The use of feeds and the continued release of effluents into nearby waters cause water quality deterioration in the ponds, and by receiving water overtime as the total nitrogen (N) and phosphorus (P), nitrite, silicate, orthophosphate, dissolved oxygen, and biological oxygen demands increase, the water visibility also decreases in intensive culture, which often leads to cases of massive fish kills and economic losses in the industry [59–62]. This is mainly because of high nutrient deposits in the sediment and the water column from fish feed wastes, which can trigger algal blooms that affect shellfishes, and that may pose a threat to mariculture activities, such as the farming of milkfish (*Chanos chanos*) and tilapia (*Oreochromis niloticus*) [61,62]. For instance, various factors have been implicated in the occurrence of fish kills in Taal Lake, which is a known aquaculture site, and most fish cage operators and fish farmers attribute these to environmental and anthropogenic causes, which arise from milkfish and tilapia aquaculture effluents [61]. Vista et al. (2006) attribute this water quality deterioration to high stocking densities and feed inputs from the fish farmers [62]. In addition, Primavera and co-workers suggest that chemical effluents in shrimp farming are a concern, as well as their possible impacts on the environment and on human health, and that they will continue to be a subject for future debates because of insufficient knowledge regarding waste management [19,39,63,64]. The negative impacts of marine pollution on capture fisheries and aquaculture are becoming more apparent. Even the municipal fishery subsector, which has traditionally been the main source of fish for domestic consumption, has been declining steadily over the past several years [65,66]. Because most ponds used for shrimp culture are located in brackish water, with mangroves converted for their use, mangrove forests have declined to only 120,000 ha, while fish/shrimp culture ponds have increased to 232,000 ha [63,64]. The ecological services lost because of this mangrove conversion include the shoreline protection from tsunamis and the impacts of typhoons, and it leads to the impairment of the function of the mangrove forests, which act as carbon sinks, and to the destruction of the nursery and spawning grounds of fish, shellfish, and other aquatic life [64,67]. Along with mangrove decline is the ecosystem's susceptibility to climate change, particularly in terms of the rising sea levels, which can lead to higher risks of flooding, tsunamis, cyclones, and storm surges [68]. Fortunately, over the last few years, aquacultural activity in the Philippines has been largely directed towards the production of milkfish, tilapia, seaweeds, and mudcrabs, and it has not reverted back to an aggressive shrimp culture, particularly for the giant tiger prawn, *Penaeus monodon*. *P. vannamei* is currently the culture of choice among shrimp farmers, despite the challenges that affect shrimp farming.

Table 7. Environmental impacts of shrimp aquaculture.

Environmental Inputs	Chemical Used	Use/Effect
Pesticide	Saponin (teaseed powder)	Use during pond preparation (broadcast) and rearing phase (periodic); disease control for 30–60 days.
	Copper compounds	Use during pond preparation (spray) and rearing phase (until phytoplankton bloom).
	Potassium Permanganate	Use during pond preparation (spray).
Antibiotics	Tetracycline	Every other day from stocking to harvest.
	Rifampicin	Disease control daily or until it disappears.
	Chloramphenicol	Every other day from stocking to harvest; disease control daily or until it disappears.
	Nitrofuran	Every other day from Z_1 to harvest; disease control for 3 d (long bath).
	Erythromycin	Disease control for 3 d (long bath).
Feeds (Inorganic Fertilizer)	16-20-0 (monoammonium phosphate)	Use during pond preparation (broadcast) and rearing phase (periodic, broadcast).
	18-46-0 (diammonium phosphate)	Use during pond preparation (broadcast).
	14-14-14 (NPK, complete fertilizer)	Rearing phase (periodic, broadcast).
	46-0-0 (urea)	Pond preparation, rearing phase.
	21-0-0 (ammonium sulfate)	Pond preparation, rearing phase.
	0-20-0 (solophos)	Pond preparation, rearing phase.
Organic Fertilizer	Chicken manure	Use during pond preparation, rearing phase (tea bags).
	Cow manure	Pond preparation, rearing phase (tea bags).
	Carabao manure	Pond preparation, rearing phase (tea bags).
	VIMACA (chicken/pig manure)	Pond preparation (tea bags).
	B-4	Pond preparation (substitute for manure).
Other Chemicals (Soil and Water Treatment)	Lime	pH control in pond preparation (3–7 days; 20 cm–1.3 m).
	Dolomite	Pond preparation.
	Zeolite	Water quality control, disease control.
	Benzalkonium chloride	Water disinfectant.
	Oxytetracycline	Control of bacterial diseases.
	Teaseed cake	Predator control.

Source: Cruz-Lacierda et al. [42].

3.4. Socioeconomic Impacts

There are several studies that report that aquaculture has been the cause of several problems, with economic and social impacts [23]. Aquaculture importation has been a worldwide practice, and *Penaeus vannamei* has been imported for more than five decades, which already raises some concern, as this adds to the cost of cultivation [69]. In addition, since 70% of most Filipinos live in coastal areas, their livelihoods are dependent on fishing, aquaculture, and the other auxiliary industries related to the fisheries, with 1.6 million of them being highly dependent on aquaculture for their livelihoods and protein requirements [15,70,71]. The marketing of seafood products in the Philippines is usually channeled to fish brokers, with profit-making taking place among the wholesalers, retailers, and brokers in the fisheries [72,73]. This causes the higher market prices for aquatic products, which puts them outside of the range of poor urban consumers [73,74]. Black tiger prawn (*Penaeus monodon*) and Pacific whiteleg shrimp (*Penaeus vannamei*) are highly traded species in the Philippines. Black tiger shrimp leads with the highest production ranges, with 45,000–50,000 mt of annual production from 2008 to 2019, and is followed by the Pacific white shrimp, with a production of nearly 2000 mt in 2008, which gradually increased to 19,000 mt in 2019. These species contributed around USD 120 million to the Philippines' export earnings in 2014, which is much higher than in 2013, when it was USD 67.5 million [21]. While there is no arguing with the increase in their production, problems arise because of the socioeconomic impacts. However, the studies are limited to food security, equity, and development. More commonly, it has been stated that aquaculture, which also applies to fish farming, has been responsible for the marginalization of coastal communities and the increased unemployment [23]. In contrast to this view, shrimp industry players, operators, feed companies, and other stakeholders and politicians that support the industry perceive that economic growth, especially in terms of the livelihood opportunities, is created through the shrimp industry, even in remote areas of the country [71,74,75]. The industry has been growing by 2.4%, and it has produced an average of 65,000 mt in the past 20 years. Shrimp farming activities contribute significantly to both the local and national economies of the Philippines, and shrimp continues to be an export commodity to Japan, the United States, and South Korea, with high demand and prices, even in local and national markets [15]. Its production offers livelihood opportunities, even to rural women, and it has other value-adding activities, which provide employment and poverty alleviation for the country [76]. The role of women is very important and strategic, as they are considered to be the key determinants for the food security and nutritional statuses of their households [77–79]. Moreover, empowered women help to improve the nutritional statuses of their children [79]. Clearly, a balance is needed, where both the location of large-scale shrimp farms, even those of small-holder farmers, must not necessarily displace the existing artisanal fishers, gleaners, fry collectors, tourists, and other stakeholders that also utilize the mangrove and water resources of the area. Even if there are trade-offs, both livelihoods and environmental concerns (water pollution, the depletion of fry in the wild, the spread of diseases, the biodiversity impacts, aquatic invasions) should both be addressed, as they go together in aquaculture [19,38,39,80,81].

3.5. Climate Change

The Philippines ranks second in terms of its global climate risk because of its vulnerability to climate change impacts [82,83], which are projected to be the key reason for the decline of the fisheries, with huge economic costs [40]. Climate change affects the targeted population range and the productivity, habitats, and costs of fisheries and aquaculture [84]. The changes in the climatic variables facilitate the increased frequencies of typhoons and the spread of disease, which cause physical damage to the farm's pond structure and the deterioration of the water quality, as well as the spread of disease and infection in shrimp ponds [83,85]. Issues and problems have arisen, and the decrease in wild-caught shrimp fry, the lack of hatcheries in strategic locations to supply shrimp farmers, and the increasing price of feeds are the major concerns [83]. Few studies have analyzed the economic impacts of climate change on aquaculture and fisheries with regard to the national economy. The Philippines is projected to decrease the GDP of its fisheries by 9% with the climate change mitigation scenario, and to decrease it by 18% with the extreme scenario without mitigation [40]. As the aquaculture industry grapples with the impacts of climate change, and particularly with heavy rains, cold months, and extreme events, which inevitably impact the growth, survival, and performance of the cultured species, which lowers their productivity, and with the possibility of higher disease transmission because of water quality deterioration, this has economic costs. The government should adopt further adaptation measures in order to prevent the catastrophic impacts of climate change and the variabilities within the aquaculture sector [86]. This may include: the climate proofing of postharvest facilities; increasing the number of aquaculture hatcheries to avoid insufficient supplies; the enforcement of regulations in terms of the number of cages, pens, cultured ponds; the regulation of the stocking density and proper land-use planning; the observance of aquaculture practices; and the proper coordination between local governments and the Bureau of Fisheries and Aquatic Resources (BFAR) for licensing and for the registration of fish cages, ponds, and operators, as well as with the Department of Environment and Natural Resources (DENR) for regular water quality monitoring [32,33,87].

4. Conclusions and Recommendation

The intensification of shrimp farms in the past has led to the loss of mangrove areas, affected the water quality, biodiversity, and habitat, and has encouraged the proliferation of pathogens, to the detriment of all shrimp farmers, operators, and other stakeholders. The social ramifications include the displacement of subsistence fishers, gleaners, and fry collectors, as well as their markets, as mangrove fishing areas are converted for fishponds and other aquaculture uses. This has generated a suite of environmental and economic problems for the aquaculture sector in the Philippines, as well as socioeconomic benefits. These mainly include: damage to the mangrove forest and the loss of biodiversity; increased soil salinity, with a serious loss of soil fertility; algal blooms; damage to coastlines because of water quality deterioration, which affects their traditional uses for swimming and recreation, as well as for tourism purposes; the displacement of subsistence fishers and gleaners, as well as mangrove wood collectors; problems of land ownership and the illegal occupation of protected landscapes and seascapes; the loss of ecosystem services because of the effluent impacts on the phytoplankton diversity and the fish diversity; the destruction of seagrass and the mangrove carbon sink; as well as aquatic invasions, antibiotic resistance, and disease problems [19,64,81–86]. On the other hand, the positive impacts of shrimp aquaculture include: the local employment of workers on the small-holder farms and on largescale commercial farms; higher incomes for workers and operators, which improves their economic conditions; foreign direct investments in hatcheries, farms, and postharvest facilities, as well as in feed mills; the involvement of women in the fish farms, which provides higher incomes; value-adding activities; improvements in marketing; business diversification activities due to the profit from shrimp farms (e.g., lands, farms, and vans were acquired as a result of the profits); and better educational and economic opportunities for the children of shrimp farmers [77,81,87–89]. The findings of this review show both the negative and positive impacts of shrimp farming. In order to address the current challenges of shrimp farming in the Philippines, the Bureau of Fisheries and Aquatic Resources (BFAR) have provided a blueprint for the strategies that will improve the sustainability of shrimp farming in the Philippines. These strategies are for the purposes of: securing a pathogen and disease-free fry/seed supply; investing in propagation facilities (e.g., broodstocks, hatcheries, nurseries and laboratories); institutionalizing good aquaculture practices and promoting sustainable aquaculture; assuring quality and traceable aquaculture inputs and outputs; optimizing the operation of mariculture parks; and ensuring a climate-/disaster-proof aquaculture sector [85,89]. Good aquaculture practices are now required for food safety and for the traceability for responsible seafood sourcing [89–91].

Thus, on the basis of the above discussions and summary, in terms of the lessons learnt from the environmental and socioeconomic impacts of shrimp farming, the following recommendations can be made about shrimp culture:

1. Considering the economic potential to uplift various households from poverty, clearly planned coastal zone use and buffer areas should be delineated, and shrimp pond operators should be educated and informed about land ownership and renting or

leasing from the local government and the Department of Environment and Natural Resources (DENR) in the cases that these culture sites are also located in protected areas;

2. Aquaculture operators, whether they are small-holders or large-scale operators, should be encouraged and taught how to organize themselves legally, and they should be registered so that they can avail themselves of technical help from the local government, as well as from the Bureau of Fisheries and Aquatic Resources (BFAR);
3. Continuous efforts should be extended by the government to organized fish farmers, especially in terms of disease monitoring and water quality monitoring, in order to prevent the spread of disease and eventual economic losses;
4. Access to information and educational awareness should be spread within the community organization, as well as to other small-holder farmers, for the uniform implementation of government policies related to shrimp culture, especially with regard to environmental and disease monitoring;
5. The development and investments for hatcheries, nurseries, and laboratories should be encouraged among private sector companies, apart from government-led initiatives;
6. Shrimp farming should not be allowed on land where it would pose a great threat to cultivated crops, tourism, or recreational areas; proper coastal zoning should be observed by all stakeholders; and unplanned no-consultation aquaculture areas should be discouraged;
7. Where there is competition for water resources, such as for crop cultivation and for aquaculture usage, priority is given to rice since it is a staple food. As much as possible, farmlands and shrimp cultivation areas should not be found in the same area because of the possible effluent discharges and seepage;
8. In the shrimp farm areas, the proper provision of a network of water supply and drainage canals should be instituted with the observation of better management practices. These should be properly or regularly monitored by the local government, as well as by the BFAR;
9. Feeding, fertilizer usage, and the chemicals used should be applied only at the recommended rates to avoid feed wastage and to prevent chemical contamination;
10. Food safety, traceability practices, and better farm management practices should be observed, with the corresponding sanctions and with regular monitoring;
11. Strong networks among research organizations, local governments, and universities and colleges, as well as NGOs, through forums and extension services, could improve knowledge, the prevention of diseases, and the adoption of sustainable practices by shrimp farmers, which will lead to better management practices.

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