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Main title: Environmental and Socioeconomic impacts of Shrimp Farming in the Philippines:

A critical analysis using PRISMA

Short title: Environmental and Socioeconomic impacts of Shrimp Farming

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ABSTRACT

Aquaculture production 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. Its intensification has led to negative and positive impacts, which raised a range of environmental and socioeconomic problems. This paper reviewed the environmental and socioeconomic challenges, shrimp culture industry using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method. We examined gaps and changes required to revitalize the industry. It considers and gives details on the impacts of shrimp culture on the environment e.g. shrimp farm management, marine pollution, disease outbreaks, climate change among others. 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 of 40,080 mt in 1997 to 51,000 mt in 2014 in the industry. Recommended strategies were considered to improve shrimp aquaculture, including disease management, adopting good aquaculture practices, proper environmental monitoring, sustainable practices at the farm level and priorities for future research.

Keywords: Aquaculture, environmental impacts, PRISMA, shrimp aquaculture, shrimp diseases, socioeconomic impacts

INTRODUCTION

Aquaculture serves the employment and food security needs of most Asian coastal countries, from Bangladesh, China, India, Indonesia, Philippines, Thailand and to Vietnam, are all aquaculture-reliant countries with large aquaculture sectors [3-7]. It is a major driver of socioeconomic development in poor rural and coastal communities, particularly in Asia, and is considered to relieve pressure and help maintain the sustainability of wild-caught species from rivers, lakes, and oceans as it provides for the shortfall of capture fisheries [8]. The rise of aquaculture has been one of the most profound changes in global food production over the past 100 years [9]. This industry has become a major source of food protein and is foreseen to support our seafood production as a sustainable alternative to wild-caught fisheries [5,10]. There is a prediction that the per-capita seafood consumption will continue to increase by 1.5 kg per year by 2025 [11]. Population growth and increased individual consumption indicate that farmed seafood products will be gradually more important as an additional food source, and aquaculture will play a vital role as natural fish stocks continue to decline [11,12].

Crustaceans contribute a significant portion of production and value among other aquatic species developed for aquaculture [13]. Penaeid shrimps are the most preferred crustaceans in aquaculture, as shown by its vast expansion of land area devoted to shrimp farming [14,15]. Globally, about 9.4 million metric tons (mt) of farmed crustaceans were produced in 2020. Of this, 5.7 million mt were *Penaeus vannamei* (Pacific white shrimp) and *Penaeus monodon* (black tiger shrimp) production [1]. In most recent years it was the world's most valuable aquaculture species, increasing from less than 75,000 mt in 1980 to over 5.7 million mt in 2020 [1]. In the Philippines, shrimp production remains a valuable export commodity with total production in 2019 at 66,252 mt, ranking fourth in value at U$ 42.36 million, exported in Japan, South Korea, and the USA [2].

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

In the Philippines, shrimp production was mainly located in Negros and Panay Islands in Western and Central Visayas. Recently, this has changed, and shrimp production has been growing and increasing in other areas, such as in Central Luzon, other parts of Central Visayas, SOCCSKSARGEN, and Davao regions [4,14,19,20]. Thus, *P. vannamei* production has spread in various parts of the country whether cultured alone or in combination with other finfish species [8,21]. There are new cultivation techniques applied and new cultivation areas that were previously non-existent, which means farmers were encouraged to adapt because of high economic returns [17,22]. Despite what happened to the *P. monodon* crises in the mid-and-late 1990s, shrimp farmers and investors have high hopes and expectations for better market demand 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] throughout northern Luzon to the southernmost part 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). Based on this, the year beyond 2000 showed the lack of a clear industry roadmap for reinvigorating the shrimp industry in the Philippines despite the availability of all relevant technologies to expand and to increase its existing capacity. While Republic Act 8550, otherwise known as the Philippine Fisheries Code of 1998, was enacted to law, it vaguely contained references on incentivizing the fisheries and the aquaculture industry. For instance, in section two (2) objective three (3), it states, the *"Improvement of productivity of aquaculture within ecological limits".* This law only states increasing the aquaculture production but does not specify how to protect the ecosystem for instance the mangrove ecosystem during forest clearing, pond construction and release of waste water 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 based on the best available scientific expertise. Even the more specific provisions such as in article three (3), section eight (8) of the same law which provides for incentives and disincentives of proper cultivation or culture of species, do not properly discuss the process to attain the proper method of culturing species at all stages such that it reduces possible environmental impacts. Further, in the implementing rules and regulation of RA 8550, the act of reforestation of bays, shores and dikes and building of structures to minimize water pollution by the fishpond lessee are all stated (rule 46.2), including good aquaculture practices (rule 47.1) that would be crafted by the Bureau of Fisheries and Aquatic Resources (BFAR) was also specified. Yet a cursory visit to fishpond farms (small-scale and commercial operators) actually lack these practices or 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 European countries that require adherence to food safety rules and protocols, the required compliance certificates for food safety and traceability become external motivating factors to access those premium markets for seafood products.

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is a published approach that helps in facilitating a process-oriented flow for the researchers to broadly evaluate and review resources [31] and had been utilized by researchers [32-34]. The PRISMA approach requires four stages: (1) identification; (2) screening; (3) eligibility assessment; and (4) inclusion. This paper reviews the possible environmental and socioeconomic impacts, challenges, and disease outbreaks that affected the Philippines shrimp industry over the years using the

PRISMA method, and examined gaps and possible solutions required to revitalize the industry for future resilience.

Table 1. Milestones of Shrimp Industry in the Philippines

Year	Milestone	References
1960s	• The Philippines was one of the pioneers in shrimp farming • Extensive method of production was introduced • Shrimp farming was fry dependent on the wild • Annual production is far below 5,000 mt	[17,24]
1970s	• The first culture systems were extensive and used of fry from tidal flow or hand collection • *Penaeus monodon* became popularized in Japan • Exported first trial shipment to Japan	[17,24]
1980s	• Southeast Asian Fisheries Development Center (SEAFDEC), Aquaculture Department (AQD) promoted breakthroughs on hatchery production • Shrimp farming became a significant industry • Semi-intensive and intensive farming was introduced • Establishment of large-scale shrimp production • Japanese market absorbed 80% produced in Asia • First trial of polyculture with milkfish and shrimp	[17,26,27]
1990s	• Japanese market collapsed • Start up or development period • Rapid increase in production due to increased number of pond areas • Rapid growth/attracted more investors • Government support and financing no longer a problem • The “boom and bust” period • Industry reach its peak of produce and suddenly declined due to outbreak of disease • Shrimp production continue to decrease	[17,23,24,28]
2000s	• Verification runs on shrimp culture conducted by SEAFDEC AQD using environment-friendly protocol under different climatic conditions • SEAFDEC AQD started to respond to the requests of private sectors for on-farm techno-transfer/demo	[17,29]

	• Philippines shrimp production gradually increased from 34,627 mt in 1999 to 42,390 mt in 2001 • First investigations on biocontrol of shrimp diseases	
2010s	• Current production hit 60,000 mt in 2019 • Exports of shrimp in South Korea, Japan and the USA • Shrimp fry sourcing from hatcheries are still an issue to small-holder fish farmers • Sustainable production using IMTA (Integrated Multi-Trophic Aquaculture), polyculture and greenwater technology have been tested	[2,21,22,30]

MATERIALS AND METHOD

This paper applied the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to review the interaction between shrimp farming and the natural environment, assess the impacts of shrimp farming, and suggest solutions for gaps that the government may need to fill-up. The systematic review was carried out using the scheme presented in Figure 1. The literature search encompassed the period between 1990 to 2021. Inclusion criteria were based on the ISI/SCOPUS publication in WOS (Web of Science) and SCOPUS databases. Records were first identified through data searching followed by the removal of duplicates. Next, screening and data extraction were performed, which means removing 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 its abstract or content. The last step was selecting studies included in the review based on articles that passed the eligibility assessment [32]. The search for papers to be included in this review includes key search terms such as ‘‘shrimp farming in the Philippines’’, ‘‘environmental and socioeconomic impacts’’, ‘‘climate change impacts on shrimp fisheries’’, ‘‘viral diseases on shrimps’’ and papers published by authors on the Philippines shrimp fisheries.

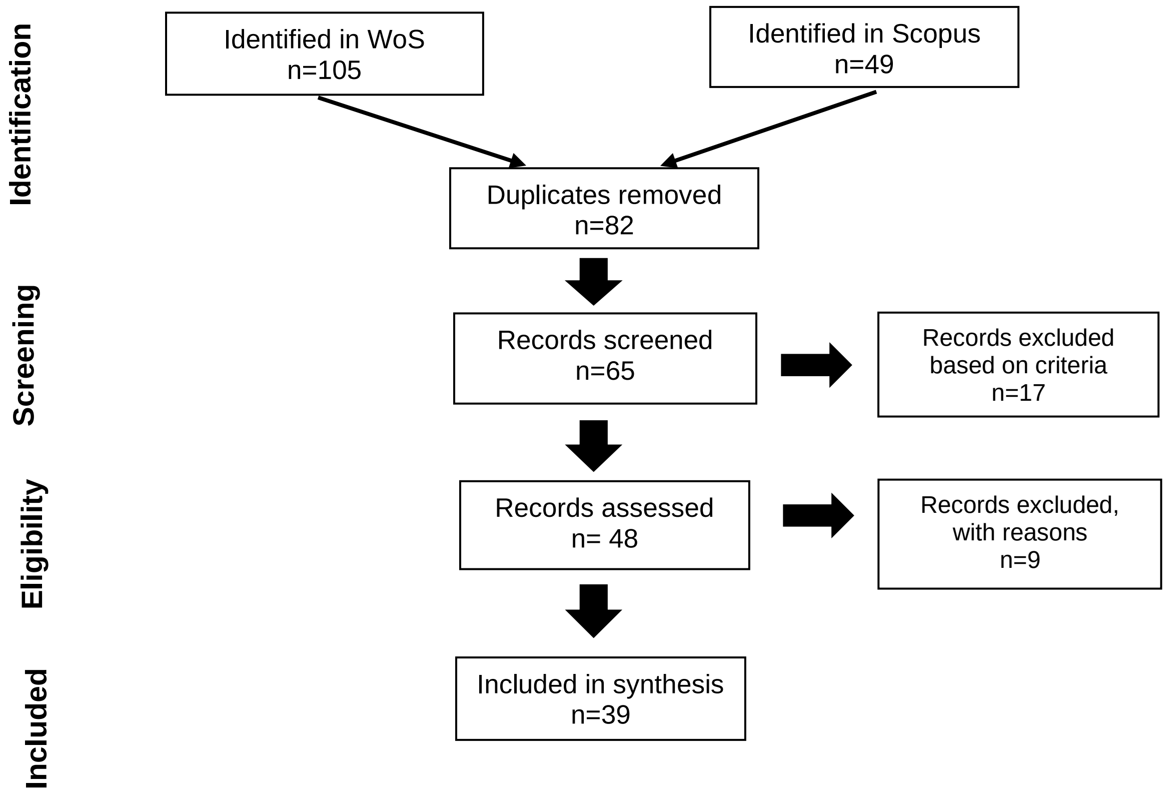

Figure 1. Flow of information through the different phases of a systematic review (adapted from Moher et al., 2009).

The papers included were identified from the Web of Science (WoS) and Scopus databases of the literature. These two databases were chosen because of their comprehensive and quality publications they host and curate. This means that we excluded reports especially those coming from agencies such as DENR (Department of Environment and Natural Resources), DA (Department of Agriculture), BFAR (Bureau of Fisheries and Aquatic Resources) and SEAFDEC (Southeast Asian Fisheries Development Center) that were unpublished and not found in the two databases. We still think that this will not have an impact to the generated insights provided by this method. For this investigation, we limited our coverage to studies on shrimp aquaculture from 1990 to 2021 and considered only full-text articles in English.

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RESULTS AND DISCUSSION

Found below are Figures 2 and 3 which showed the co-occurrence map based on keywords and text data from the various study abstracts and titles from 1990 to 2021. The most commonly-used keywords (Figure 2) are clustered into three: cluster one (in red color) were aquaculture, socioeconomic effects, ecological effects, pollution, *Penaeus monodon,* mangroves; cluster two (in green color) were fishery production, Philippines, and decapoda; and cluster three (in blue color) were shrimp farming/culture, and economics. The most common words from the text data (Figure 3) were also categorized into three clusters: cluster one (in red color) were farm, practice, use, access, seaweed, milkfish; cluster two (in green color) were shrimp farming, development, area, service, enforcement; and cluster three (in blue color) were input, industry, and feed. Terms in larger circles (i.e. aquaculture, Philippines, decapoda) indicate higher number of publications in which these occur together. Cluster in the same color suggests a similar topic among the publications

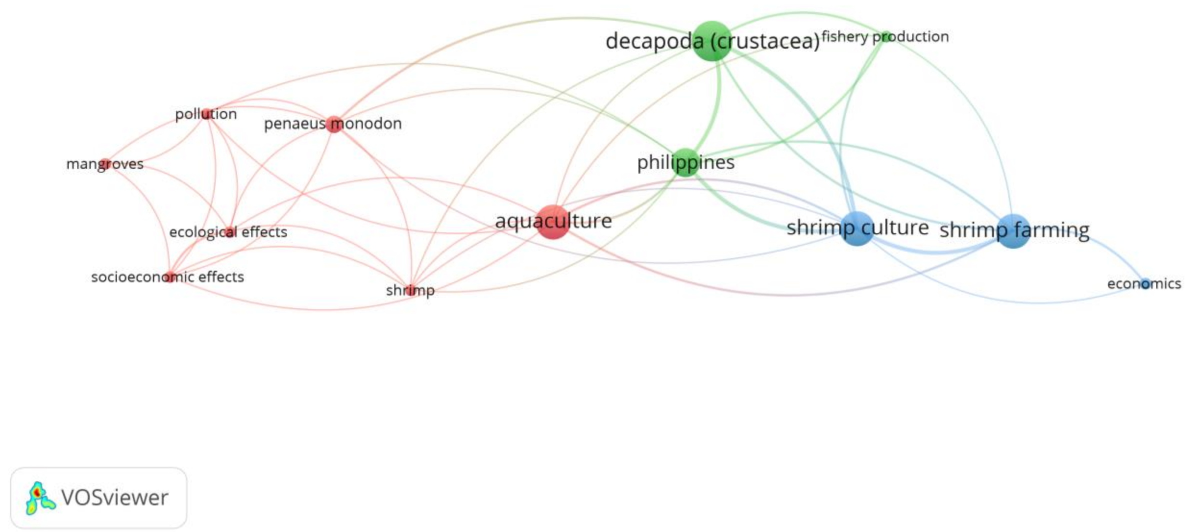

Figure 2. Co-occurrence map based on keywords

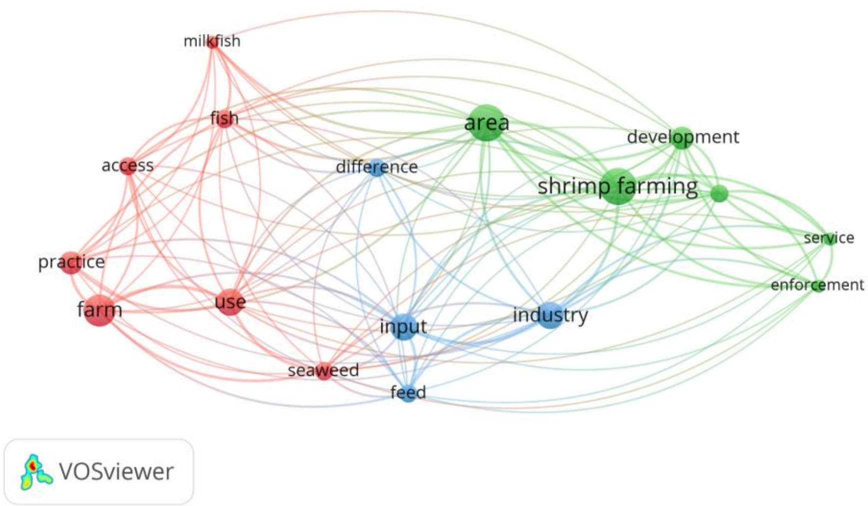

Figure 3. Co-occurrence map based on text data

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

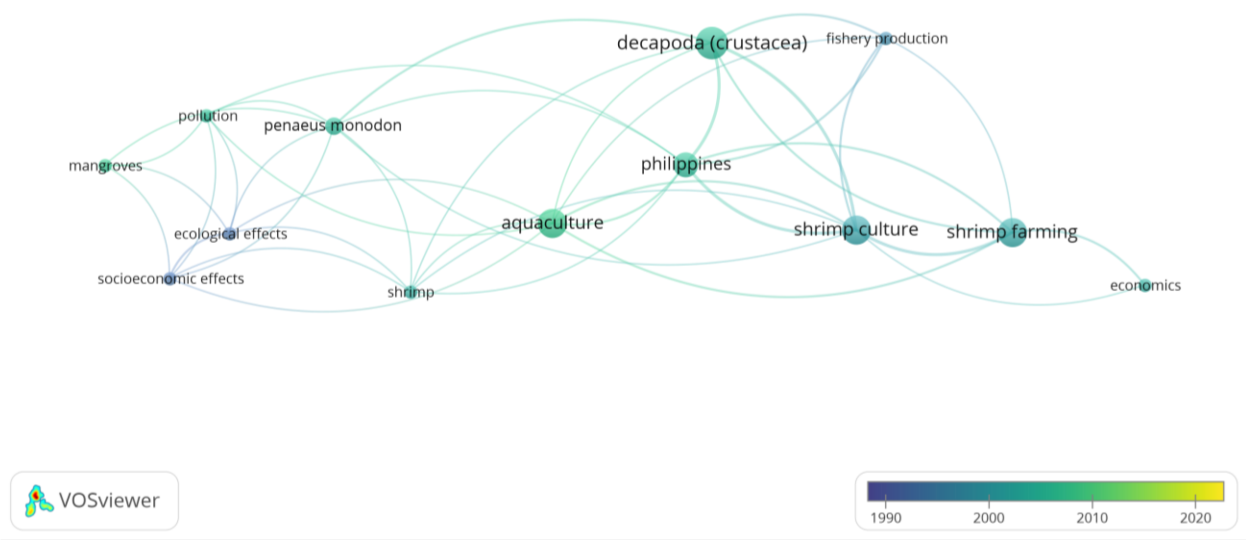

Figure 4.Overlay visualization of most frequently-used terms

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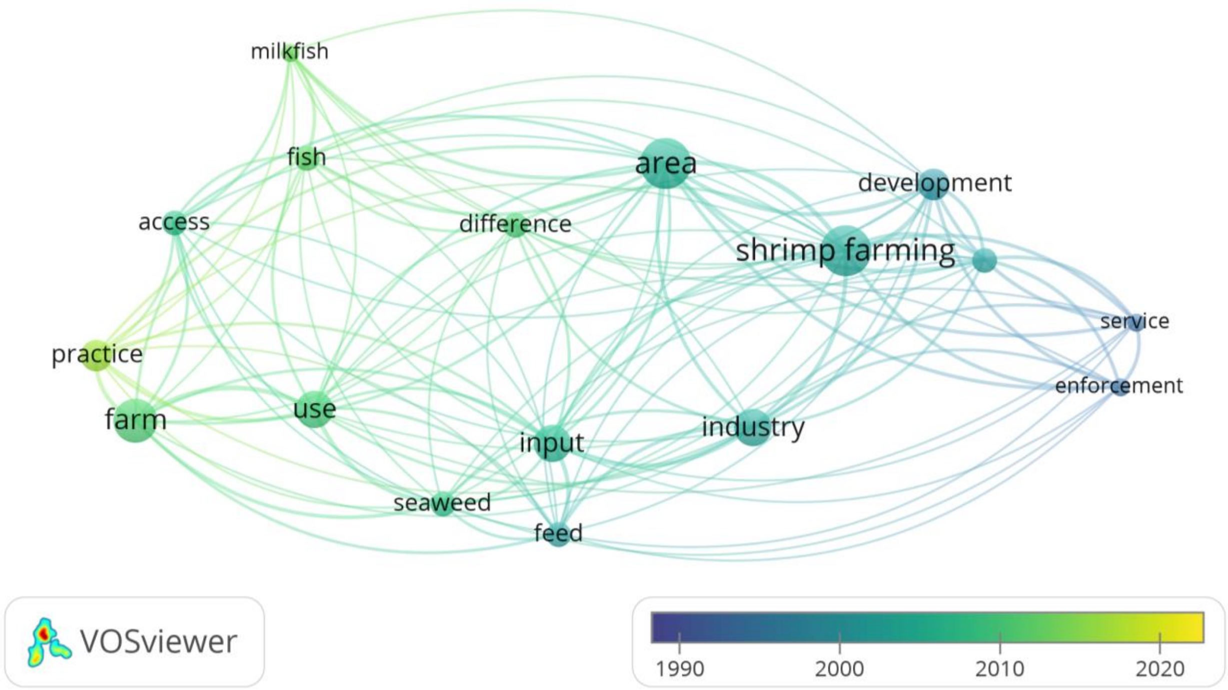

Figure 5. Overlay visualization of most frequently-used terms

The reviewed literature on critical problems associated with aquaculture in the Philippines regarding environmental and socioeconomic impacts have been published in the year 2007 (18%) and in 2011 (10%) (see Table 2). This reflects the studies conducted in the fisheries and aquaculture sectors during this time which were specifically limited in relation to environmental impacts and socioeconomic studies.

Table 2. Literature profile by year of publication.

Year	No. of Studies	%	Journal Name
1993	1	2.56	Philippine Journal of Science Philippine Agricultural Scientist Fisheries Science Estuarine Coastal and Shelf Science Journal of General and Applied Microbiology Aquaculture Research
1995	2	5.13	
1997	2	5.13	
1998	2	5.13	
1999	1	2.56	
2000	1	2.56	
2001	2	5.13	
2002	1	2.56	
2003	2	5.13	

2004	1	2.56	Journal of Social, Political, And Economic Studies
2005	1	2.56	Diseases of Aquatic Organisms
2006	1	2.56	Bulletin of Marine Science
2007	7	17.95	Environmental Management
2008	2	5.13	Fish Pathology
2009	1	2.56	Hydrobiologia
2011	4	10.26	Journal of General and Applied Microbiology
2012	1	2.56	
2014	1	2.56	
2015	1	2.56	
2017	1	2.56	
2018	1	2.56	
2020	1	2.56	
2021	2	5.13	
Total	**39**	**100.00**	

Among the papers reviewed using the method of identifying, analyzing and reporting patterns (themes) within the data, they were categorized into five broad categories based on the keywords, title, 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 shown in Table 3. These broad categorizations also conform with the earlier clustering of keywords and text data mainly related to marine pollution or ecological impacts, socioeconomic effects, shrimp farming and practices, development and inputs and fishery production.

Table 3. Literature categorized according to the Keywords.

Themes	No. of Studies	%
Farm Management	12	30.77
Disease	9	23.08
Marine Pollution	8	20.51
Socio-economic impacts	8	20.51
Climate Change	2	5.13
Total	**39**	**100.00**

Impact assessment has been pointed out in several studies to be essential for better management to be identified and reduce disease and pollution impacts for the industry [35]. Moreover, the major issues of shrimp farming included the loss of important ecological and socioeconomic functions of mangrove ecosystems [23,36] and impacts of climate change to the fisheries sector leading to possible economic effects in the long term [37,38].

1. Farm management

Awareness about the need to reduce the impacts of shrimp farming has been a global issue. The major issues of shrimp farming include the loss of important ecological and socioeconomic functions of mangrove ecosystems [35]. Farm and health management practices focusing on disease prevention rather than treatment, maintenance of hygiene and biosecurity measures, and the responsible and effective use of chemicals could be the key to the sustainability of aquaculture [39].

2. Disease

From the studies reviewed, the presence of viral disease 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. They have now occurred in Pampanga, Bataan, Batangas, Bulacan, Camarines Norte and Mindoro Oriental and Palawan in Luzon; Capiz, Bohol, and Negros Oriental in Visayas; General Santos and Sarangani Province in Mindanao [40]. In the 1980s, the intensive monoculture of *Penaeus monodon*, commonly known as black tiger shrimp, was introduced and gained acceptance in the Philippines. Later, this cultured shrimp was affected by infectious diseases and caused the decline of its economic opportunities. In the Philippines, intensive shrimp farmers have reduced their culture runs due to the bacterial disease outbreak [41]. Diseases of penaeid shrimps may be caused by living agents like bacteria, fungi, parasites, and viruses and non-living factors such as nutritional deficiencies, toxic substances, and environmental problems. *Penaeus monodon, Penaeus merguiensis,* and *Penaeus indicus* were major species cultivated in the Philippines affected by diseases [42]. Diseases are the topmost issues and challenges in shrimp aquaculture worldwide [9,18]. According to Andrino-Felarca and companions (2015), the major viral pathogens affecting 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 host for TSV are the *Penaeus vannamei* and the *Penaeus stylirosis.* 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 [18,43]. On further investigation, WSSV was found to have originated in Chinese hatcheries, where infected hatchery-produced *Penaeus japonicas* were imported to Japan in 1993 [19,44], and which later spread to other countries such as the Philippines [45]. There were also other widespread diseases such as vibriosis and luminous bacterial (Lumbac) infections. It had the same impact as the WSSV which contributed to a significant economic loss among shrimp growers [17,46]. Due to the WSSV pandemic, the Philippine government decided to ban the importation of live shrimp except for scientific or educational purposes following required permission. This is to prevent the spread of the diseases [16]. Technically *Penaeus 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 *Penaeus vannamei* labeled as milkfish fry from Taiwan in 1997. Later in 2001, because of this incidence, the government also prohibited the culture of this shrimp species with corresponding penalties [47]. Despite this early setback in the culture of *Penaeus vannamei* in the Philippines, by 2006, the Philippines has become one of the main producer countries of *Penaeus vannamei based* on FAO Fishery Statistic in 2006. The illegal shipments of the shrimp remain uncontrolled, possibilities of contamination of TSV remains [48]. The viral disease appears to be more widespread during the dry season than during the wet. The presence of TSV had also been detected in *Penaeus monodon* adults. This disease has increased social impacts associated with shrimp farming, including 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 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, including their markets and livelihoods are gone. In other cases, the process of pond construction and maintenance, the former occupants of the cultivated area are given priorities during the hiring of workers. Nonetheless, worldwide shrimp aquaculture production has been depressed by disease, particularly caused by luminous vibrio and/or viruses [18,49].

Table 4. Common diseases and their effects on the various life stages of shrimp

Disease	Effects	Stage of Culture	References
White Spot Syndrome Virus (WSSV)	This was first described from Japan where initial outbreak occurred in *Penaeus japonicus* in 1993, however it was first reported in the Philippines only in 1990. Develops rapidly reaching 100% mortality within 3-10 days, the white inclusion evidently represents abnormal deposits of calcium salt	All larval stages of *Penaeus monodon*	[50-52]
Hepatopancreatic Parvo Virus (HPV)	The hepatopancreas of affected shrimp that cause abnormal metabolism and eventual death. Mortalities may reach to 50% within 4-8 weeks	Juveniles and adults of *Penaeus monodon* and *P. merguiensis*	[53]
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 affected pond-cultured *Litopenaeus vannamei,* include reddening of the tail fan and visible necrosis in the cuticle	Post-larvae and broodstocks	[28,48,54,55]

Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV)	First reported in Hawaii in 1980, the presence of the virus can cause death of the cell of the cuticle, blood-forming tissues, and connective tissues which cause abnormal metabolism that eventually leads to mortalities of the shrimp	All life stages of *Penaeus monodon*	[53,54]
Shell Disease	Appearance of brownish to black erosin of the carapace, abnominal segment, tail, gills and appendages. The affected shrimp appendages shows a cigarette butt-like appearance	All life stages of *Penaeus monodon, P. merguiensis* and *P. indicus*	[28,53]
Infectious Myonecrosis Virus (IMNV)	Also first reported in Hawaii in 1980, viral occurrences affect cell nuclei from subcuticular epithelium of the mouth appendage, gill, thoracic ganglion, and nerve fiber of the walking leg, but can also occur sparsely in the cytoplasm	Post-larvae and broodstock	[21,28]
Filamentous Bacterial Disease	Larval shrimp are less prone to infestation than post-larval, juvenile and adult stages due to the rapid succession of molts throughout the different larval stages while infected eggs show a thick mat of filaments on the surface which may affect the respiration or hatching	All life stages of *Penaeus monodon, P. merguiensis* and *P. indicus*	[28,53]
Monodon Baculovirus (MBV)	The affected shrimp exhibit pale bluish-gray to dark to dark blue-black coloration that cause sluggish and inactive swimming movements, loss of appetite, and retarded growth. The presence of virus damage the organ that weaken the shrimp and lead to gradual mortalities	All life stages of *Penaeus monodon* and *P. merguinsis*	[28,54]
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	Post larval stage and broodstock	[56]

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	have discolored portions on the body. Systemic infection reach to 100% of the affected population	

3. Marine Pollution

More than 100 chemicals are used in aquaculture during pond preparation to harvest early in the mid 1990s in the Philippines. The traditional practice did not pose any major problems, however, when farm methods were shifted to the semi-intensive and intensive system, high stocking density and formulated feeds were used. Thus, intensification has resulted in several infectious diseases, and consequently, the use of chemical and biological products is certain [39]. Mangroves have declined to only 120,000 ha while fish/shrimp culture ponds have increased to 232,000 ha [57] and this intensification deteriorated and brought the decline of the industry [29]. Over the last few years, aquacultural activity in the Philippines was largely directed towards the production of milkfish only (*Chanos chanos*) which has not for a longtime converted into shrimp, particularly the giant tiger prawn *Penaeus monodon* [24]. Primavera and co-workers (2007) suggested that chemical effluents in shrimp farming have been a concern and their possible impacts on the environment and human health, and will continue to be a subject for debate in the future for lack of knowledge in waste management [36,58]. The negative impacts of marine pollution on capture fisheries and aquaculture are becoming more apparent. Even the municipal fishery sub-sector, traditionally the main source of fish for domestic consumption, has declined steadily over the past years [59,60].

Table 5. Environmental impacts of shrimp aquaculture*

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Environmental Inputs	Chemical used	Use/Effect
Pesticide	• Saponin (Teaseed Powder)	• Pond preparation (broadcast) about 20 cm – 1m water. • 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 disappears.
	• Chloramphenicol	• Every other day from stocking to harvest. Disease control, daily or until disappears.
	• Nitrofuran	• Every other day from Z_1 to harvest. Disease control, 3 d (long bath).
	• Erythromycin	• Disease control, 3 d, (long bath).
Feeds (Inorganic Fertilizer)	• 16-20-0 (Mono-ammonium phosphate)	• Use during pond preparation (broadcast). • 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 and rearing phase.

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	• 21-0-0 (Ammonium Sulfate)	• Pond preparation and rearing phase.
	• 0-20-0 (Solophos)	• Use during pond preparation and rearing phase.
(Organic Fertilizer)	• Chicken manure	• Use during pond preparation (tea bags). • Rearing phase (tea bags).
	• Cow manure	• Use during pond preparation (tea bags). • Rearing phase (tea bags).
	• Carabao manure	• Use during pond preparation (tea bags). • Rearing phase (tea bags).
	• VIMACA (chicken/pig manure)	• Use during pond preparation (tea bags).
	• B-4	• Use during 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.* [61]

4. Socioeconomic impacts

There have been several reports that aquaculture has been the cause of several problems such as 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 raised some concern as this adds to the cost of cultivation [62]. 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 for their livelihoods and protein requirement [63]. The marketing of seafood products in the Philippines is usually channeled to fish brokers with profit-making taking place within wholesalers, retailers, and brokers in the fisheries [64]. This causes the higher market price for aquatic products that puts them outside the range of urban poor consumers [65]. Black tiger prawn (*Penaeus monodon*) and Pacific Whiteleg (*Penaeus vannamei*) are highly traded species in the Philippines. Black tiger shrimp leads the highest production ranges from 45,000-50,000 mt annual production in 2008 to 2019, followed by the Pacific white shrimp with a production of nearly 2,000 mt in 2008 that gradually increased to 19,000 mt in 2019. They have contributed to our export earnings around U$ 120 million in 2014, much higher than in 2013 that was U$ 67.5 million [21]. While there is no arguing with the increase in its production, problems arise due to its socio-economic impacts. However, 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 increased unemployment [23].

5. Climate Change

The Philippines ranks second in terms of global climate risk due to its vulnerability to climate change impacts [66,67], where it is projected to be a key reason for decline of the fisheries with huge economic costs [37]. Climate change affects the targeted population range and productivity, habitats, and fishery and aquaculture cost [63,68]. Changes in climatic variables

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facilitate the increased frequency of typhoons, and disease spread, causing physical damage to the farm's pond structure, deterioration of water quality and spread of disease and infection in shrimp ponds [69]. Issues and problems have arisen such as decrease in wild-caught shrimp fry and lack of hatcheries in strategic locations to supply shrimp farmers and increasing price of feeds are major concerns [60,70]. Few studies have analyzed the economic impacts of climate change on aquaculture and fisheries dealing with the national economy. The Philippines is projected to decrease by 9% its fisheries GDP with the climate change mitigation scenario and a decrease of 18% with the extreme scenario without mitigation [37]. The government should adopt further adaptation measures to prevent the catastrophic impacts of climate change and variabilities with the aquaculture sector [68].

CONCLUSION AND RECOMMENDATION

The intensification of the shrimp farms has led to the destruction of mangroves and encouraged the proliferation of pathogens to the detriment of all shrimp farmers. As this has generated an economic problem for the aquaculture sector in the Philippines over its possible environmental, social, and economic impacts, essential studies to comprehensively investigate the sustainability of Philippines shrimp aquaculture is lacking. Using the WoS and Scopus databases, this paper has analyzed and synthesized 39 literature to answer the research aim. Our analyses revealed that shrimp farm management and their ecological and disease impacts were the main concerns of several studies from the 1990s to 2021. Moreover, the results of this review have also shown gaps needed to be addressed which could further improve the shrimp industry in terms of environmental sustainability, economic profitability, and social acceptability. This includes the adoption of sustainable practices, use of life cycle assessment from fry to farms, and market to evaluate the environmental and economic performance of different shrimp farming systems in the country [71]. Next is the need to add a comprehensive suite of public policies that will provide the basic framework and support the industry's adoption measures of sustainability practices. These practices apply to small-scale and large-scale commercial exporters from farm owners to feed manufacturers to be resilient to climate change impacts and other threats such as marine pollution, diseases, and natural disasters [72,73].

Moreover, there is a need for increased government investments for developing hatcheries, laboratories, and training technicians adept in good aquaculture practices and able to recognize the early stages of diseases to prevent outbreaks [68]. The government may include crucial investments in smart and artificial intelligence in the aquaculture sector to recognize indicators of diseases even before an outbreak can occur. These government-led investments can lead to better food security especially in clustered farming areas to reduce overhead costs and increase the interaction between technicians and farmers. Most importantly, good farming practices observed in export-led companies are non-existent in small-scale farmers who generally lack biosecurity protocols when there is a disease outbreak or in discharging untreated waste water to the natural environment. This could compromise the supply, marketing, and economic profitability of the whole production chain [74].

Moreover, there is little value adding in the production chain including waste products coming from aquaculture such as pond slurry, cut heads of shrimps that can be processed to other useful forms. Further processing may be needed and later sold in other industries particularly among farmers or other entrepreneurs for value additions. Finally, there is also the general lack of clear spatial zones and local environmental policies to situate shrimp farms to avoid user conflicts with the recreation, tourism industries or avoid marine conservation areas. To sum up, shrimp farms need to be managed sustainably, require regular monitoring for disease outbreaks, chemical use and environmental impacts to prevent environmental catastrophe [19].

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