 doi:10.20944/preprints202203.0137.v2

Article

Typology of Small-Holder and Commercial Shrimp (*Penaeus Vannamei*) Farms, Including Threats and Challenges in Davao Region, Philippines

Misael B. Clapano[1,2], Jenie Mae T. Diuyan[2], France Guillian B. Rapiz[1,2], Edison D. Macusi[1,2,*]

1 Institute of Agriculture and Life Sciences (IALS), Davao Oriental State University (DOrSU), Mati City, Davao Oriental, Philippines
2 Shrimp Vulnerability Assessment Project, Davao Oriental State University (DOrSU), Mati City, Davao Oriental, Philippines
* Corresponding Author: Edison D. Macusi edison.macusi@dorsu.edu.ph

Abstract: The shrimp industry in the Philippines play a vital role in the local and national economy through exports with markets abroad such as in South Korea, Japan, the USA, and others. This study aimed to describe the various cultural and operational characteristics of small-holder and commercial shrimp farms (*P. vannamei*) in the Davao region. It also evaluated the current risks and challenges faced by the shrimp farmers. A semi-structured questionnaire that focused on shrimp farmers, and operators in the region was used to collect data with N=41 farmers and operator. The results showed that respondents were engaged in small-holder farming activities which had an average yield of 10 tons/ha. On the other hand, the commercial farms that operate intensively had an average yield of 24 tons/ha. Most small-holder operators used electric generator machines to conduct aeration in their farms using paddlewheels and blowers. For the commercial farms, more paddlewheels and blowers were employed per pond compared to small-holder farms. Generally, the income of a farm was related to the yield of farms or the number of fries rather than social factors or size of farms cultivated. In terms of input costs, feeds were found to have the highest input costs, followed by the fry, fuel, labor, and others (fertilizers and water treatment chemicals). Most of the farmers mentioned that they are affected by diseases such as white spot syndrome (60%), black gills (35%), and red tail (5%). They perceived that the main contamination come from the water source (31%). The main threats mentioned are declining shrimp prices in the market, source of fry, water disposal, and overstocking, and water quality. Based on this study, farmers should follow good shrimp aquaculture practices and there is a need for them to regularly monitor their water quality.

Keywords: Aquaculture; Davao region; Mati City; *Penaeus vannamei*; shrimp farms; water management

1. Introduction

The shrimp industry in the Philippines plays a vital role in the economy since recovering from disease outbreaks in the mid-1990s to the present. The rapid expansion and growth of shrimp aquaculture in the past years had led to its significant contribution to the fisheries sector. Because of this, the Philippines has become a top producing country for shrimp production with an export value of U$38 million for fresh, frozen and chilled shrimps/prawns exported to Japan, South Korea, and the USA of value [1], and lately, this

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 April 2022 doi:10.20944/preprints202203.0137.v2

production reached 66,000 mt of total shrimp production in 2019 [2-3]. *Penaeus vannamei* and *Penaeus monodon* are the most cultured shrimp species and dominates shrimp aquaculture production by contributing the largest percentage (60%) of farmed crustaceans in 2020 [4-6]. *P. vannamei* only became a preferred species due to its fast-growing capability, especially the female one. Shrimp farming has provided employment and food security for most Asian coastal countries that are avid consumers of seafood products and with large aquaculture sectors including the Philippines [7-11]. The growth of aquaculture has been a part of the most significant changes in global food production over the past 100 years [12] . Apart from being a major source of proteins, aquaculture is considered to be a better alternative for wild-caught fisheries in terms of seafood production [8,13]. Similar to other countries like Bangladesh shrimp farming became one of the most popular activities and has been practiced in several districts [14]. In Thailand, they started from traditional shrimp farming until they adopted the modified farming system, semi-intensive to intensive farming to increase their production [15]. The center of intensive shrimp farming in the Philippines way back in 1990s was Negros Island, but after it was hit by a disease outbreak, its production dropped during 1997 [1,2]. Due to the incidence, development of several effective strategies such as fish-shrimp integrated culture technology also known as green water culture technique or a polyculture of tilapia and shrimp, and others were introduced. When the disease was declared to be manageable in 2004, the shrimp industry slowly recovered and has been growing in many areas of the Philippines, including in the Davao region [2,5,16]. As of 2019 data, 1.5% from the total shrimp production (66,252.68 mt) was harvested in Davao region [3].

Though aquaculture has benefited the economy, food security, and livelihood, this was also accompanied by detrimental impacts on marine coastal ecosystems such as seagrass and mangrove ecosystems [17]. Mangrove forests are found in 121 countries around the world including the Philippines [18]. Mangrove deforestation and degradation have become one of the major impacts of aquaculture expansion particularly from intensive and extensive commercial aquaculture [19-20]. As aquaculture increases, mangrove deforestation also increased. Hectares of mangrove trees have been removed in the middle of the forest to create ponds without cutting in the border to prevent wave disturbance. Aquaculture had been recorded as the largest factor – around 20% to 40% of the decrease of mangrove trees globally since 1980 [17,21,22]. In 2007, the estimates of mangrove cover for the Philippines are 1,097 km^2, visibly lower than it was first recorded in 1918 when it had an area of 4,000 - 5,000 km^2 [23]. Mangroves ecosystem has a vital role in environmental and socio-economic functions [18,24]. This can be a source of wood supply and non-wood forest products; protection against storm surges; erosion and flood

 doi:10.20944/preprints202203.0137.v2

control [18,25,26]. It is also considered as a nursery ground for various fish, shellfish, and other invertebrates, however, deforestation as a result of pond construction and other farm activities causes biodiversity loss [27-30]. It also provides livelihood to nearby local communities on whatever product can be benefited from the mangrove ecosystem [18]. The degradation of mangroves and continuous conversion can lead to the loss of its important functions in the ecosystem [18,31,32].

In terms of socio-economic impact, this mainly refers to impacts on livelihood, reduction of employment opportunities, food insecurity, social imbalance, and marginalization of coastal communities that results in social conflicts. Food security has been affected because most of the aquaculture produced is usually exported instead of being consumed at home [33-36].

Moreover, it is suspected that the emergence of new diseases is the result of the rise of intensive aquaculture. However, the rapid growth of the industry also brought a threat among shrimp farmers worldwide [12,37]. Early mortality syndrome (EMS) had caused mass mortality in several developing countries, which was later named acute hepatopancreatic necrosis disease (APHND) [38]. White spot syndrome virus (WSSV) which was found to have originated from China, has widely affected the Philippines and left the industry with significant economic loss [39]. There were also some viral pathogens such as monodon baculovirus (MBV), yellow head virus (YHV), hepatopancreatic parvovirus (HPV), and infectious hypodermal and hematopoietic necrosis virus (IHHNV), that cause minimal effects on the growth and survival of black tiger shrimp due to its high tolerance [38-40]. Apart from the mentioned pathogenic microorganisms that cause diseases on shrimps, they can also be accompanied by nutritional deficiencies and environmental factors.

Due to the limited studies that focused on the cultural and operational practices in the production of *Penaeus vannamei* in the Philippines, this paper aimed to describe and compare the various cultural and operational characteristics of smallholder and commercial shrimp farms (*P. vannamei*) in the Davao region. In addition, it also assessed the current risks and challenges experienced by shrimp farmers during the time of the pandemic. We think this will be helpful for the development of policies that will enhance and strengthen the shrimp industry in the Davao region and in the Philippines. The study made use of quantitative and qualitative methodology to collect data and insights for the shrimp industry.

2. Materials and Method

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 April 2022 doi:10.20944/preprints202203.0137.v2

2.1 Study site

This study was conducted in selected areas of the Davao Region (Figure 1). Davao Region is a coastal area officially designated as Region XI in the Philippines, which occupies the southeastern section of Mindanao. It has an area of 204.33 km² data as of 2013. It is composed of 5 provinces, the Davao de Oro (previously known as Compostela Valley), Davao del Norte, Davao del Sur (where Davao City was located, the highly urbanized city), Davao Occidental, and Davao Oriental.

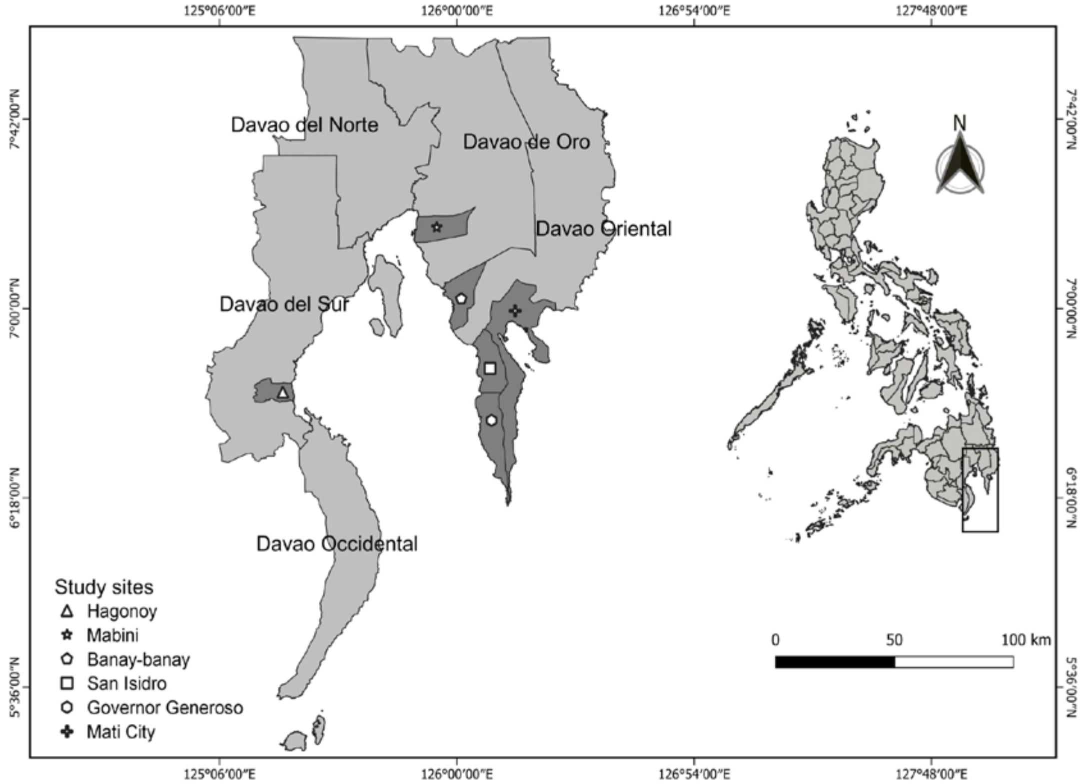

Figure 1. Map of the Philippines showing Davao region.

2.2 Data collection

The data were collected from small-holder and commercial shrimp farmers and operators in the the provinces of the Davao region. The primary data were collected by first identifying the target respondents through some listing by the Bureau of Fisheries and Aquatic Resource (BFAR) in terms of registered shrimp operators in Davao region. The barangay captains also assisted in the survey by referring locations of shrimp farms and farmers in the area. The respondents of the survey were the farmers and operators of shrimp aquaculture within the Davao region. There were N=41 respondents being interviewed using semi-structured survey questionnaire and focus group discussion. The questions were clearly explained to the respondents to enhance better understanding. While responding to the given questions, respondents were also asked further explanations to support the acquired information. The survey questions include the assessment of farm characteristics such as land area, pond size, cultured species and diversity, culture system adapted, water supply, use of aeration, frequency of cropping,

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 April 2022 doi:10.20944/preprints202203.0137.v2

crop yield, and employed individuals. Also, the cultural practices encountered environmental problems and diseases as well as management responses were asked. Economic factors on the production like the cost of inputs and estimated income per production were also gathered for return of investment on both small-holder and commercial shrimp farmers. Farm owners or head managers were also interviewed about their experience during the pandemic and how it affected their production. A focus group discussion was conducted before formulating the questionnaire. Data collection procedure and pilot testing of the survey questionnaire was conducted to evaluate its effectivity before the final survey. The researchers conducted the interviews and collected data from July to September 2021.

2.3 Data Analysis

All data from interviews were encoded in Microsoft Excel 2016, and preliminary data analyses were done using Analyse-it Excel add-in software. All possible dependent variables were first checked for their normality and homogeneity and plotted on graphs for visualization. Quantitative data were analyzed for relationships regarding income from the farm as a response variable with other predictor variables that included farm area, sociodemographic variables (age, education, household size, number of years farming, health), and total yield. Only the data from small-holder farms (N=38) were used in the analysis as there were only three data representatives from the commercial farms. The sociodemographic variables were reduced to one variable by using PCA (principal component analysis) where the component scores were used as the social variable that was later related to the response variable (income). In order to find out the best predictor for the farm income, the social, farm area, and total yield variables were related to the response variable using multiple linear regression. The response variable was first transformed by using a $\log_{10}$ transformation to fulfill a normal distribution using Kolmogorov-Smirnov (KS=0.065; P>0.15) test then the regression was performed. All analyses were performed using MINITAB 17.0 (State College, Pennsylvania, United States).

3. Results

3.1 Sociodemographic profile

A description of the sociodemographic variables included age, where the age of fish farmers ranged from 26-40 and 41-55 years, with 70% of the fish farmers having an average age of 41 years old mostly from small-holder farms (Figure 2A). In terms of their educational attainment, most shrimp farmers have attended schools with 39% of them finishing up to elementary level or have graduated elementary; about 9% of them studied in secondary schools and graduated, and 2% have undertaken vocational courses while 32% have pursued their college degrees (Figure 2B). Another variable included the sizes of households, where small-holder shrimpfish farmers have less than 10 individuals in every household, with sizes ranging from 1-6 members. Most shrimpfish farmers have a

 doi:10.20944/preprints202203.0137.v2

family with 3-4 members (36%), and the least with family having 7-8 members (5%) (Figure 2C). Concerning community residences, about 66% of the shrimpfish farmers have resided in the community for less than 10 years, 11% of the shrimpfish farmers have resided for about 41-50 years, 8% for both 11-20 years and 31-40 years of residency and 5% for a range of 21-30 years (Figure 2D). There were some organizations of shrimpfish farmers in Davao Oriental but only 58% of the interviewed farmers were members of the organization (Figure 2E). Only 24% of the farmers have access to borrow financial or in-kind expenses while the rest reported not having access to credit (76%) (Figure 2F). In terms of the ownership of land being used for shrimp farming, 92% were owned by the shrimp farmers and 8% were renting (Figure 2G). Many of the smallholder shrimpfish farmers have just started their culturing for less than a year and others had as many as 21 years already. But most of the shrimpfish farmers have only been farming for the past 1-3 years (26%), 4-6 years (45%), followed by 7-9 years (5%), 10-12 years (8%), 13-15 years (8%), 19-21 years (5%), and 16-18 years (3%).

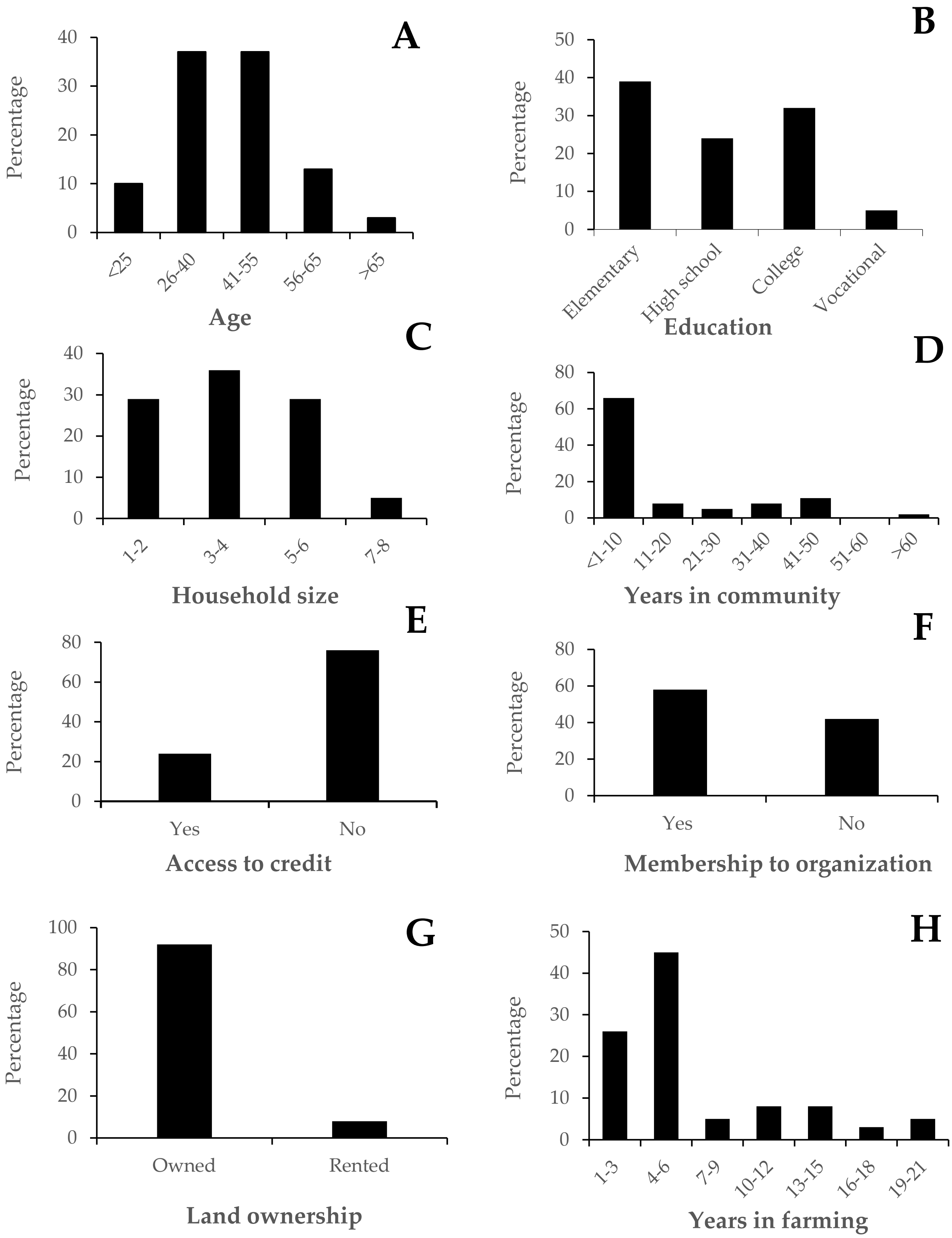

Figure 2. Age of respondents (A), their level of education (B), household size (C), years in community (D), access to credit (E), membership to organization (F), land ownership (G), and years in farming (H).

 doi:10.20944/preprints202203.0137.v2

3.2 Characteristics

3.2.1 Shrimp Farms

Smallholder: Farms were mostly located in Mati City with an area of less than 3 hectares. Shrimp production in these farms used a monoculture of whiteleg shrimp (*Penaeus vannamei)*. The number of cropping practiced by small-holder farmers was about 1 to 3 times per year, almost the same with commercial farms. Farms were semi-intensively operated by a limited number of employees (1-10 or a maximum of two persons each pond). Stocking density was lower than the other type of farm using paddlewheel alone as means of aeration. The number of ponds cultivated simultaneously in one cropping range from 1-5 ponds, fewer compared to commercial farms but with a larger pond size (4,000-5,000 m^2). Ponds were commonly rectangular and traditional irregular shapes. Farmers also used the fermentation process aside from probiotics and molasses as supplements for shrimps. This fermented product is composed of rice bran and molasses. In terms of commercial feeds consumption of post-larvae within the whole culture period (70-110 days), ranges from 1,000-3,000 kg. By an average production, the harvested shrimp weighs 14-30g when sold in the market. The cost of inputs are two thirds of the amount of revenue per ha per cropping including the costs of post-larvae, feeds, fuel/electricity, labor, supplements, and other inputs during pond preparation while the rest would be their gained profit (~Php 1 million; U$ 21,000).

Commercial: Most of these farms were operated by corporations with an area much larger than small-holder farms (4-50 hectares). Shrimp production in these farms focused on monoculture whiteleg shrimp (*Penaeus vannamei)*. Farms were intensively operated by numerous employee (8-71 persons was recorded during the interview). Stocking density was higher than small-holder farms and employed paddlewheel and blower as means of aeration. They practiced cultivating a number of ponds (38) in single cropping at the same time, compared to the small-holder farms but in a smaller pond area/pond size (2,000-3,000 m^2); shapes of ponds are common in rectangular and modern circular shapes. Farmers also use supplements like probiotics and molasses for shrimps. Commercial feeds consumption of 100,000 post-larvae within the whole culture period (80-100 days) ranges from 850-2,650 kilograms, slightly lower than the small-holder farms. Most of the harvested shrimp is in 27-35 g average body weight, the average total cost of variable inputs such as post-larvae, feeds, electricity, labor, supplements, and other inputs during pond preparation cost 60% of the total revenue per ha per cropping while the rest (40%) would be their gained profit (~Php 3 million; U$ 60,301).

Results from the data analysis regarding farm income showed that the model was highly and positively related to the yield (Df=1, MS=2.16, F=43.55, P=<0.0001) but not to the social factors or the farm area (Df=1, MS=0.12, F=2.41, P=0.129). The overall model (Df=2, MS=1.50, F=30.25, P=<0.0001) with an R^2=63.3% explains the variation well and there was no autocorrelation between variables.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 April 2022 doi:10.20944/preprints202203.0137.v2

Table 1. Comparison of small-holder and commercial farms

Variables	Small Holder	Commercial
Farm area (ha)	0.3-3.0	4.8-50
Number of cropping per year	1-3	2-3
Yield per cropping (kg/ha)	10,000	24,000
Revenue per ha/cropping (US$)	62,814	150,754
Average income per ha/cropping (US$)	20,938	60,302
Number of employed individuals	1-10	8-71
Stocking density (PL/m²)	25-200	60-350
Aeration	Paddle wheel	Paddle wheel, Blower
Number of ponds	1-5	3-38
Average pond size (m²)	4,000-5,000	2,000-3,000
Shape of pond	Rectangular, Irregular	Rectangular, Circular
Use of supplements	Probiotic, Molasses, Fermentation	Probiotic, Molasses
Commercial feed (kg/100,000PL/crop)	1,000-3,000	850-2,650
Days of culture period	70-110	80-100
Average body weight (g)	14-30	27-35

*PL = post larvae

3.2.2 Variable cost of inputs

The operational cost of inputs varies in an area and intensity of production. Input cost such as feeds lead the highest contributor in both small-holder and commercial farms. In *small-holder farms* (figure 3A), feeds cost contributes 59% of the total cost. The fry also shares 15% from the total cost and 12% for the fuel cost that is used to generate electricity for aerator and other mechanical equipment within the farm. Labor cost refers to the payment for employee in a given culture period amounting mostly 10% of the total cost. The 4% that represents for others are the supplements, limestone, tea seed, water treatment (mostly needed during pond preparation) as well as additional expenses for repair and maintenance. However, in *Commercial farms* (Figure 3B), unlike from small-holder farms electricity is the second highest contributor with 24% of the total cost. Other inputs are closely related from small-holder farms in terms of cost percentage distribution, where the cost of the fry is 17%, the labor cost (11%) and 3% of the total cost are from the supplements, limestone, tea seed, water treatment and additional expenses for repair and maintenance.

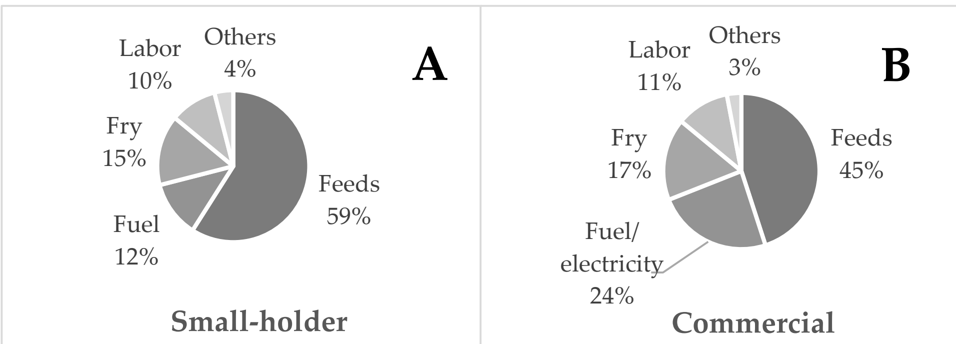

Figure 3. Distribution of variable cost of inputs of small-holder (A) and commercial farms (B).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 April 2022 doi:10.20944/preprints202203.0137.v2

3.3 Prevalence of disease and probable causes

According to the farmers' experience in diseases particularly among small-holder farms, white spot syndrome (WSS) is the most contagious and around 60% of the farmers that have encountered diseases on shrimp experienced WSS, 35% of them experienced Black gills syndrome, and slightly 5% on the red tail or other known as Taura syndrome (Figure 4A). Farmers have mentioned probable causes of diseases: most of them (44%) pointed out water quality as the main cause of the presence of diseases such as WSS, black gills, and red tail. This water quality refers to the alkalinity and acidity of the water in the pond, water temperature, salinity, as well as level of dissolved oxygen. They were also aware of the effects of climatic conditions (25%) on shrimp diseases such as WSS and black gills. Climatic conditions like heavy rain, hotter temperature, and rising sea level sometimes can directly affect the ponds. For instance, heavy rains can lead to flooding which changes the quality of water. These factors could affect shrimp culture since they are sensitive to changes in their environment, especially water quality. Farmers have also mentioned cases of water contamination (19%), where water is contaminated with diseases or pathogenic organisms, pesticides, and other chemical substances brought by flooded water. Another transmission mechanism could be vector-borne (12%) either by human or animals that cause the spread of the particular diseases (Figure 4B). But these factors are found to be less prevalent in commercial farms as they have well-constructed ponds and availability of resources to mitigate these factors.

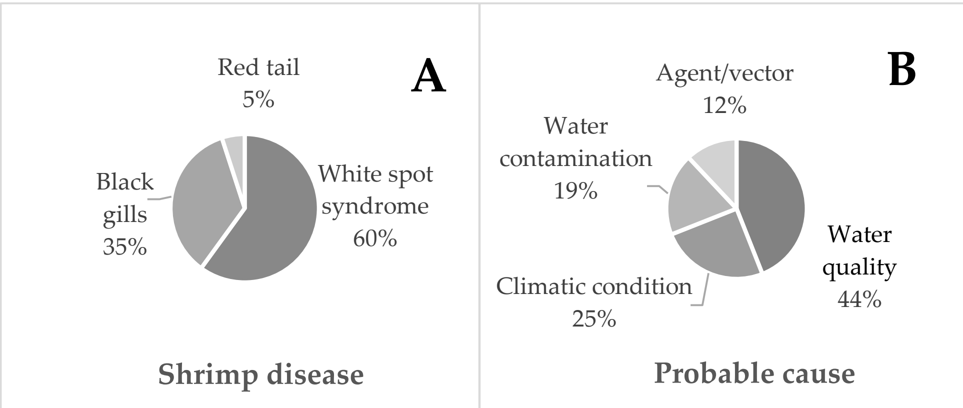

Figure 4. Encountered shrimp diseases (A) and probable cause (B).

3.4 Risks, challenges and possible solutions

Respondents have mentioned different challenges that affected their production such as disease, overstocking, waste disposal, water quality, pollution, source of fry, high cost of inputs, lack of capital, low market demand, and pandemic (see Table 2). These factors have brought corresponding negative impacts on shrimp production. In particular, diseases have reduced harvest yield due to massive loss in production. Overstocking has led to shrimp death due to lack of oxygen supply and disease outbreaks.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 April 2022 doi:10.20944/preprints202203.0137.v2

Moreover, improper water disposal can lead to water contamination and possible disease and nutritional deficits affecting the growth of cultured shrimps. Pollution can also lower the survival rate of postlarvae while the lack of capital can prohibit farmers to increase their

Table 2. Challenges, impacts on shrimp production and farmers suggested solutions

Factors	Impacts	Suggested Solution
Disease	Shrimp death	Proper cultural management Strict implementation of biosecurity and government intervention
Overstocking	Lack of oxygen	Following the standard stocking density suitable to the capacity of the pond area and availability of aerator
Waste disposal	Increased contamination	Total removal of excess solid or liquid waste inside the pond Construction of sludge pond/reservoir for solid and liquid pond waste Treating the wastewater before the release into the waterways
Water quality	Cause diseases on shrimp Stunted/low growth rate	Water quality testing kit/lab to regularly monitor the optimum level of water parameters in the pond.
Pollution	Low survival rate of shrimp post larvae	Good source of water
Source of fry	Insufficient supply Potential in carrying disease	Accessible hatchery Disease-free, high quality and cheaper source of fry
High cost of inputs	Limited and insufficient supply of inputs required for better production Production declines	Access to a cheaper supply input for production Other alternatives to lessen the cost of production
Lack of capital	Disable the farmers to increase their production Unable to support the needs of the farm	Access to credit (money/in kind)
Low market demand	Low profitability	Processing plant for shrimp produced.
Pandemic	Decreasing buyer due to mobility restriction It prolongs the culture period of shrimps led to an increase in input cost Low market price	Government policy to loosen the mobility restriction to allow the people work and earn for their necessities, as well as it will enable the transportation of goods in and out of the town Government assistance to help the shrimp farmers that is affected by the pandemic overcome

production. Lastly, the pandemic brought a significant impact specifically on the market aspect of shrimp aquaculture, mobility restrictions have shrunk the number of consumers in the market. Moreover, the farmers have given suggestions to help mitigate the above-mentioned challenges. These are: having a good source of water; proper waste disposal, following the required stocking density, having an accessible, good quality and cheaper source of fry, processing plant for shrimp export, proper cultural management and

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 April 2022 doi:10.20944/preprints202203.0137.v2

biosecurity, availability of water quality testing kit/lab, cheaper supply inputs, access to credit, and government assistance to help farmers to mitigate the challenges.

4. Discussion

4.1 Farming Characteristics

There were two identified shrimp farmers in the region, the small-holder commercial shrimp farmers were both producers of *P. vannamei* as their main cultured species of preference. They usually have two to three cropping per year [44]. In the Davao region, small-holder farms dominate the sector which was also the same in other parts of Asia [45]. Commercial shrimp farms were intensively cultivated and technically well-supported and financially awashed with cash. They have well-constructed ponds, lined with HDPE rubber liner that do not need to have a prolonged period of pond preparation, particularly for drying. Thus, it enabled them to proceed on the next cropping with shorter time of preparation compared to farmers with earthen ponds. Most of the smallholder farms were local growers employ their own family members. They tend to have smaller size of farms when compared to those commercial farms cultivated by a corporation or an export-oriented company. Since these commercial farms cultivate shrimps in large volumes, they were very particular on their mode of production. In addition, commercial farms can hire personal farm technicians that supervise inputs and actions needed to maximize the production. In contrast, small-holder farms, have limited access to a farm technician from the company that supplied them feeds and seedstock. In addition, the income of smallholder farmers is highly dependent on the total yield that they produce [46]. The fact that their age, number of household sizes or even their health and farm area were not positively related to their level of income could be due to dependence on stocking density of the shrimp. The higher this stocking density, the more shrimps can be grown and produced to desired sizes which explains why income is better predicted by stocking density rather than farm size. While this could be good economically, the higher stocking density of shrimps could also lead to prevalence of diseases in highly intensive farms [3].

4.2 Cultural Practices

Shrimp production in Davao region employs pond preparation prior to stocking. This pond preparation was very crucial to possible risk throughout the culture period. Pond preparation in smallholder farms is costlier and requires longer period than commercial farms as it relies on natural sun drying. In contrast, commercials farms have HDPE liners on their ponds, making it easier to clean, remove sediments or debris and may not need long period of drying which leads to quicker pond preparation. The removal of any unwanted particles and excess organic load in the pond from the previous cropping is also essential. Complete drying as indicated by visible cracks in the soil is required among smallholder farms. These practices are intended to remove dangerous organisms and other particles that may affect the quality of water for stocking. In 30 days or more, after the drying period, and pond preparation, filling of water in the pond follows. The water used was usually treated with chlorine. Application of tea seed was also practiced by some farmers and liming to neutralize acidity in the soil prior to stocking.

The seedstocks/post larvae (PL) that were used for culture were imported from other nearby hatcheries such as from General Santos City and Butuan City. Currently, the pacific whiteleg shrimp is the most preferred culture species in Davao region. Seeds are stocked at ages (PL8) 8 to (PL15) 15 days. Older seeds were observed to have a lower mortality rate; however, its cost is higher compared to younger ones. Therefore, to compromise, most farmers stock PL10. Technically, they are provided by hatcheries with recommended stocking density, where in 1,000 m^2 pond area should accommodate only 100,000 PLs in semi-intensively cultured farm. In the Mekong Delta, there are also factors that represents the intensification and specialization of the farm. One of these is the stocking density, high stocking density monoculture uses high level of inputs and equipment. Similarly, most extensive ponds operate larger ponds than those of intensive or semi-intensive ponds [4]. The lower stocking density can obtain higher maximum production and survival rate as proven in other studies [50] . High survival rate can also be attainable in small intensive ponds with best management practices [51]. However, poor management can reduce production and profitability even when the prices are high [52]. The profitability of the farm always depends on the management practices as well as the price in the market [53].

Maximization of shrimp production with its feed efficiency, farmers have followed recommended feeding guide. Blind feeding is the term used in the first month of culture with regular monitoring on its feeding efficiency. The regular monitoring of the amount of feed consumed will help determine the amount of feeds the shrimp needs. Commercial and formulated feeds are used to increase the growth of shrimp. However, improper feeding can lead to a waste of feeds. Farmers have practiced broadcasting feeds within the pond excluding in the middle part. Most of the excess feeds sink into the pond bottom as a solid waste with other organic loads. But in commercials farms, they have auto feeding machines, which help mitigate issues on excess feeding as well as labour problems. Moreover, the application of supplements can help improve the nutrition of shrimps. During the rainy season, the production of ammonia in the pond water increases, therefore the initiation of liming and water exchange (top drain) can be a solution in maintaining the suitable water quality in the pond. Mostly, in smallholder farms, they use paddlewheels for aeration, generated by fuel or electricity. It is one of the reasons for high electricity cost for shrimp production as aeration is important for the shrimps and reduces mortality from disease [51]. The culture period of pacific whiteleg production in Davao region is usually within 90 days. Sometimes it takes up to 110 days, depending on the availability of buyer. They gradually harvest the shrimp by netting and complete draining. The marketable size of shrimps ranges from 10g average body weight (ABW) and above, but farmers preferred to harvest their shrimps around 20g to 25g ABW.

4.3 Prevalence of marine pollution and disease

 doi:10.20944/preprints202203.0137.v2

Perceived causes of marine pollution and disease is affected by farming practices, waste disposal, use of chemicals, mangrove conversion and improper implementation of biosecurity measures that prevent spread or entrance of diseases. Commercial farms are more particular in their biosecurity measures such as tire bath/foot bath disinfectant, crab fence, bird scaring device, individual paraphernalia in ponds, as well as settling and treatment pond. They start practicing lesser use of water by recycling. They also provide filtration system to ensure that waste water to be release into the environment is free from toxins. However, if these practices will be neglected, the risk will probably occur. Released waste water from shrimp farms that was accompanied with fecal matter and unused feeds are largely composed of nitrogen, that can cause oxygen depletion as well as marine pollution. Diseases usually spread from nearby ponds/farms due to lack of proper management and mishandling of the situation. Waste water from the infected ponds is also released to the water ways which will contaminate the water source. And if it is absorbed by other ponds, since these are not rubber lined, then the disease can easily spread to other ponds. Other factors could be transmission thru agents and vectors as well as the quality of fry being introduced in the farm. Moreover, most of the smallholder farms are more vulnerable to contamination and spread of diseases as they do not have sufficient implementation of biosecurity measures under good aquaculture practices (GAqP). Concurrent with its importance in the economic sector and development in many Asian countries, shrimp farming has been facing various issues regarding its negative effects on the environment [29]. Concern has been expressed regarding the use of chemicals in shrimp farms, and its potential impacts on the environment and human health [54] . Liming compounds and water treatment are the common substances that help mitigate water pollution and contamination. For instance, zeolite (hydrated alkali–aluminum silicates) for the removal of ammonia and neutralizes particularly the pH level of the pond water [55]. Fertilizers are used to enhance the growth of phytoplankton that provides alternative food supply for the shrimps and improve the general environment in the pond. There were also application of antibiotics that helps prevent and treat viral infections; microorganism (probiotics) as treatment for the water or sediments; and vitamin products to enhance growth of shrimp and resistance to diseases [56].

Due to pollution and occurrence of problems such as diseases, the world production of shrimp has stagnated even gone down over the last few years. The same was experienced by Vietnam, as they have previously applied feeds, pesticides and antibiotics which led to water pollution. The intensification of shrimp farming has resulted to environmental problems [29]. In the Philippines, the prevalence of IHHNV in various wild populations of *Penaeus monodon* has been correlated with shrimp culture intensification and decline in mangrove status [57] , associated with other disease like WSSV, MBV, HPV, YHV [40,58,59]. Accumulated pollution from watershed activities and from self-generated organic load has resulted in slower growth of shrimp, higher susceptibility to diseases, and the worst is mass mortalities [60].Presence of disease in populations and ecosystems is influenced by numerous environmental factors, including infectious organisms mostly viruses, pollutants such as chemical and biological wastes, and deficiency in essential nutrients [29].

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 April 2022 doi:10.20944/preprints202203.0137.v2

4.4 Challenges in the time of COVID-19 pandemic and coping strategies

Corona Virus Disease (COVID-19) has affected various sectors, including the aquaculture sector which forced strict mobility lockdowns [61-62]. In the Philippines, entire aquaculture supply chain and marketing system faced multiple challenges. Many farmers have reduced their activities due to low demand and uncertainty. It brought various challenges on rural livelihoods and economic problems such as loss of income and job opportunities. Moreover, disaster-prone communities were struggling with COVID-19 restrictions and its severe economic impact [13,63, 64, 65].

Within the study area itself, mobility restriction showed as the main health protocol during the pandemic that negatively affect aquaculture farm as well as market disruption that hampered their marketing operations [64, 65]. Though in some commercial farms that have some access to the market, they are less affected by market disruption. But to some commercial farmers who do not have an access are struggling to market their produce. They tend to compete with local or small-scale producer in the huge market and even with those local traders. Hence, as the supply of shrimp commodity in the market arises given with constant to lowering demand results to a lower buying price. Also, producers are forced to compete on the price demand. In this situation, local traders who mostly bought the produce of those small-scale farmers will also initiate lower price. Thus, with the high production cost and temporary increase on some input cost, lead to the decrease in profitability of production to small-holder farms. Also, limited availability of fry and fingerlings, temporary rise in cost of farm inputs, limited local supply of various inputs, timing of lockdown, and reduced shrimp farmers' ability to access needed inputs. They were constraints in accessing inputs particularly when it involved crossing a municipal boundary due to pass requirements and mandatory quarantine of 14 days when one returns to his/her municipality, even if the distance travelled is only a few kilometers [66].

Market disruption, as mentioned, significantly affected the operability of shrimp production. For instance, farmers that produced such high-priced commodity, reduction in its demand results to the decrease in price by as much as 50%. Shrimps were currently sold for as low as $3- $5 /kg from $6- $7/kg weighing 10 – 20g ABW. Due to lack of demand, they have to prolong their harvest until there is available buyer. In this case, there is additional costs of inputs during the culture period as they extended the number of culturing days. Even though the situation was difficult, most of the interviewed farmers still produced shrimp for lack of better alternative livelihoods specifically in small-holder farms. However, there were differentiated capacities for taking advantage of this sustained demand. Large-scale shrimp farmers, due to better linkage, were able to connect into other markets and do reselling in urban areas. They tend to have their own vehicles and other necessary documents that enabled them to transport their product accordingly [66]. Market operations were also reduced from 7 to 6 days in a week to give time for disinfection and in some other areas, markets were only opened after lunch time and closes early in the evening. Therefore, other vendors resorted to some alternative arrangements such as peddling their supply (fish, crabs, shrimp, etc.) in their communities and selling it in local street markets called *talipapa*.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 April 2022 doi:10.20944/preprints202203.0137.v2

Other effects of COVID-19 to the shrimp fishers family included experiencing the closing of their educational institutions which was difficult for the family that depends on fishing and farming [64,65]. Digital learning that has emerged and online learning has now become an alternative educational mode [67] . Yet most vendors can barely teach their children at home due to lack of knowledge and additional finances for internet connection [63,64,65]. Due to the sudden change, many students experienced negative impacts of the COVID-19 outbreak [68,70]. This also reduced the families' income, the limited access to digital resources and high cost of internet connectivity would cause radical change to the academic life of the student particularly in some rural areas [69,70,71] .

Sunny and colleagues (2021) estimated that the global population depends on small-scale fisheries for their livelihood that result in rising food insecurity among fishing communities [72]. Here, importance of aquaculture in food supply could help decrease threat to food insecurity. Fisheries and aquaculture provide nutritious food for hundreds of millions of people around the world and livelihoods for over 10% of the world's population [73]. Government and industry responses are needed to address the immediate economic and social hardships that the crisis is provoking in the shrimp sector. Governments also need to maintain long-term ambitions for protecting natural resources and ecosystems, and the viability of fisheries. Transparency in policy responses probably would help build trust in the future of fishery sector and markets, and use all the lesson that is acquired from the experienced crisis to improve the sustainability and the resiliency of every sector. Economic equity and environmental considerations discussed similar best practices: support the incomes of those most in need rather than subsidize inputs and ensuring that evidence-based management are intact and implemented [74].

5. Conclusion

Production of *Penaeus vannamei* has been continuously practiced in some parts of the region, from family-operated to company owned establishments, shrimp farms share some cultural practices but may differ in the level of intensification. Commercial shrimp farms are more intensified and technology advanced, the reason why they are more productive and profitable. While smallholder farms remain partially dependent on ways and knowledge they used to have over the past years of farming, and did not adopt new technologies that will help them improve their production. There are various challenges enumerated in this paper, but disease outbreak remains as a major constraint in the development of the shrimp aquaculture sector. Cultural and operational management also played significant role to prevent possible risk along the production. Shrimp aquaculture is known as an expensive farming; hence, financial resources is important to sustain the needs of the farm. Moreover, market disruption made the most significant impact regarding experience on shrimp farming during the COVID-19 pandemic. Along with this challenge: mobility restrictions, lockdown, temporary rise of input cost, lower market price of shrimps due to lower demand also affected shrimp farming.

6. Recommendation

This study recommends that farmers, should follow good shrimp aquaculture practices as stated in R.A.8550 also known as "The Philippine Fisheries Code of 1998" particularly in section 47 [75]. There must be a proper management of water quality, waste disposal and strict implementation of biosecurity and access to reliable source of post larvae to prevent outbreak of disease. In addition, the government intervention particularly in times of calamities and other form of crisis should provide programs (shrimp-related seminars, trainings, and financial or in kind support) to help farmers mitigate challenges encountered and further learn to adapt into it. Regarding the impacts of the pandemic, this has highly affected the distribution and marketing of shrimp produce. Thus, there is a need for processors to device new or other alternative products that utilize the excess supply of shrimp. Moreover, there is also a need to enhance better trading aspects of shrimp to eliminate market threat in shrimp industry.

Funding: The funding for this study was provided by DA-PRDP (Department of Agriculture-Philippine Rural Development Plan) through the project entitled: *Vulnerability assessment of Pacific Whiteleg Shrimp (Penaeus vannamei) and associated species through the fisheries value-chain in Davao region.*

Acknowledgement: This paper would not have been possible without the earlier help of our research assistants Nitcel Aymie Albarido and Darshel Ester Estor as well as the cooperation of the shrimp farmers of Davao Region who participated during the survey. We are also indebted for the opportunities provided by PRDP (Philippine Rural Development Program) for this study.

References

1. Vergel, J. C. V. (2017). Current Trends in the Philippines' Shrimp Aquaculture Industry:A Booming Blue Economy in the Pacific. *Oceanography & Fisheries Open Access Journal*, *5*(4). https://doi.org/10.19080/ofoaj.2017.05.555668
2. BFAR. (2020). Philippine Fisheries Profile 2019. *Bureau Of Fisheries And Aquatic Resources*. Quezon City, Philippines. pp. 76.
3. PSA. (2020). Fisheries Statistics of the Philippines 2017-2019. *Philippine Statistics Authority*. Quezon City, Philippines. pp. 321.
4. FAO. (2021). The State Of World Fisheries And Aquaculture 2020. FAO *Sustainability in action*. Rome. (Vol. 32, Issue 6). https://doi.org/10.4060/ca9229en
5. Loc, V. T. T. (2003). Quality management in shrimp supply chain in the Mekong Delta, Vietnam: problems and measures. *Quality Assurance*, *43*, 27.
6. Martinez-Cordova, L. R., & Martinez-Porchas, M. (2006). Polyculture of Pacific white shrimp, *Litopenaeus vannamei*, giant oyster, Crassostrea gigas and black clam, Chione fluctifraga in ponds in Sonora, Mexico. *Aquaculture*, *258*(1–4), 321–326. https://doi.org/10.1016/j.aquaculture.2006.03.026
7. Guerrero, R. D. (2019). Farmed tilapia production in the Philippines is declining: What has happened and what can be done. *Philippine Journal of Science*, 148(2), xi–xv.
8. Henriksson, P. J. G., Banks, L. K., Suri, S. K., Pratiwi, T. Y., Fatan, N. A., & Troell, M. (2019). Indonesian aquaculture futures — identifying interventions for reducing environmental impacts. *Environmental Research Letters*, 5, 1–25. https://doi.org/10.1088/1748-9326/ab4b79
9. Islam, M., & Yasmin, R. (2017). Impact of Aquaculture and Contemporary environmental issues in Bangladesh. *International Journal of Fisheries and Aquatic Studies*, *5*(4), 100–107.
10. Joffre, O. M., & Bosma, R. H. (2009). Typology of shrimp farming in Bac Lieu Province, Mekong Delta, using multivariate statistics. *Agriculture, Ecosystems and Environment*, *132*(1–2), 153–159. https://doi.org/10.1016/j.agee.2009.03.010
11. Weimin, M., Mohan, C. V, Ellis, W., & Davy, B. (2013). Adoption of aquaculture assessment tools for improving the planning and management of aquaculture in Asia and the Pacific. FAO for Asia and the Pacific Bangkok, Thailand. Rap Publication 2013/11. pp 136.
12. Walker, P. J., & Winton, J. R. (2010). Emerging viral diseases of fish and shrimp. Veterinary Research, 41(6), 51. https://doi.org/10.1051/vetres/2010022
13. Béné, C., Barange, M., Subasinghe, R., Pinstrup-Andersen, P., Merino, G., Hemre, G. I., & Williams, M. (2015). Feeding 9 billion by 2050 – Putting fish back on the menu. *Food Security*, *7*(2), 261–274. https://doi.org/10.1007/s12571-015-0427-z
14. Afroz, T., & Alam, S. (2013). Sustainable shrimp farming in Bangladesh: A quest for an Integrated Coastal Zone Management. *Ocean and Coastal Management*, *71*, 275–283. https://doi.org/10.1016/j.ocecoaman.2012.10.006

15. Tendencia, E. A., Bosma, R. H., Verdegem, M. C. J., & Verreth, J. A. J. (2015). The potential effect of greenwater technology on water quality in the pond culture of Penaeus monodon Fabricius. *Aquaculture Research*, *46*(1), 1–13. https://doi.org/10.1111/are.12152
16. Cruz, P. S., Andalecio, M. N., Bolivar, R. B., & Fitzsimmons, K. (2008). Tilapia-shrimp polyculture in Negros Island, Philippines: A review. *Journal of the World Aquaculture Society*, *39*(6), 713–725. https://doi.org/10.1111/j.1749-7345.2008.00207.x
17. Jickling, N. (n.d.). Shrimp Aquaculture in Aguadulce: Impacts on mangrove forest health and shrimp larvae populations in two sites on the Salado coastline. *Independent Study Project Collection. 2729. 1-31.* https://digitalcollections.sit.edu/isp_collection
18. Ashton, E. C. (2008). The impact of shrimp farming on mangrove ecosystems. In *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* (Vol. 3, pp. 1–12). https://doi.org/10.1079/PAVSNNR20083003
19. Barbier, E. B. (2006). Mangrove dependency and the livelihoods of coastal communities in Thailand. *Environment and Livelihoods in Tropical Coastal Zones: Managing Agriculture-Fishery-Aquaculture Conflicts. CAB International Wallingford, UK*, 126–139. https://doi.org/10.1079/9781845931070.0126
20. Gopal, B., & Chauhan, M. (2006). Biodiversity and its conservation in the Sundarban mangrove ecosystem. *Aquatic Sciences*, *68*(3), 338–354. https://doi.org/10.1007/s00027-006-0868-8
21. Cienfuegos, H. H. A., & Macinnis, R. (2015). An Analysis of Mangrove Conservation and Land Use Management in the Pablo Arturo Barrios Wildlife Refuge. *Smithsonian Tropical Research Institute*, 1–47.
22. TEEB - The Economics Of Ecosystems And Biodiversity. (2009).
23. Primavera, J. H., & Esteban, J. M. A. (2008). A review of mangrove rehabilitation in the Philippines: Successes, failures and future prospects. In *Wetlands Ecology and Management* (Vol. 16, Issue 5, pp. 345–358). https://doi.org/10.1007/s11273-008-9101-y
24. Camacho, L. D., Gevaña, D. T., Carandang, A. P., Camacho, S. C., Combalicer, E. A., Rebugio, L. L., & Youn, Y. C. (2011). Tree biomass and carbon stock of a community-managed mangrove forest in Bohol, Philippines. *Forest Science and Technology*, *7*(4), 161–167. https://doi.org/10.1080/21580103.2011.621377
25. Garcia, K. B., Malabrigo, P. L., & Gevaña, D. T. (2014). Philippines' mangrove ecosystem: Status, threats and conservation. In *Mangrove Ecosystems of Asia: Status, Challenges and Management Strategies* (pp. 81–94). Springer New York. https://doi.org/10.1007/978-1-4614-8582-7_5
26. Orchard, S. E., Stringer, L. C., & Quinn, C. H. (2015). Impacts of aquaculture on social networks in the mangrove systems of northern Vietnam. *Ocean and Coastal Management*, *114*, 1–10. https://doi.org/10.1016/j.ocecoaman.2015.05.019
27. Blaber, S. J. M. (2007). Mangroves and fishes: Issues of diversity, dependence, and dogma. *Bulletin of Marine Science*, *80*(3), 457–472.
28. Nagelkerken, I., Blaber, S. J. M., Bouillon, S., Green, P., Haywood, M., Kirton, L. G., Meynecke, J. O., Pawlik, J., Penrose, H. M., Sasekumar, A., & Somerfield, P. J. (2008). The habitat function of mangroves for terrestrial and marine fauna: A review. In *Aquatic Botany* (Vol. 89, Issue 2, pp. 155–185). https://doi.org/10.1016/j.aquabot.2007.12.007
29. Anh, P.T., Kroeze, C., Bush, S.R., Mol, A.P.J. (2010). Water pollution by intensive brackish shrimp farming in south-east Vietnam: *Causes and options for control. 97(6), 0–882*. doi: 10.1016/j.agwat.2010.01.018
30. Sheridan, P., & Hays, C. (2003). *Are Mangroves Nursery Habitat For Transient Fishes And Decapods? 23*(2), 449–458.
31. Islam, S., & Wahab, A. (2005). A review on the present status and management of mangrove wetland habitat resources in Bangladesh with emphasis on mangrove fisheries and aquaculture. In *Hydrobiologia* (Vol. 542, Issue 1, pp. 165–190). https://doi.org/10.1007/s10750-004-0756-y
32. Rudianto, R., Bengen, D. G., & Kurniawan, F. (2020). Causes and effects of mangrove ecosystem damage on carbon stocks and absorption in East Java, Indonesia. *Sustainability (Switzerland)*, *12*(24), 1–17. https://doi.org/10.3390/su122410319
33. Alauddin, M., & Hamid, M. A. (2000). Shrimp culture in Bangladesh with emphasis on social and economic aspects. In: Smith PT, editor. Towards Sustainable Shrimp Culture in Thailand and the Region. ACIAR Proceedings No. 90. Australian Centre for International Agricultural Research, Canberra, Australia. Pp. 53–62.
34. Bondad-Reantaso, M. G., Subasinghe, R. P., Josupeit, H., Cai, J., & Zhou, X. (2012). The role of crustacean fisheries and aquaculture in global food security: Past, present and future. In *Journal of Invertebrate Pathology* (Vol. 110, Issue 2, pp. 158–165). https://doi.org/10.1016/j.jip.2012.03.010
35. Fonseca, H. (2002). Mangroves Local livelihoods vs. corporate profits. World Rainforest Movement: Gilbert AJ, Janssen R. Use of environmental functions to communicate the values of a mangrove ecosystem under different management regimes. Ecological Economics 1998; 25:323-46.
36. Macusi, E. D., Katikiro, R. E., Deepananda, K. H. M. A., Jiminez, L. A., Conte, A. R., & Nur Fadli. (2011). Human Induced Degradation of Coastal Resources in Asia Pacific and Implications on Management and Food Security *Journal Nature of Studies* 9(2)/10(1):xxx-xxx..
37. Shinn, A. P., Pratoomyot, J., Griffiths, D., Trong, T. Q., Vu, N. T., Jiravanichpaisal, P., & Briggs, M. (2018). Asian Shrimp Production and the Economic Costs of Disease. *Asian Fisheries Science*, *31S*, 29–58.
38. Dabu, I. M., Lim, J. J., Arabit, P. M. T., Orense, S. J. A. B., Tabardillo, J. A., Corre, V. L., & Maningas, M. B. B. (2015). The first record of acute hepatopancreatic necrosis disease in the Philippines. *Aquaculture Research*, 1–8. https://doi.org/10.1111/are.12923
39. De La Peña, L. D., Lavilla-Pitogo, C. R., Villar, C. B. R., Paner, M. G., Sombito, C. D., & Capulos, G. C. (2007). Prevalence of white spot syndrome virus (WSSV) in wild shrimp Penaeus monodon in the Philippines. *Diseases of Aquatic Organisms*, *77*(3), 175–179. https://doi.org/10.3354/dao01834

40. Flegel, T. W., Nielsen, L., Thamavit, V., Kongtim, S., & Pasharawipas, T. (2004). Presence of multiple viruses in non-diseased, cultivated shrimp at harvest. *Aquaculture*, *240*(1–4), 55–68. https://doi.org/10.1016/j.aquaculture.2004.06.032
41. Karunasagar, I., & Ababouch, L. (2012). Shrimp viral diseases, import risk assessment and international trade. *Indian Journal of Virology*, *23*(2), 141–148. https://doi.org/10.1007/s13337-012-0081-4
42. Cuvin-Aralar, M. L. A., Lazartigue, A. G., & Aralar, E. V. (2009). Cage culture of the Pacific white shrimp Litopenaeus vannamei (Boone, 1931) at different stocking densities in a shallow eutrophic lake. *Aquaculture Research*, *40*(2), 181–187. https://doi.org/10.1111/j.1365-2109.2008.02081.x
43. Briggs, M., Funge-Smith, S., Subasinghe, R., & Phillips, M. (2004). Introductions and movement of Penaeus vannamei and Penaeus stylirostris in Asia and the Pacific. *FAO: Bangkok, Thailand*, 88.
44. Cao, L. (2012). Characterization Of Chinese Shrimp Farming Systems Towards Typology, Economic And Social Sustainability. *Farming Shrimp For The Future: A Sustainability Analysis Of Shrimp Farming In China*, 103–131.
45. White, P., Phillips, M., & Beveridge, M. (2010). Review of environmental impact, site selection and carrying capacity estimation for small scale aquaculture in Asia FAO expert workshop on Site Selection and Carrying Capacity Estimates for Inland and Coastal Waterbodies.
46. Rapsomanikis, G. (2015). The economic lives of smallholder farmers. *Food and Agriculture Organization*. www.fao.org/publications
47. Li, Y., Li, J., & Wang, Q. (2006). The effects of dissolved oxygen concentration and stocking density on growth and non-specific immunity factors in Chinese shrimp, Fenneropenaeus chinensis. *Aquaculture*, *256*(1–4), 608–616. https://doi.org/10.1016/j.aquaculture.2006.02.036
48. Araneda, M., Pérez, E. P., & Gasca-Leyva, E. (2008). White shrimp Penaeus vannamei culture in freshwater at three densities: Condition state based on length and weight. *Aquaculture*, *283*(1–4), 13–18. https://doi.org/10.1016/j.aquaculture.2008.06.030
49. Thakur, K., Patanasatienkul, T., Laurin, E., Vanderstichel, R., Corsin, F., & Hammell, L. (2018). Production characteristics of intensive whiteleg shrimp (Litopenaeus vannamei) farming in four Vietnam Provinces. *Aquaculture Research*, *49*(8), 2625–2632. https://doi.org/10.1111/are.13720
50. Eid, A., Ali, B., Al Sayed, K., Marzok, S., Khames, M., & Khames, D. (2020). Stocking density, Survival rate and Growth performance feed utilization and economic evaluation of Litopenaeus vannamei (Boon, 1931) in different cultured shrimp farms in Suez Canal Region. *Egyptian Journal for Aquaculture*, *10*(3), 96–114. https://doi.org/10.21608/eja.2020.43323.1036
51. Ruiz-Velazco, J. M. J., Hernández-Llamas, A., Gomez-Muñoz, V. M., & Magallon, F. J. (2010). Dynamics of intensive production of shrimp Litopenaeus vannamei affected by white spot disease. *Aquaculture*, *300*(1–4), 113–119. https://doi.org/10.1016/j.aquaculture.2009.12.027
52. Smith, M. D., Roheim, C. A., Crowder, L. B., Halpern, B. S., Turnipseed, M., Anderson, J. L., Asche, F., Bourillón, L., Guttormsen, A. G., Khan, A., Liguori, L. A., McNevin, A., O'Connor, M. I., Squires, D., Tyedmers, P., Brownstein, C., Carden, K., Klinger, D. H., Sagarin, R., & Selkoe, K. A. (2010). Sustainability and global seafood. *Science*, *327*(5967), 784–786. https://doi.org/10.1126/science.1185345
53. Paul, B. G., & Vogl, C. R. (2011). Impacts of shrimp farming in Bangladesh: Challenges and alternatives. In *Ocean and Coastal Management* (Vol. 54, Issue 3, pp. 201–211). https://doi.org/10.1016/j.ocecoaman.2010.12.001
54. Gräslund, Sara, & Bengtsson, B. E. (2001). Chemicals and biological products used in south-east Asian shrimp farming, and their potential impact on the environment - A review. *Science of the Total Environment*, *280*(1–3), 93–131. https://doi.org/10.1016/S0048-9697(01)00818-X
55. Cataldo, E., Salvi, L., Paoli, F., Fucile, M., Masciandaro, G., Manzi, D., Masini, C. M., & Mattii, G. B. (2021). Application of zeolites in agriculture and other potential uses: A review. In *Agronomy* (Vol. 11, Issue 8). MDPI AG. https://doi.org/10.3390/agronomy11081547
56. Gräslund, S., Holmström, K., & Wahlström, A. (2003). A field survey of chemicals and biological products used in shrimp farming. *Marine Pollution Bulletin*, *46*(1), 81–90. https://doi.org/10.1016/S0025-326X(02)00320-X
57. Maralit, B. A., Caipang, C. M. A., Santos, M. D., & Maningas, M. B. B. (2011). PCR detection of white spot syndrome virus (WSSV) from farmed Pacific white shrimp (Litopenaeus vannamei) in selected sites of the Philippines. *Aquaculture, Aquarium, Conservation & Legislation International Journal of the Bioflux Society*, *4*(4), 474–480. http://www.bioflux.com.ro/aacl
58. Lavilla Pitogo, C. R., Lio Po, G. D., Cruz Lacierda, E. R., Alapide Tendencia, E. V., & De la Peña, L. D. (2000). Diseases of Penaeid Shrimps in the Philippines. In *SEAFDEC Tigbauan, Iloilo* (Issue 16).
59. Natividad, K. D. T., Migo, M. V. P., Albaladejo, J. D., Magbanua, J. P. V., Nomura, N., & Matsumura, M. (2006). Simultaneous PCR detection of two shrimp viruses (WSSV and MBV) in postlarvae of Penaeus monodon in the Philippines. *Aquaculture*, *257*(1–4), 142–149. https://doi.org/10.1016/j.aquaculture.2006.02.061
60. Corre, V. (1993). The Shrimp Farming Industry In The Philippines. Proceedings of the Aquaculture Workshop for SEAFDEC/AQD Training Alumni; 8-11 September 1992; Iloilo, Philippines. *SEAFDEC Aquaculture Department, Iloilo, Philippines*, 88–103.
61. Hall, G., Laddu, D. R., Phillips, S. A., Lavie, C. J., & Arena, R. (2020). A tale of two pandemics: How will COVID-19 and global trends in physical inactivity and sedentary behavior affect one another? *Progress in Cardiovascular Diseases*, *64*(xxxx), 108–110. https://doi.org/10.1016/j.pcad.2020.04.005
62. Shereen, M. A., Khan, S., Kazmi, A., Bashir, N., & Siddique, R. (2020). COVID-19 infection: Origin, transmission, and characteristics of human coronaviruses. *Journal of Advanced Research*, *24*, 91–98. https://doi.org/10.1016/j.jare.2020.03.005

63. Ferrer, A. J. G., Pomeroy, R., Akester, M. J., Muawanah, U., Chumchuen, W., Lee, W. C., Hai, P. G., & Viswanathan, K. K. (2021). Covid-19 and small-scale fisheries in southeast asia: Impacts and responses. *Asian Fisheries Science*, *34*(1), 99–113. https://doi.org/10.33997/j.afs.2021.34.1.011
64. Macusi, E.D., Siblos, S.K.V., Betancourt, M.E.S., Macusi, E.S., Calderon, M.N., Bersaldo, M.J.I., Digal, L.N. (2022) Impacts of COVID-19 on the catch of small-scale fishers and their families due to restriction policies in Davao Gulf, Philippines. *Frontiers in Marine Science 8*, *770543*, doi:doi: 10.3389/fmars.2021.770543.
65. Macusi, E.D., Rafon, J.K.A., Macusi, E.S. (2021) Impact of COVID-19 and closed fishing season on commercial fishers of Davao Gulf, Mindanao, Philippines. *Ocean & Coastal Management 217*, *105997*, doi:DOI: 10.1016/j.ocecoaman.2021.105997.
66. Manlosa, A. O., Hornidge, A.-K., & Schlüter, A. (2021). Aquaculture-capture fisheries nexus under Covid-19: impacts, diversity, *and* social-ecological resilience. *Maritime Studies*, *20*, 75–85. https://doi.org/10.1007/s40152-021-00213-6/Published
67. Chaturvedi, K., Vishwakarma, D. K., & Singh, N. (2021). COVID-19 and its impact on education, social life and mental health of students: A survey. *Children and Youth Services Review*, *121*, 105866. https://doi.org/10.1016/j.childyouth.2020.105866
68. Kapasia, N., Paul, P., Roy, A., Saha, J., Zaveri, A., Mallick, R., Barman, B., Das, P., & Chouhan, P. (2020). Impact of lockdown on learning status of undergraduate and postgraduate students during COVID-19 pandemic in West Bengal, India. *Children and Youth Services Review*, *116*, 105–194. https://doi.org/10.1016/j.childyouth.2020.105194
69. Bestiantono, D. S., Agustina, P. Z. R., & Cheng, T.-H. (2020). How Students' Perspectives about Online Learning Amid the COVID-19 Pandemic? *Studies in Learning and Teaching*, *1*(3), 133–139. https://doi.org/10.46627/silet.v1i3.46
70. Aucejo, E. M., French, J., Ugalde Araya, M. P., & Zafar, B. (2020). The impact of COVID-19 on student experiences and expectations: Evidence from a survey. *Journal of Public Economics*, *191*, 104–271. https://doi.org/10.1016/j.jpubeco.2020.104271
71. Lee, J. (2020). Mental health effects of school closures during COVID-19. *The Lancet Child and Adolescent Health*, *4*(6), 421. https://doi.org/10.1016/S2352-4642(20)30109-7
72. Sunny, A. R., Sazzad, S. A., Prodhan, S. H., Ashrafuzzaman, M., Datta, G. C., Sarker, A. K., Rahman, M., & Mithun, M. H. (2021). Assessing impacts of COVID-19 on aquatic food system and small-scale fisheries in Bangladesh. Marine Policy, 126, 104422. https://doi.org/10.1016/j.marpol.2021.104422
73. Roubík, H., Lošťák, M., Ketuama, C. T., Procházka, P., Soukupová, J., Hakl, J., Karlík, P., & Hejcman, M. (2022). Current coronavirus crisis and past pandemics - What can happen in post-COVID-19 agriculture? Sustainable Production and Consumption, 30, 752–760. https://doi.org/10.1016/j.spc.2022.01.007
74 Howarth, W., Hernandez, R., & Houtte, A. Van. (2001). Legislation Governing Shrimp Aquaculture: Legal Issues, National Experiences and Options. FAO Legal Papers Online, 149. http://www.fao.org/fileadmin/user_upload/legal/docs/lpo18.pdf

75 Congress of the Philippines. (1998). The Philippine Fisheries Code of 1998 "An Act Providing for the Development, Management and Conservation of the Fisheries and Aquactic Resources, Integrating all laws pertinent thereto and for other purposes" (Republic Act no. 8550). Quezon City, Philippines