

## Article

# Vulnerability Assessment of Pacific Whiteleg Shrimp (*Penaeus vannamei*) Farms and Vendors in Davao, Philippines Using FishVool

Edison D. Macusi <sup>1,\*</sup> , Nitcel Aymie Albarido <sup>1</sup>, Misael B. Clapano <sup>1</sup> and Mudjekeewis D. Santos <sup>2</sup>

- <sup>1</sup> Shrimp Vulnerability Assessment Project, Institute of Agriculture and Life Sciences (IALS), Davao Oriental State University (DOOrSU), Mati City 8200, Philippines; cutenitcel23@gmail.com (N.A.A.); loymbc@yahoo.com (M.B.C.)
- <sup>2</sup> National Fisheries Research Development Institute (NFRDI), 101 Mother Ignacia Street, Quezon City 1008, Philippines; mudjiesantos@gmail.com
- \* Correspondence: edison.macusi@dorsu.edu.ph

**Abstract:** The impacts of climate change on shrimp aquaculture can vary widely and can have environmental and socioeconomic consequences. This study assessed the vulnerability to climate change impacts of selected small-scale shrimp farms of *Penaeus vannamei* and shrimpfish market vendors in the Davao region, the Philippines, using a modified Fisheries Vulnerability Assessment Tool (FishVool). Shrimp farmers and vendors were interviewed using two separate semi-structured questionnaires. A total of thirty-nine ( $n = 39$ ) shrimp farmers and forty-eight ( $n = 48$ ) market vendors from various market areas within the region were interviewed. Data regarding exposure (E), sensitivity (S), and adaptive capacity (AC) were collected following the FishVool parameters with modifications. Results revealed that the overall climate change vulnerability of the shrimp farmers was medium (M), where both exposure and adaptive capacity were low (L) while sensitivity was medium (M). In addition, the shrimp market vulnerability of the various sites examined revealed medium (M) scores for markets in Pantukan, Mabini, Tagum, Maco, Lupon, Davao City, and Digos, and high (H) vulnerability scores for the markets in Panabo and Sta Cruz. Overall, the study provided a better understanding of shrimp farming in relation to climate change impacts and vulnerability and provided information for future shrimp farm management, marketing, and climate change adaptation in the region.

**Keywords:** aquaculture; climate change; Davao Oriental; FishVool; management; Mati City; shrimp culture



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## 1. Introduction

Shrimp production provides a wide range of economic benefits, for instance, food security, livelihood, and the well-being of fisherfolk, fish farmers, and processors [1,2]. Hence, the culture of shrimp in coastal communities makes significant contributions to national and global economies, poverty reduction, and food security for the world's well-being and prosperity [3]. The production value of white shrimp (*Penaeus setiferus*) aquaculture in the Philippines was estimated at 1175 mt and valued at Php 216 million, and 1018 mt valued at Php 288 million in 2019 and 2020 [4]. Meanwhile for *Penaeus vannamei* this was 19,152 mt valued at Php 4.9 billion and 20,632 mt valued at Php 5.2 billion in 2019 and 2020 [4]. *P. vannamei* was introduced in the Philippines in 1978–1979 and later in 1988 in China, but commercially it has only been introduced since 1996 in Mainland China and Taiwan, followed by most other coastal Asian countries [5].

The commercial success of *P. vannamei* and its introduction into Asia can be attributed to its superior aquaculture traits when compared with the most popular cultured penaeid shrimp, the *Penaeus monodon*. Its advantages include higher availability of genetically

selected viral-pathogen-free domesticated broodstock, high larval survival, faster growth rate, better tolerance to high stocking density, lower dietary protein requirement, more efficient utilization of plant proteins in formulated diets, stronger adaptability to low salinity, better tolerance to ammonia and nitrite toxicity, and lower susceptibility to serious viral pathogens infecting *P. monodon*, and some marketing advantages [5,6]. For the tiger prawn (*Penaeus monodon*), the production volume was 45,732 mt valued at Php 23 billion and 42,093 mt valued at Php 20.4 billion in 2019 and 2020 [4]. The total area of shrimp farms in the country in 1992 was 49,478 ha, of which 47,774 was devoted to the black tiger shrimp; 1006 ha was allotted to endeavor shrimp (*Metapenaeus ensis* or “hipong suahe”); and 638 ha to white shrimp (*Penaeus indicus*, *Penaeus setiferus* or “hipong puti”). The total hectares under shrimp production constitutes 23% of the country’s brackish water fishponds. Luzon has 20,940 ha (44%) of total shrimp farm area; Visayas has 14,314 ha (30%); and Mindanao has 12,519 ha (26%) [7]. On the other hand, there were 260,000 ha of brackish water ponds, 6700 ha of freshwater pens and about 500 ha of marine pens and cages used to culture milkfish [8]. However, shrimp production in the past years has been affected by various challenges, including diseases, stricter biosecurity measures, marine pollution, a lack of premium access to markets abroad, and climate change impacts. Shrimp farming has brought about widespread social and economic benefits. However, a wide range of environmental issues, including climate change, has recently been identified to threaten the sustainability of coastal aquaculture [9]. Seafood farming (aquaculture) is probably the fastest-growing sector in the world for food production. Yet, they may also have negative effects on the environment that should be properly addressed, to make aquaculture a sustainable activity [10]. Shrimp ponds have traditionally been constructed near estuarine zones, especially in wetlands and mangrove swamps, creating a concern with environmental impacts, since it may cause the destruction of large areas of mangrove forests [11].

Globally, shrimp farming has been under intense criticism because of its socioeconomic and environmental impacts [8–10]. During the 1980s and 1990s, the rapid growth of shrimp farming caused the widespread destruction of mangroves in a number of countries, including Bangladesh, Brazil, China, India, Indonesia, Malaysia, Mexico, Myanmar, Sri Lanka, the Philippines, Thailand, and Vietnam [11,12]. Today, most of these mangrove areas have been seriously damaged or replaced with ponds with devastating effects on mangroves [7,13,14].

Changes in climate variables largely affect shrimp production and market by increasing the frequency of shrimp disease, causing physical damage to farm structures, and deteriorating the quality of water. These damages to fisheries, aquaculture, and farm infrastructures have been previously documented in past events and even based on fisher knowledge [2,15,16]. Shrimp farmers try to adapt to these changes in various ways, including increasing pond depth, exchanging tidal water, strengthening earthen dike and netting and fencing around the dike, or using paddle wheels to increase the oxygen content of the pond water and allow better water circulation in the pond [17]. However, there is a lack of understanding concerning the impacts of climate change and its effects on local shrimp farmers and their livelihood. It is essential to understand the impacts of climate change variabilities and the corresponding vulnerabilities of fish farmers so that these insights for localized adaptations will help build their climate resilience in this aquaculture system [17].

Climate change impacts have also been implicated as one possible cause of the destruction of ponds as well as the spread of disease [2]. According to the study of Eckstein et al. [18], the Philippines ranks fourth (4th) overall among the most affected by extreme weather events due to climate change based on the long-term climate risk index (CRI). Vulnerability is particularly defined by the IPCC [19] as “the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt” [20,21]. Given the possible impacts of climate change on various aquaculture systems, there is a need for a vulnerability assessment to be conducted from time to time

to provide status, a course of action, and possible adaptation to the impacts of climate change [21]. Vulnerability assessment (VA) provides a framework for climate change impacts evaluation over a broad range of systems. Vulnerability assessments, especially for fisheries and aquaculture, provide a better way to understand the interactions among the natural system, pressures, and threats, which serve as a basis for the development of climate change adaptation (CCA) options [22,23]. Tools such as the Fisheries Vulnerability Assessment Tool (FishVool) have been developed for vulnerability assessments in the fisheries [2,24–26]. In the past, this was applied to assess the vulnerability of tuna fishery in General Santos City and sardine fishery in Zamboanga City, where fifty local fishermen were interviewed at selected landing sites, of which 25 were from General Santos and 25 were from Zamboanga City. The vulnerability indices for tuna fishers in General Santos and sardines in Zamboanga City indicate medium overall vulnerability, which indicates that the tuna and sardine resources were vulnerable to climate change impacts. In this study, we assessed the level of vulnerability of Pacific whiteleg shrimp (*Penaeus vannamei*) to the impacts of climate change and measured the impacts of climate change variability on the shrimp farming sectors using a modified FishVool tool [2,26].

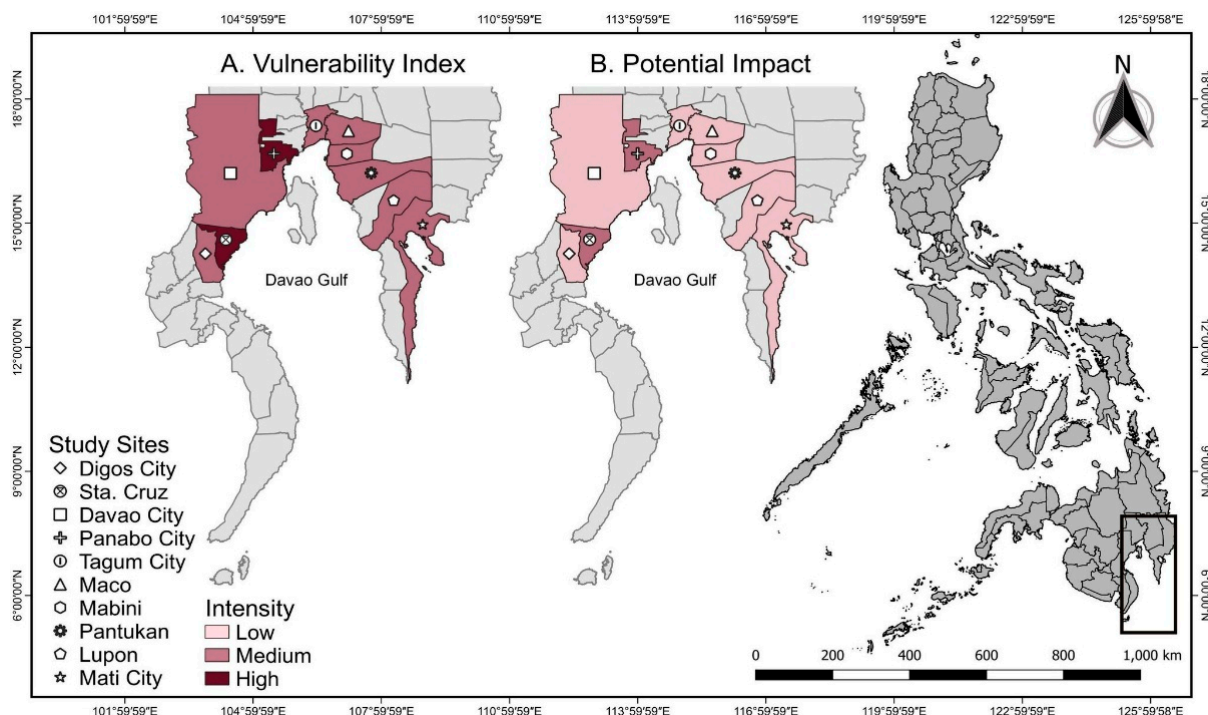
## 2. Methodology

### 2.1. Description of Study Area

The study was conducted in selected shrimp farms areas in Davao Region (Figure 1). The areas were selected according to the list given by BFAR XI through the municipal agriculture offices of the selected municipalities and barangays. Davao region is located in the southeastern portion of the island of Mindanao surrounding the Davao Gulf. It is bounded on the north by the provinces of Surigao del Sur, Agusan del Sur and Bukidnon. In the east, it is bounded by the Philippine Sea, and in the west by the Central Mindanao provinces. Within the broader geographic context, the Davao region area faces Micronesia in the Southern Pacific Ocean to the east, and Eastern Indonesia through the Celebes Sea to the south. Davao region is blessed with a good climate as it experiences Types II and IV climates and lies outside the typhoon belt. Type II climate is characterized by the fair distribution of rainfall and sunlight throughout the year; with very pronounced rainfall from November to January. This affects Davao Oriental and most parts of Compostela Valley. The region's annual rainfall based on climatological data of Davao City ranges from 1673.3 mm to 1941.8 mm with an average temperature in the region that ranges from 28 °C to 29 °C. Warm temperatures are experienced from February to October while the coolest months start from November up to January (<http://davao.da.gov.ph/index.php/about-us/regional-profile>; accessed on 13 February 2022).

### 2.2. Data Collection and Analysis

The Fisheries Vulnerability Assessment Tool (FishVool) was used to gather information on exposure, sensitivity, and adaptive capacity through key informant interviews [24]. This tool was previously developed by Jacinto and his colleagues [24] for a simplified vulnerability assessment of fishing communities and their fisheries resources. The revision of this FishVool for application in various fisheries commodities has been elaborated in Macusi et al., 2021 [2]. Every fishery resource, including aquaculture resources, have unique aspects to them in terms of vulnerability to climate change impacts as well as adaptation to these impacts because they differ in various aspects, such as economic, social, cultural and even environmental aspects, making it imperative that successful vulnerability assessments require modifications of tools used in one fisheries resource [2,25]. In data gathering, key informants were interviewed using the questionnaires derived from FishVool with some modifications for the farm vulnerability assessment and for the market vulnerability assessment; see Table 1.



**Figure 1.** Map of the study area including its Climate Change Vulnerability Index (A) and Potential Impacts (B).

**Table 1.** Shrimp vulnerability assessment matrix (scoring guide: low = 1 to 2, medium = 2 to 3.9, high = 4.1 to 5).

Components	Score			
	1 or 2	3 or 4	5	
Mortality rate (S1; compare your harvest 5 years ago)	Low; Very low	Medium; High	Very high	
Growth rate (S2; weight of harvest per unit area)	Highly increased; Increased	No change; Decreased	Highly decreased	
Water quality of pond (S3)	Low; Very low	Medium; High	Very high	
Water temperature (S4)	Very low frequency; Low frequency	Medium frequency; High frequency	Warmed compared 5 yrs ago	
Source of pond water (S5)	Silted; Low siltation	Neutral; No siltation	Good quality	
Source of fry/post-larvae (S6)	Highly abundant, Abundant	No change; Decreased	Highly decreased	
Change in salinity level (S7)	Very low frequency; Low frequency	Medium frequency; High frequency	Salinity has changed compared 5 yrs ago	
Exposure	Shrimp pond exposure in the farm (E1)	Rare occurrence (0–1; 2)	intermediate occurrence (3–4; 5–6)	Frequent occurrence (>6 times a year)
	Household site exposure to extreme events (E2)	Rare occurrence (0–1; 2)	intermediate occurrence (3–4; 5–6)	Frequent occurrence (>6 times a year)
	Community site exposure to extreme events (E3)	Rare occurrence (0–1; 2)	intermediate occurrence (3–4; 5–6)	Frequent occurrence (>6 times a year)

Table 1. Cont.

	Components	Score		
		1 or 2	3 or 4	5
Adaptive capacity	Climate change awareness (AC1)	1; 2	3; 4	5
	Access to information (AC2)	1; 2	3; 4	5
	Adaptive strategies (AC3)	1; 2	3; 4	5
	Cultural practices modification (AC4)	1; 2	3; 4	5
	Climate change support (AC5)	1; 2	3; 4	5
	Literacy (AC6)	1; 2	3; 4	5

This study assessed  $n = 39$  shrimp farmers and  $n = 48$  market vendors for a total of  $N = 87$  respondents. Data were analyzed using the scoring guide, and the rubrics provided by the FishVool manual elaborated in Jacinto et al., 2015, with minor modifications implemented in terms of parameters that were used for sensitivity, exposure, and adaptive capacity, as we adopted it to the shrimp fisheries and shrimp market assessment [24,25]. These modifications were discussed in each criterion, for the farm vulnerability index and the market vulnerability index.

### 2.3. Farm Vulnerability Index Criteria for Vulnerability Components

**Sensitivity.** Sensitivity (S) represents the present state of the shrimps in response to the exposure factors arising from climate change. In the case of sensitivity factor 1 or S1, the *mortality rate* measures the rate of damage or dead shrimps during the culture period. While sensitivity factor 2 or S2 is the *growth rate*, which measures the average length of shrimp which pertains to the age or size from the stocking period up to harvest. In the case of sensitivity factor 3 or S3, this refers to the *water quality* of the pond, and sensitivity factor 4 or S4 is for the *water temperature*, which pertains to probabilities of changes that were compared to the past 5 years. For sensitivity factor 5 or S5, this refers to the *source of pond water*, which measures the quality of water if it is good or has experienced siltation. Additionally, for sensitivity factor 6 or S6, this refers to the *source of fry*, which refers to the quantity of fry delivered to the farm from the source hatchery. Lastly, for sensitivity factor 7 or S7, this refers to a change in the *salinity level* experienced in the past 5 years.

**Exposure.** Exposure (E) factors are those climate variables included in the assessment that could impact the shrimps (e.g., typhoons, tidal fluctuations, sea-level rise, flood, unpredictable rainfall, and increasing water temperature). Here, exposure factors were chosen based on the criteria adapted from Jacinto et al. [24]. Exposure factor 1 (E1) is for *shrimp pond exposure*, which pertains to the frequency and severity of exposure of shrimp ponds to extreme weather disturbances. While for exposure factor 2 (E2), this is for the exposure of *households site*, and for exposure factor 3 (E3), the exposure of the *community sites* to extreme weather disturbances, pertaining to human exposure and to the community.

**Adaptive Capacity.** Adaptive capacity (AC) pertains to the ability of the system to cope with the impacts associated with the changes in climate. For adaptive capacity 1 or AC1, this refers to the *level of awareness* and the extent of the shrimp farmers' knowledge of climate change and its impacts on their livelihood. While for adaptive capacity 2 (AC2), this refers to *access to information* or the shrimp farmers' accessibility to climate-related knowledge through different means. In the case of adaptive capacity 3 (AC3), this refers to the *precautionary measures* that the shrimp farmers undertake before, during, and after an extreme weather event. Moreover, adaptive capacity 4 (AC4) refers to *shrimp farming modification* or changes adopted for better and more effective shrimp farming practices. Adaptive capacity 5 (AC5) refers to *the community support systems* and programs. Lastly,

adaptive capacity 6 or (AC6), refers to *literacy* which pertains to the educational attainment of the farmers.

All of these were referred to in Table 1, while slight changes have been done to accommodate aspects of the market vulnerability assessment of this study, which is also discussed below.

#### 2.4. Market Vulnerability Index Criteria for Vulnerability Components

**Sensitivity.** Sensitivity (S) represents the present state of the shrimps in response to the exposure factors arising from climate change. S1 refers to the *volume of shrimp supply*, which measures the quantity of delivered shrimp in the market. While S2 refers to the *rate of damage* to shrimp products during transport and measures the number of dead shrimps during delivery to the marketplace. In the case of S3, this refers to the *growth of sales*, which measures the income of the vendor/seller in a span of time. In connection with S3, S4 refers to the dependence on a resource, which relates to the *sellers' source of income*. Additionally, S5 will refer to the changes in temperature, which pertains to *environmental changes* in temperature in the marketplace when compared to 5 years ago. Lastly, S6 also refers to the *health condition* or the health needs of the vendors/sellers.

**Exposure.** Exposure (E) factors are those climate variables included in the assessment that could impact the shrimps (e.g., typhoons, tidal fluctuations, sea-level rise, flood, unpredictable rainfall, and increasing water temperature). Here, exposure factors were chosen based on the criteria adapted from Jacinto and others [24]. E1 refers to the *stall or marketplace exposure*, which pertains to the frequency and severity of exposure of the marketplace to extreme weather disturbances. In addition, E2 pertains to the *exposure of households' sites* and E3 relates to exposure of the *community sites* to extreme weather disturbances, pertaining to human exposure and to the community.

**Adaptive Capacity.** Adaptive capacity (AC) refers to the ability of the system to cope with the impacts associated with the changes in climate. AC1 pertains to the *level of awareness* and the extent of the shrimp vendors' knowledge of climate change and its impacts on their livelihood. On the other hand, AC2 relates to the *access to information* or to the vendors'/seller's accessibility to climate-related information through different means. While for AC3, this refers to the adaptive strategies or *precautionary measures* that the shrimp farmers undertake before, during, and after the occurrence of an extreme weather event. In the case of AC4, this is for the modification of the *marketing strategies* adopted for better and effective selling of shrimp. Additionally, AC5 pertains to the *community support systems* and programs for shrimp vendors about climate change. Lastly, AC6 is for *literacy*, which refers to the seller's educational background. Below, you will find Table 1, which contains the scoring matrix used in the study with a point system from 1 to 5, and Tables 2 and 3 refer to the rubrics which were used to find the potential impact and the level of vulnerability of the fish farmers and farming communities as well as the markets. Table 4 will refer to the vulnerability category based on the scores of the respondents from the assessment.

**Table 2.** Potential impact scoring.

		Potential Impact		
		Sensitivity		
Exposure		L	M	H
	L	L	L	M
	M	L	M	H
	H	M	H	H

**Table 3.** Overall vulnerability index scoring.

		Vulnerability			
		Adaptive Capacity			
Potential Impact		L	M	H	
		L	M	L	M
		M	H	M	L
		H	H	H	M

**Table 4.** Vulnerability category based on score.

Vulnerability Category	Score
Low	0 to 2
Medium	2.1 to 4
High	4.1 to 5

### 3. Results

Exposure (E) analysis revealed 1.5 and 1.3 values for E1 and E2 criteria (Table 1). These values indicate that both shrimp ponds (E1) and households and communities (E2), experienced rare (0–2 times) occurrences of weather disturbances, such as typhoons, floods, tidal fluctuations, storm surges, or other extreme events.

Sensitivity (S) analysis on whiteleg shrimps revealed values of 2, 2.9, 2.2, 2.1, 2.5, and 1.7 for S1, S2, S3, S4, S5, S6, and S7 criteria, respectively (Table 5). Thus, most shrimp farmers experienced a low mortality rate and observed no changes in the growth of shrimp in the past 5 years of farming. In terms of other criteria, like water quality, water temperature, water source, and source of fry, those were observed to be on neutral to medium parameters that range from 2–3 times, respectively. In addition, the change in the salinity level of the water in the pond was low for the past 5 years.

**Table 5.** Average scores and vulnerability index for sensitivity, exposure, and adaptive capacity of shrimp farmers in Davao Oriental, Philippines.

Vulnerability Assessment (VA) Components	Parameters	Score	Average Score	Vulnerability Index
Sensitivity (S)	S1: Mortality rate	2	2.3	M
	S2: Growth	2.9		
	S3: Water quality of pond	2.2		
	S4: Water temperature	2.1		
	S5: Source of pond water	2.5		
	S6: Source of fry	2.5		
	S7: Change in salinity	1.7		
Exposure (E)	E1: Exposure of shrimp ponds to weather disturbances/natural hazard	1.5	1.4	L
	E2: Household site assessment	1.3		
	E3: Community site assessment	1.3		
Adaptive Capacity (AC)	AC1: Climate change awareness	2.5	2	L
	AC2: Source of information	1.8		
	AC3: Adaptive strategy	2.3		
	AC4: Modification of cultural practices	1.4		
	AC5: Support on climate change organization	1.5		
	AC6: Literacy	2.7		

The adaptive capacity (AC) of the whiteleg shrimp farms in terms of climate change activities revealed values of 2.5, 1.8, 2.3, 1.4, 1.5, and 2.7 for AC1, AC2, AC3, AC4, AC5,

and AC6 criteria (Table 5). These findings revealed that some shrimp farmers have a modest knowledge of what climate change is and how such a phenomenon may affect their lives and livelihood. The basic source of information for shrimp farmers on climate change mostly comes from television, the internet, and school. Most of them have minor precautionary measures undertaken to mitigate the impacts of weather disturbances that might occur, such as the deep excavation of water drainage, and elevated dikes, to prevent the possible damage of ponds and shrimps. However, there were slight modifications applied to their cultural practices (feeding, water management, etc.), including attending seminars to increase their knowledge, yet no additional resources were given to them that could have increased their harvest yield. Moreover, most of the shrimp farmers did not receive any kind of support from other organizations with regard to climate change-related programs.

Overall, the average vulnerability assessment score revealed a medium vulnerability. The scores were 2.3 or medium for sensitivity, 1.4 or low for exposure and 2 or low also for adaptive capacity. Moreover, the scores indicated a low (L) potential impact and medium (M) vulnerability for whiteleg shrimp (*Penaeus vannamei*) in Davao region (Table 6).

**Table 6.** Overall average values of sensitivity, exposure, and adaptive capacity.

Overall Average Assessment Values		
Sensitivity	2.3	M
Exposure	1.4	L
Adaptive Capacity	2	L

To quantify and obtain the climate change vulnerability index of the various markets in Davao region, the FishVool tool was used to gather information on exposure, sensitivity, and adaptive capacity through surveys of shrimp vendors, with some questions that were also modified.

For the exposure (E) analysis, the assessment revealed that most of the markets in Davao region have low exposures to weather disturbances and natural hazards which may have been due to better infrastructures or sheltered markets, and this could be the same for their households and their communities (Table 7). These low values indicate that the marketplace (E1) and household site (E2) and community site (E3), experienced a rare (0–2 times) occurrence of weather disturbances in a year, such as typhoons, floods, tidal fluctuations, and storm surge. Exposure was also categorized to have an indirect and direct effect. In the case of Panabo and Sta. Cruz, the barangay markets examined were located in nearby coastal areas, the shrimp vendors were also living near exposed coastal areas, prompting them to provide answers classified as under medium exposure.

**Table 7.** Vulnerability index of sensitivity, exposure, and adaptive capacity by public market in Davao region (legend: L = low, M = medium, H = high).

Site/Market	Vulnerability Index		
	Sensitivity	Exposure	Adaptive Capacity
Pantukan	M	L	L
Mabini	M	L	L
Tagum	M	L	L
Maco	M	L	L
Lupon	M	L	L
Panabo	M	M	L
Davao	M	L	L
Digos	M	L	L
Sta cruz	M	M	L



For the sensitivity (S) analysis of whiteleg shrimps in the market, this has a medium score in all the public markets of Davao region which corresponds to the factors that were taken. Sensitivity is usually defined as the natural degree to which biophysical, social and economic conditions are likely to be influenced by foreign stresses or hazards [27]. A medium sensitivity score is an indication that the vendors in the market experienced frequent changes in the supply of shrimp, had medium counts of damaged shrimps during transportation, observed no change in sales or the volume sold per kilogram per day, and most of the interviewed vendors were not dependent on the income they got from selling shrimp from five years ago. Some of them also sell fish, while other vendors have other non-shrimp commodities that they also sell for additional income. In terms of the air temperature, they did not notice any changes in weather in their marketplace. In addition, most of the vendors also experienced occasional ailments or diseases.

In terms of the adaptive capacity (AC) of the vendors in the marketplace, this was low (L). This score indicates that the shrimp vendors in the different markets of Davao region were not really aware of what climate change is, and its potential impacts on them as well as on their livelihood. Their source of information on climate change is not verified or credible and they are not equipped regarding climate change impacts, variabilities, and its possible effects on their sales of fish or shrimp. When talking about climate change, they were just aware of it, but not really knowledgeable. The same situation persists with regard to climate change adaptation; the shrimp vendors were not aware and do not take precautionary measures to mitigate the possible impacts of weather disturbances brought by the changing climate. Another factor that has been investigated in the adaptive capacity criteria was the vendors' modification or change in marketing strategies. Most of the vendors do not have any marketing strategies or techniques. There was no program or education support from the government that could help the vendors to raise their awareness regarding climate change impacts and variabilities and what can be done regarding these matters. Overall, the climate change vulnerability assessment score for markets in Davao region revealed medium (M) scores for markets in Pantukan, Mabini, Tagum, Maco, Lupon, Davao, and Digos. Moreover, the assessment also revealed high (H) vulnerability scores for the markets in Panabo and Sta Cruz. The markets showed low (L) and medium (M) potential impacts (Table 8).

**Table 8.** Vulnerability assessment by market in Davao region (legend: L = low, M = medium, H = high).

Site/Market	Potential Impact	Vulnerability
	(Sensitivity × Exposure)	(Adaptive Capacity × Potential Impact)
Pantukan	L	M
Mabini	L	M
Tagum	L	M
Maco	L	M
Lupon	L	M
Panabo	M	H
Davao	L	M
Digos	L	M
Sta cruz	M	H

#### 4. Discussion

##### 4.1. The Direct and Indirect Impacts of Climate Change

The direct effects of climate change include changes in the abundance and distribution of exploited species and assemblages, the increase in the frequency and severity of extreme events, such as floods and storms, and an increasing sea surface temperature which affects fishing operations and infrastructure, which is also connected to exposure of cultured species such as *Penaeus vannamei* [15,28–30]. Moreover, the growing occurrence of disasters and extreme weather events, such as the consequences of a changing climate, have a composite impact on aquatic ecosystems and the livelihoods of those who depend

on them, mainly fishers, fish farmers, and including fish vendors. For instance, in Mati, the small-holder fish farmers have adapted to these higher temperature exposures and low dissolved oxygen in pond water by adding paddle wheels to reduce shrimp culture mortality rates. The use of paddle wheels in culturing shrimp species is essential for increasing the dissolved oxygen content of the pond water and increasing water circulation. In the case of commercial farms, these are required installations, including ponds with blowers, and ponds with HDPE linings for disease prevention and better water quality management.

On the other hand, the indirect effects of climate change are changes in aquatic habitat quantity and quality, such as ecosystem productivity and the distribution and abundance of aquatic competitors and predators [31–35]. It can also have an impact on other food production sectors that affect people's food security and livelihoods [33,36–38]. A third impact that is unrelated to their economic activities includes diseases or damage to their homes [39–42]. For the *P. vannamei* farmers, the other indirect impacts of climate change are associated with worsening water quality due to high stocking density, semi-intensive and intensive culture of finfish or shrimps, overfeeding and obstruction of waterways, and a lack of clear government policy in terms of common area management for a body of water, such as the Tilapia farms in Taal Lake in Batangas [43–45]. In addition, the prevalence of shrimp diseases has been connected to the worsening water quality, or the inability to control and manage water quality and the use of a good source of fry or post-larvae [46].

Thus, given the complex emergencies, conflicts and prolonged crises due to the climate change impacts on food production systems and the ecosystem itself, this can increase pressure on the fisheries and aquaculture due to rising food prices, costs of transport and logistics, possible damages and destruction [16,47,48]. Those dependent on fisheries and aquaculture for their livelihoods must navigate the increasing disaster risks that flow from climate change and human-induced hazards [48,49]. Effective resilience and emergency response strategies require an in-depth understanding of fisheries and aquaculture as well as damage and loss monitoring and assessment systems and practices [20].

#### 4.2. Local Impact of Climate Change Variabilities

There was neither an increase nor decrease in *Penaeus vannamei* production according to the fish farmers in Mati City and most of them, perceived that they were able to achieve their volume targets, including the average weight of the shrimp after a culture period (e.g., 24–30 g/70–100 days of culture). In the component of sensitivity for vulnerability assessment, one of the set criteria or parameters is “growth rate” which for the Mati shrimp farms, corresponded to a medium score (2.9) for the farmers. There were few farmers who answered that there was an increase in the volume of shrimp produced compared to five years ago, however, predominantly most of the respondents gave an answer of no observed changes. In relation to this occurrence of no growth or change, it is possible that the farmers have actually reached the maximum capacity of their farms, in terms of intensity of culture, feeding strategies and other cultural methods. Moreover, it is also possible that changes in an aquatic ecosystem that could be severe, for instance, sudden changes in water temperature, can have a negative impact on the growth and production of shrimps as this is a highly sensitive condition for cultured shrimps [1,8]. Even fishers and other finfish farmers have observed the occurrence of a sudden change in weather conditions within a day or in a season; the weather sometimes becomes very unpredictable [50,51]. With regards to climate change awareness, most shrimp farmers understood the word “climate change” but are not informed regarding the possible effects of this phenomenon on their cultural practices, livelihoods, and lives.

Some of the shrimp farmers did not perceive the effects of climate change to be occurring around them which were in contrast to the fishers of Davao Gulf or the coral reef fishers of Mati and Surigao [50,51]. They are more focused on the technicalities of production and neglect the presence and effects of climate change on their production. Perhaps these farmers have not been visited and informed regarding climate change impacts and vulnerabilities, which is often the case when technicians are also not informed

or schooled regarding climate change. This was again in contrast to the fishers who seem to be more aware of the impacts of changes in seasonality and weather with regard to their livelihoods [20,50]. Many of the interviewed respondents were unaware of the possible impacts of climate change variabilities, specifically with extreme events and weather systems that could impact their production, logistics, and marketing, which was in direct contrast to the awareness of small-scale fishers who perceived that the weather changes erratically [52]. A possible explanation for this seeming disregard for extreme events or unpredictable impacts of variable weather or season is their working environment, which is not highly exposed to incessant rains, typhoons, or drought.

#### 4.3. Adaptation of Shrimpfish Farmers

Adaptation refers to the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to the expected climate and its effects [19]. In this study, the adaptation capacity of shrimp farmers toward the changing climate reflects a low score. This low score could be due to a lack of support from government or non-government organizations in battling the impacts of climate change. Many of the shrimp farmers were not fully informed of what climate change is, and its variabilities. There were no programs and seminars conducted for the farmers in connection with climate-related incidents. There were no support programs, such as having technical advice for the betterment of shrimp farming from local to regional agencies that could be of great help for the fishers' cultural practices as well as to their livelihood, which was also similar for the case of small-scale fishers [50,51]. The adaptive strategies taken by the shrimp farmers to mitigate the impacts of climate change were mostly derived from their own experiences and not from the experts. The farmers' understanding of climate change was too shallow, which drove them to have a low score in terms of their adaptive capacity. Adaptations for the possible impacts of climate change can be achieved through better management practices in site selection, pond construction and preparation, selection of post-larvae for stocking, pond management, bottom sediment management, and disease management, together with reducing non-climate stressors, such as pollution, conservation of sensitive ecosystems and the adoption of dynamic management policies [3,20,53,54].

Adaptation strategies in coping with the impacts of climate change on shrimp farming must be developed to achieve a green and stable economy. With regard to climate change, this is a challenge for the sustainability of coastal aquaculture. Considering extreme vulnerability to the effects of climate change, community-based adaptation strategies must be introduced to cope with the challenges [52,55,56]. The potential impacts of climate change on shrimp farming could have severe effects on food production, export earnings, livelihoods of the coastal poor and their socioeconomic conditions [57]. Since shrimp farming is one of the main sources of livelihood for people living in the coastal region, building resilience and better adaptation strategies should be encouraged, or implemented [58].

Sustainable adaptive measures can be a steppingstone for successful shrimp farming, but it is the least acknowledged [17,59]. In economic terms, vulnerability has many potential costs, not least in foregone potential economic development [60]. Preparing for the potential impacts of extreme events and identifying coping strategies have been positively related to risk minimization, which has positive impacts [15,61]. Thus, the uncertainty of climate variation has an economic cost in terms of resource sub-optimal allocation but can be reversed or prepared for in terms of adaptation and building resilience [60,62]. In order to effectively reduce climate risks and disasters, it is important to identify the possible impacts of climate change vulnerabilities and then address them one by one to increase the adaptive capacity of fishers, fish farmers, or the vulnerable sectors. Educating our fish farmers through different extension services, including financial and market access and alternative livelihoods can address some of the underlying issues of vulnerability of fishers, which is poverty [63–66]. Education can provide the necessary foundation needed for the growth

and development of every individual fish farmer or fisher by empowering them with new technologies and knowledge that can help them in their trade [67]. Through additional training and participation in extension education, they can be equipped to understand environmental factors that are affecting their cultured shrimps [68]. Moreover, they become more open to ideas and link up with other traders and businessmen when they become market-connected. In the small-scale fisheries sector, the education and awareness of fishers were recognized as necessary factors for the success of various conservation measures such as community-based resource management [69–71].

## 5. Conclusions and Recommendations

Shrimp farming is an essential source of food and livelihood for people living in Mati City. Their shrimp culture was considered to be medium vulnerable to the impacts of climate change using the FishVool tool. This indicates a low adaptive capacity of the fish farmers towards the impacts of climate change. Most of the shrimp vendors and the markets that were assessed around the Davao Gulf, these too, have a medium vulnerability which may require that the local governments, the Department of Agriculture and the Bureau of Fisheries and Aquatic Resources (BFAR) should engage them for their adaptation and building resilience towards potential climate change impacts. These are relevant issues that the government should investigate, provide alternative livelihoods for the affected fish farmers, and help them to adapt to the possible impacts of climate change, including providing them with additional financial support as well as training and seminars on how to adapt to the challenges that they might encounter in their aquaculture [20,72]. Moreover, the government should help provide access to export markets and processing firms so that the farmers do not need to worry about disposing of and selling their seafood products [2]. As there is a high possibility that climate change may worsen or increase the frequency of extreme events occurring, such as floods, and storm events, greater awareness of climatic variability and change should be promoted [2,33]. Increasing sensitivity and awareness to climate issues will facilitate public engagement and the successive adoption of adaptive measures to prepare for climate variability and climate change. The government should extend their support by conducting and implementing activities beneficial to the farmers. There is a need for a wide implementation of strict biosecurity measures and protocols to avert the risks of exposure to possible damage and impacts of climate change on production and the whole stocking process [73,74].

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