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Main title: Vulnerability assessment of Pacific whiteleg shrimp (*Penaeus vannamei*) farms and vendors in Davao, Philippines using FishVool

Short title: Vulnerability assessment of Pacific whiteleg shrimp farms and vendors in Davao, Philippines

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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 Davao region, 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 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. But high (H) vulnerability scores for the markets in Panabo and Sta Cruz. Overall, the study provided a better understanding about shrimp farming in relation to climate change impacts and vulnerability and provided information for future shrimp farm management, marketing and climate change adapation in the region.

Keywords: Aquaculture, Climate change, Davao Oriental, FishVool, Management, Mati City, Shrimp culture

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INTRODUCTION

Shrimp production provides a wide range of economic benefits, for instance, food security, livelihood and 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 1,175 mt valued at Php 216 million and 1,018 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]. 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; 1,006 ha was alloted to endeavor shrimp (*Metapenaeus ensis* or "hipong suahe"); and 638 ha to white shrimp (*Penaeus indicus*, *Penaeus setiferus* or "hipon puti"). The total hectarage under shrimp production constitutes 23% of the country's brackishwater 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%) [5]. On the other hand, there were 260,000 ha of brackishwater ponds, 6,700 ha of freshwater pens and about 500 ha of marine pens and cages used to culture milkfish [6]. However, shrimp production in the past years have been affected by various challenges, including diseases, stricter biosecurity measures, marine pollution, lack of premium access to markets abroad, and climate change impacts. Shrimp farming have brought about widespread social and economic benefits. However, a wide range of environmental issues including climate change have recently been identified to threaten the sustainability of coastal aquaculture [7].

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 widespread destruction of mangroves in a number of

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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 the shrimp production and market by increasing frequency of shrimp disease, causing physical damage to farm structure and deteriorating 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 oxygen content of the pond water and allow better water circulation in the pond [17]. However, there is a lack of understanding about the adaptation measures taken by the local shrimp farmers with respect to the emergence of specific impacts from changes of climatic variables. It is essential to understand the adaptations of locals to get more insights into the resilience of this aquaculture system [17].

Climate change impacts have also been implicated as one possible cause of 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 vulnerability assessment to be conducted from time to time to provide status, 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.

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Vulnerability assessments, especially for fisheries and aquaculture, provide a better way to understand the interactions among the natural system, pressures, and threats, which serves as a basis for the development of climate change adaptation (CCA) options [22,23]. Tools such as Fisheries Vulnerability Assessment Tool (FishVool) have been developed to do vulnerability assessments in the fisheries [2,24-26]. In the past, this was applied to assess the vulnerability of tuna fishers in General Santos City and sardine fishers 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 indicate that the tuna and sardine resources are vulnerable to climate change. In this study, we assessed the level of vulnerability of Pacific whiteleg shrimp (*Penaeus vannamei*) on the impacts of climate change and measured the impacts of climate change variability on the shrimp farming sector using a modified FishVool tool [2,26].

METHODOLOGY

Description of Study Area

The study was conducted in selected shrimp farms areas in Davao Region. The areas were selected according to the list given by BFAR XI thru 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 the Eastern Indonesia through the Celebes Sea to the south. Davao region is blessed with good climate as it experiences Types II and IV climate and lies outside the typhoon belt. Type II climate is characterized by 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 1,673.3 mm to 1,941.8 mm with an average temperature in the region that ranges from 28 ^{0}C to 29 ^{0}C. Warm temperatures is 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).

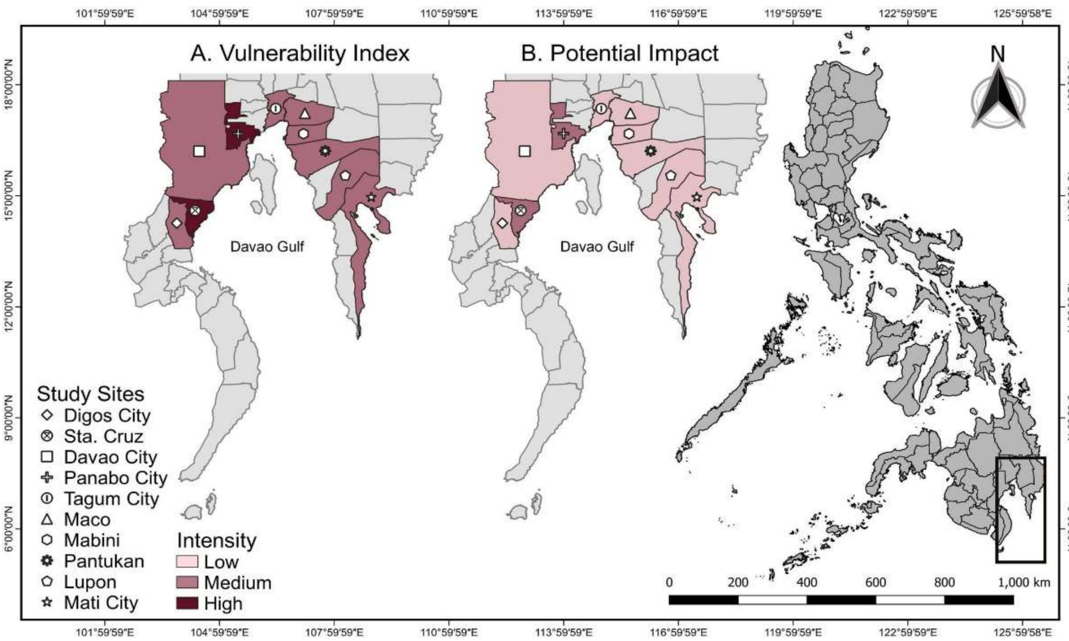

Figure 1. Map of the study area including its Climate Change Vulnerability Index (A) and Potential Impacts (B).

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 simplified vulnerability assessment of fishing communities and their fisheries resources. The revision of this FishVool for application in various fisheries commodities have been elaborated in Macusi et al., 2021 [2]. Every fishery resource, including aquaculture resources have unique aspects to it 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

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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.

This study assessed n=39 shrimp farmers and n=48 market vendors for a total 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.

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 is the *mortality rate* which measures the rate of damage or dead shrimps during culture period. While for sensitivity factor 2 or S2 is the *growth rate* which measures the average length of shrimp which pertains to the age or size from stocking period up to harvest. In the case of sensitivity factor 3 or S3 refers to *water quality* of the pond, and sensitivity factor 4 or S4 is for the *water temperature*, which pertains to probabilities of changes which was 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 have 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 farm from the source hatchery. And lastly for sensitivity factor 7 or S7 this refers to change in *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]. For exposure factor 1 (E1) is for the *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) is for the exposure of *households site* and for exposure factor 3 (E3) is for 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 shrimp farmers' knowledge on 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 events. Moreover, for adaptive capacity 4 (AC4) this refers to *shrimp farming modification* or changes adopted for better and effective shrimp farming practices. For adaptive capacity 5 or (AC5) this refers to *the community support systems* and programs. Lastly for the adaptive capacity 6 or (AC6), this 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.

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 *rate of damage* of shrimp product during transport and measures the number of dead shrimps during delivery to the market place. In the case of S3, this refers to the *growth of sales* which measures the income of vendor/seller in a span of time. In connection with S3, S4 refers to 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 market place when compared from 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 market place exposure*, which pertains to the frequency and severity of exposure of the market place to extreme weather disturbances. In addition, E2 pertains to *exposure of households site* 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 shrimp vendors' knowledge on climate change and its impacts on their livelihood. On the other hand, AC2 relates to *access to information* or the vendors'/seller's accessibility to climate-related knowledge through different means. While for AC3 this refers to the adaptive strategies, or *precautionary measures* that the shrimp farmers undertake before, during, and after an extreme weather events. In the case of AC4 this is for the modification on *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 the *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** refers to the rubrics which was used to find the potential impact and the level of vulnerability of the fish farmers and farming communities as well as the markets. While **Table 4** will refer to the vulnerability category based on the scores of the respondents from the assessment. For access to the published manual of FishVool please

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Table 1. Shrimp vulnerability assessment matrix (scoring guide).

Components		Score		
		1 or 2	3 or 4	5
Sensitivity	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/postlarvae (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 5yrs 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)
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

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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	L
	M	H	M	L
	H	H	H	M

Table 4. Vulnerability category.

Vulnerability category	Score
Low	0 to 2
Medium	3 to 4
High	4 to 5

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 household and community(E2), experienced rare (0-2 times) occurrence of weather disturbances, such as typhoons, floods, tidal fluctuations, and etc.

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

Vulnerability Assessment (VA) Components	Parameters	Score	Average Score	Vulnerability Index
Sensitivity (S)	S1: Mortality rate	2		
	S2: Growth	2.9		
	S3: Water quality of pond	2.2		
	S4: Water temperature	2.1	**2.3**	**M**
	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		
	E2: Household site assessment	1.3	**1.4**	**L**
	E3. Community site assessment	1.3		
Adaptive Capacity (AC)	AC1: Climate change awareness	2.5		
	AC2: Source of information	o.4	**2**	**L**
	AC3: Adaptive strategy	2.3		
	AC4: Modification of cultural practices	1.8		

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	AC5: Support on climate change organization	1.5
	AC6: Literacy	3.8

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 low mortality rate and observed no changes in growth of shrimps 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 a neutral to medium parameters that ranges from 2-3 times respectively. In addition, the changed in salinity level of the water in the pond was low for the past 5 years.

Adaptive Capacity (AC) of the whiteleg shrimp farms in terms of climate change activities revealed values of 2.5, 0.4, 2.3, 1.8, and 1.5 for AC1, AC2, AC3, AC4, and AC5 criteria (**Table 5**). These findings revealed that some of the shrimp farmers have modest knowledge of what climate change is and how such a phenomenon may affect their lives and livelihood. The basic source of information of shrimp farmers on climate change mostly comes from television, internet, and school. Most of them has minor precautionary measures undertaken to mitigate the impacts of weather disturbances that might occur, like 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 culture practices (feeding, water management, etc.) including attending seminars to increase knowledge, yet no additional resources but still found to have no changed in harvest or yield. Also, most of the shrimp farmers doesn't receive any kind of support from any organization with regards to climate change related programs.

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

For the exposure (E) analysis, the assessment revealed that most of the market places 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 market place/stall (E1) and household site (E2) and community site (E3), experienced rare (0-2 times) occurrence of weather disturbances in a year, such as typhoons, floods, tidal fluctuations, and etc. 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 Market of Davao Region.

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 market places in 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]. 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 of sales or the 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 incomes. In terms of the air temperature, they did not notice any changes of weather in their market place. 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 to them as well as to their livelihood. Their source of information towards climate change is not verified or credible and they are not equipped regarding climate change impacts and 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 regards to climate change adaptation or adaptation strategies, the shrimp vendors were not aware and do not make precautionary measures to undertake to mitigate the possible impacts of weather disturbances brought by the changing climate. Another factor that has been investigated on 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 were 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

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these matters. Overall, the climate change vulnerability assessment score for markets in the 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 of Davao Region.

Site/Market	Potential Impact (Sensitivity x Exposure)	Vulnerability (Adaptive Capacity x 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

DISCUSSION

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, and the increase in the frequency and severity of extreme events, such as floods and storms, and increasing sea surface temperature which affects fishing operations and infrastructure this is also connected to exposure of cultured species such as *P. 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 paddlewheels to reduce shrimp culture mortality rates. The use of paddlewheels in culturing shrimp species are 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, 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 which is unrelated to their economic activities, include diseases or damage to their homes [39-42]. For the *P. vannamei* farmers, the other indirect impacts of climate change are associated to worsening water quality due to high stocking density, or semi-intensive and intensive culture of finfish or shrimps, overfeeding, obstruction of waterways, and lack of clear government policy in terms of common area management for a body of water such as Tilapia farms in Taal Lake in Batangas [43-45]. In addition, the prevalence of shrimp diseases has been connected to worsening water quality or inability to control and, manage water quality and the use of a good source of fry or postlarvae [46].

Thus, given the complex emergencies, conflicts and prolonged crises due to 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 in-depth understanding of fisheries and aquaculture as well as damage and loss monitoring and assessment systems and practices [20].

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Local impact of climate change variabilities

There was neither increase or decrease of *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 g – 30 g / 70-100 days of culture). In the component of **sensitivity** for vulnerability assessment, one of the set criterion or parameters is "growth rate" which for the Mati shrimp farms, this 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. But 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 culture methods. Moreover, it is also possible that changes in aquatic ecosystem which could be severe, for instance sudden change in water temperature, can have 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 sudden change in weather conditions within a day or in a season; the weather sometimes become very unpredictable [50,51]. With regards to climate change awareness, most of the shrimp farmers understood the word "climate change" but are not informed regarding the possible effects of this phenomena 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 was 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 to 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 seems to be more aware of the impacts of changes in seasonality and weather with regards 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 indirect contrast to the awareness of small-scale fishers who perceived that the weather changes erratically [52]. A possible explanation for this seeming disregard to extreme events or unpredictable impacts of variable weather or season is their working environment which are not highly exposed to incessant rains, typhoons, or drought.

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 expected climate and its effects [19]. In this study, the adaptation capacity of shrimp farmers towards the changing climate, reflects a low score. This low score could be due to 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. No support programs like having technical advices 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 to 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 on 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 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, there is a challenge to 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 source of livelihoods 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 stepping stone for a successful shrimp farming, but then it is least acknowledged [17,59]. In economic terms, vulnerability has many potential costs, not least in foregone potential economic development [60]. By preparing for potential impacts of extreme events and identifying coping strategies, these have been positively related to risk minimization, which have positive impacts [15,61]. Thus, the uncertainty of climate variation have an economic cost in terms of resource sub-optional 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 climate change vulnerabilities and then to address these 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 underlying issues of vulnerability of fishers which is poverty[63-66]. For education, this can provide the necessary foundation needed for 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 trainings and participation in extension education, they can be equipped to understand environmental factors that are affecting their cultured shrimps [68]. Also, they become more open to ideas, linked up with other traders, and businessmen when they become market connected. In the small-scale fisheries sector, education and awareness of fishers were recognized as necessary factors for the success of various conservation measures such as in community-based resource management [69-71].

CONCLUSION AND RECOMMENDATION

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. For most of the shrimp vendors and the markets that were assessed around the Davao Gulf, these too have 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 adaptation and building their resilience towards potential climate change impacts. These are relevant issues that the government should look into, 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 trainings and seminars on how to adapt to the challenges that they might encounter in their aquaculture [20,72]. Also the government should help provide access to export markets and processing firms so that the farmers do not need to worry on disposing and selling their seafood products [2]. As there is a high possibility that climate change may worsen or increase the frequency of extreme events from 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 the public engagement and successive adoption of adaptive measures to prepare for climate variability and climate change. The government should extend their support through conducting and implementing activities beneficial to the farmers. There is a need for wide implementation of strict biosecurity measures and protocols to avert the risk of exposure to possible damage and impacts of climate change towards production and the whole stocking process [73,74].

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