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RESEARCH ARTICLE

# Vulnerability to Climate Change of "Giant Squid" (*Thysanoteuthis rhombus*) Fishery in Marinduque, Philippines

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ABSTRACT

The Philippine fisheries sector has been affected by the impacts of climate change. Vulnerability to climate change pertains to a natural system's ability to cope with the negative impacts of climate change, variability, and extremes. Vulnerability Assessment (VA) provides a framework for climate change impacts evaluation over a broad range of systems. Tools such as Fisheries Vulnerability Assessment Tool (Fish Vool) have been developed to do VA. The "giant squid" diamondback (*Thysanoteuthis rhombus*) fishery in the province of Marinduque is an essential source of food and livelihood in the area. However, its vulnerability to climate change impacts has not been assessed. In this study, the "giant squid" fishery in Gasan, Marinduque, was assessed using Fish Vool. Results revealed that overall climate change vulnerability of the fishery is high, where both sensitivity and adaptive capacity are medium while exposure is high. Overall, the study provided a better understanding of the "giant squid" fishery vis-à-vis climate change and provided information for future fisheries management and conservation in the province.

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## 1. INTRODUCTION

The Philippines is ranked fourth (4th) most vulnerable country to climate change based on the long-term climate risk index (CRI) from 2000 to 2019 (annual averages) (Eckstein 2021). The country's fisheries sector is likewise highly vulnerable to the impacts of climate change (Burke et al. 2011; Hughes et al. 2012), and if current scenarios do not change, even the economy derived from fisheries is projected to be impacted (Suh and Pomeroy 2020). Impacts contributing to the vulnerability of fisheries include direct and indirect effects of physical and chemical factors, such as temperature, winds, vertical mixing, salinity, oxygen, and pH (Brander 2010).

The Philippine climate change policy provides guidelines for developing adaptation strategies, including the conduct of vulnerability assessments (VAs) (Climate Change Commission 2011). As a result, several VA tools for fisheries in the country have been developed, such as the Vulnerability Assessment of Coastal Fisheries Ecosystems to Climate Change - Tool for Understanding Resilience of Fisheries (VA-TURF) (Mamauag et al. 2013) and the Fisheries Vulnerability Assessment Tool (Fish Vool) (Jacinto et al. 2015). Through these tools, one can assess ways to reduce risks and impacts on fisheries resources and the people who depend on them. Results on such may be used to identify gaps and possible management approaches to mitigate the effects and increase the resilience of target species, fisheries, and fishing-dependent communities.

Data and information are required to conduct VAs for fisheries. However, the fisheries in the country are almost always data-deficient; hence local fisher's knowledge has been employed to assess, for example, the decline of fish stocks over the years (Mualil et al. 2014; Lavides et al. 2016), determine the impacts

of climate change to small scale fisheries (Macusi et al. 2020; Macusi et al. 2021) and even analyze the vulnerability of the tuna and sardine fishery sectors (Jacinto et al. 2015).

The diamondback or rhomboid squid (*Thysanoteuthis rhombus*) is a giant, circum-global squid that can reach a maximum ML length (Lmax) of 130 cm (Carpenter and De Angelis 2014) and can weigh up to 30 kg (Jereb and Roper 2010). Although its 2020 global assessment under IUCN Red List is Least Concern (LC) (Barratt and Allcock 2020), its biology, physiology, and behavior, similar to other squids, could be impacted by a change in climate (Pecl and Jackson 2008).

In the Philippines, this "giant squid" have been caught from the Camotes Sea in Central Visayas, Calauag Bay in Quezon, Ormoc Bay in Leyte, and west of Mindoro Island from June to October at a depth range of 145 m to 720 m using "giant squid" jigs and small-sized milkfish as bait (Dickson et al. 2000). The "giant squid" fishing was introduced in Northern Cebu in 1988 by fishers from Negros Oriental (Lamayo et al. 2008). Among the squid species in the country targeted for fisheries, *T. rhombus* is the most uncommon and is a latent fishery resource (Dickson et al. 2000).

Marinduque is an island province where its densely populated areas are concentrated in coastal and relatively flat locations (Salvacion and Magcale-Macandog. 2015). It is rich in various fisheries and aquatic resources, with a production of 5,384 MT valued at PHP 584,207.39 in 2019 Philippine Statistics Authority 2020. The province is famous for its "giant squid," a source of food and livelihood for its small-scale fishers, which should be managed for its sustainability (M. Candelario, personal communication, July 7, 2021).

Marinduque is predicted to experience significant changes in its climate from 2020 to 2050 (DOST-PAGASA 2011). Under a medium-range emission scenario, it is projected to increase seasonal temperature at around 1°C, from an average of 28.35°C in 2020 to 29.38°C in 2050. It shall likewise experience significant shifts in the frequency of extreme weather events in 50 years; no. of days with Tmax > 35°C from 440 to 1469; no. of dry days from 7057 to 6902; no. of days with rainfall > 200 mm from 11 mm to 22 mm.

Hence, the study's objective is to assess the vulnerability of the "giant squid" fishery in Gasan, Marinduque, to the impacts of climate change. Results could be used to direct fishery management plans and conservation to sustain the said fishery in the province amidst the impacts of climate change.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

Four coastal barangays (Banuyo, Pingan, Bacong-bacong, and Dawis) from the Municipality of Gasan, Marinduque were selected as study areas (Fig. 1). The four barangays were selected based on the presence of "giant squid" fishery and the squid catcher association located in these areas (Fig. 2). Site selection was conducted in coordination with the BFAR Provincial Office thru the Municipal Agriculture Office of Gasan.

### 2.2 Data collection and analysis

The Fisheries Vulnerability Assessment Tool (Fish Vool) developed by Jacinto et al. (2014) was utilized to gather information on exposure, sensitivity, and adaptive capacity through key informant interviews. During site evaluation, key informants were interviewed using the questionnaires derived from Fish Vool with some modifications. There were 37 respondents included in this study, mainly from the squid catcher associations with at least five years or more of squid fishing experience (Figure 2). Data were analyzed following Fish Vool rubrics with minor modifications computed using the Fish Vool Excel Program (Aguila et al. 2021).

*Exposure*. Exposure (E) factors are those climate variables included in the assessment that could impact the species and the fishery (e.g., sea surface temperature changes, sea-level rise, waves and storm surges, and extreme rainfall). Here, exposure factors were chosen based on three criteria adapted from Jacinto et al. (2014). E1 is for the fishing ground (capture fisheries), which pertains to the frequency and severity of exposure of fishing grounds to extreme weather disturbances. E2 is for the exposure of households to extreme weather disturbances pertaining to human exposure. Finally, E3 is for the exposure of community sites, including records of weather disturbances to the community. These factors were equally weighted owing to the limited knowledge regarding the magnitude of effects and species responses to climate.

*Sensitivity*. Sensitivity (S) represents the present state of the species and fishery in response to the exposure factors arising from climate change. S1 is the catch comparison rate which measures the trends or changes in catch rate over the years that may show the effects of fishing. S2 is the average length of fish catches which pertains to the age or size at onset or

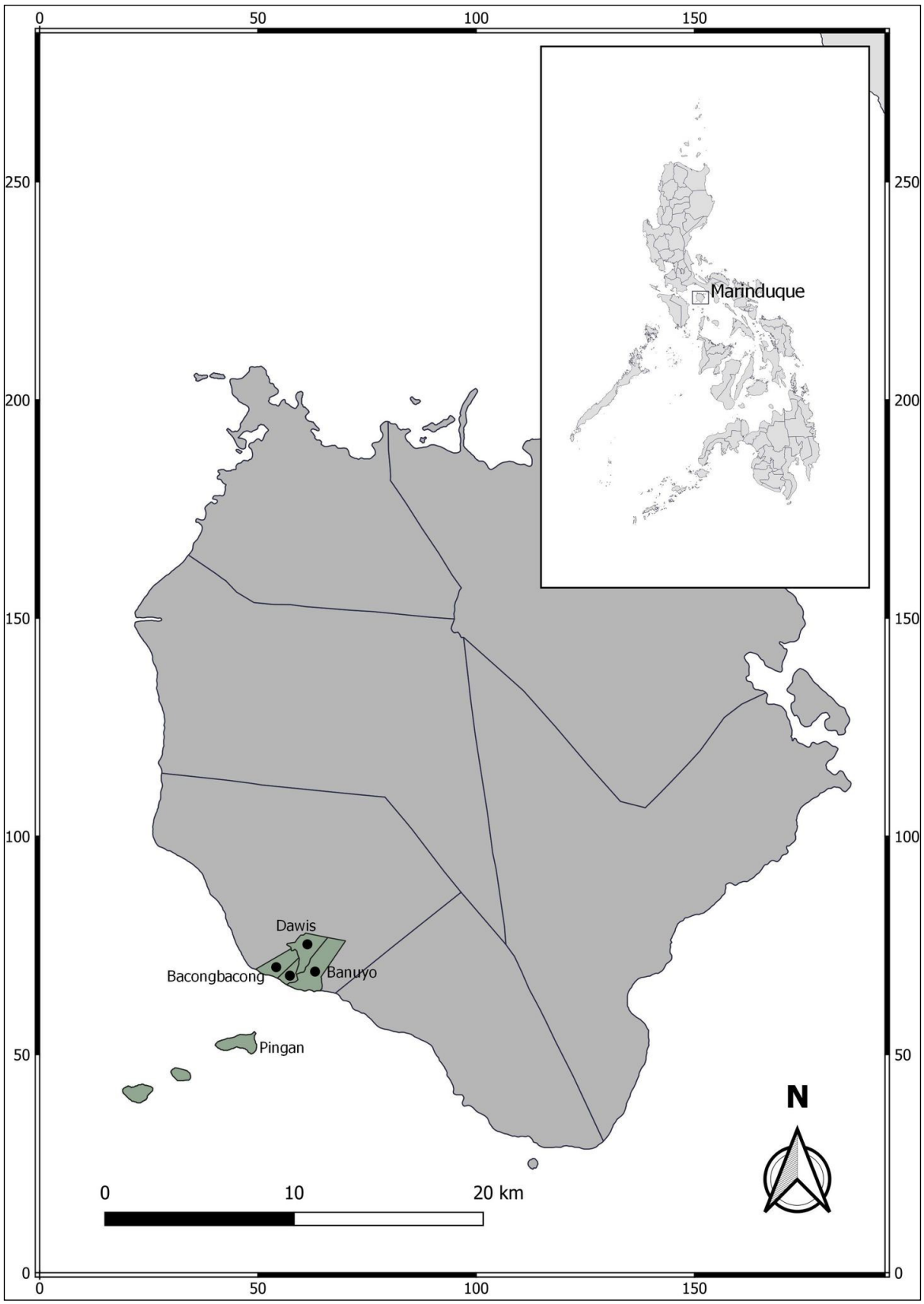


Figure 1. Location of the study area (black circles) for "giant squid" fishery in Gasan, Marinduque

Figure 2. "Giant squid" (*Thysanoteuthis rhombus*) caught in Gasan, Marinduque using squid jig

maturation and growth rate. S3 is for the dependence on resource factor, which provides information on the importance of fisheries to their household and the community's well-being. Lastly, S4 and S5 are for the socio-economics, which measures the information on socio-economic conditions, including income, health conditions, and household age structures, because these determine the fisherfolk's ability to cope with extreme weather events.

*Adaptive Capacity*. Adaptive capacity (AC) pertains to the ability of the system to cope with the impacts associated with the changes in climate. AC1 looks at the annual income from fishing, which is a common indicator that characterizes the economic profile of a community. AC2 is the level of awareness and the extent of fishers' knowledge on climate change and its impacts on their livelihood. AC3 is for access to information or the fisher's accessibility to climate-related knowledge through different means. AC4 is for the adaptive strategies, which refers to the precautionary measures the fishers undertake before, during, and after extreme weather events. AC5 is for literacy, which determines the ability of fishers to find other income-generating livelihoods. AC6 is for gear modification or replacement, which measures the fisher's adaptive capacity for a more effective fishing effort. Lastly, AC7 is for the community support systems and programs.

## 3. RESULTS

Exposure (E) analysis revealed 4.4, 4.2, and 4.2 values for E1, E2, and E3 criteria, respectively (Table 1). These values indicate that both the fishing ground and the community, including households, experienced intermediate (4-6 times) to frequent (> 6 times) occurrences of weather disturbances (e.g., typhoons, storms, flash floods, landslides, etc.), thus mostly exposed from climate-related changes.

Table 1. Average scores and vulnerability index for sensitivity, exposure, and adaptive capacity of the "giant squid" fishery in Gasan, Marinduque

| Vulnerability Assessment (VA) components | Parameters | Score | Average score | Vulnerability index |
|---|---|---|---|---|
| Sensitivity (S) | S1: Compare catch rate 20 years ago | 4.6 | 3.6 | Medium (M) |
| | S2: Average length of fish catches | 4.9 | | |
| | S3: Dependence on fishery resource | 4.9 | | |
| | S4: Household age structure | 2.2 | | |
| | S5: Health conditions | 1.6 | | |
| Exposure (E) | E1: Fishing ground | 4.4 | 4.3 | High (H) |
| | E2: Household site assessment | 4.2 | | |
| | E3: Community site assessment | 4.2 | | |
| Adaptive Capacity (AC) | AC1: Income from fishing | 1.2 | 2.2 | Medium (M) |
| | AC2: Awareness on climate change | 2.0 | | |
| | AC3: Access to information | 2.5 | | |
| | AC4: Adaptive strategies | 2.9 | | |
| | AC5: Literacy | 3.1 | | |
| | AC6: Gear modification | 1.9 | | |
| | AC7: Support systems and programs | 1.8 | | |

Sensitivity (S) analysis on "giant squid" fishery revealed values of 4.6, 4.9, 4.9, 2.2, and 1.6 for S1, S2, S3, S4, and S5 criteria, respectively (Table 1). Thus, most squid fishers experienced normal to decreasing catch rate and catch size in the past 5-10 years. Most fishers primarily rely on squid catching, although some shifted to part-time jobs (e.g., construction; repair of shoes or umbrellas; tricycle or jeepney drivers on-call basis) during bad weather conditions. In terms of the household age structure, the majority of the respondents fell within the range of 22-55 years old. In addition, the majority of the respondents and a small percentage of older than 65 years old do not need health benefits.

Adaptive capacity (AC) of the "giant squid" fishing community in terms of climate change activities revealed values of 1.2, 2.0, 2.5, 2.9, 3.1, 1.9, and 1.8 for AC1, AC2, AC3, AC4, AC5, AC6, and AC7 criteria, respectively (Table 1). These findings revealed that the annual income of the respondents from different jobs or sources ranged from PHP 30,000.00 to PHP 50,000.00. It also indicated that most of the fishers' income was generated from fishing. Some of them have knowledge of what climate change is and how such a phenomenon affects their lives. Sources of information on climate change comes from television, family or friends, and barangay officials or government. However, almost 80% of them practice more precautionary measures like going to evacuation centers and shifts to other sources of livelihood when weather disturbances occur. In terms of educational level, approximately 70% of the fishers were elementary to high school graduates. In addition, at least 20% of them carried out full gear modification due to the proliferation of squid fishers in the area, with some using advanced techniques. Some respondents noted that there are about one or two programs or support systems from the local government related to climate change, such as climate risk preparedness and management training.

Over-all average vulnerability assessment scores (Figure 3) determined for the "giant squid" fishery in Gasan, Marinduque were Medium (M) (3.63); High (H) (4.25), and Medium (M) (2.19) for sensitivity (S), exposure (E) and adaptive capacity (AC), respectively. These scores indicated both a high potential impact and high vulnerability and were represented in a vulnerability map (Fig. 4).

| OVERALL AVERAGE ASSESSMENT VALUES | | |
|---|---|---|
| Sensitivity | 3.63 | **M** |
| Exposure | 4.25 | **H** |
| Adaptive Capacity | 2.19 | **M** |

| POTENTIAL IMPACT | | | | |
|---|---|---|---|---|
| | **Sensitivity** | | | |
| | | L | **M** | H |
| **Exposure** | L | L | L | M |
| | M | M | M | H |
| | **H** | M | H | H |

| VULNERABILITY | | | | |
|---|---|---|---|---|
| | **Adaptive Capacity** | | | |
| | | L | **M** | H |
| **Potential Impact** | L | M | L | L |
| | M | H | M | L |
| | **H** | H | H | M |

| POTENTIAL IMPACT | **H** |
|---|---|

| VULNERABILITY | **H** |
|---|---|

Fig 3. Overall average values of sensitivity, exposure, and adaptive capacity, and potential impact and vulnerability indices of "giant squid" fishery in Gasan, Marinduque. L- Low, M-Medium, H-High.

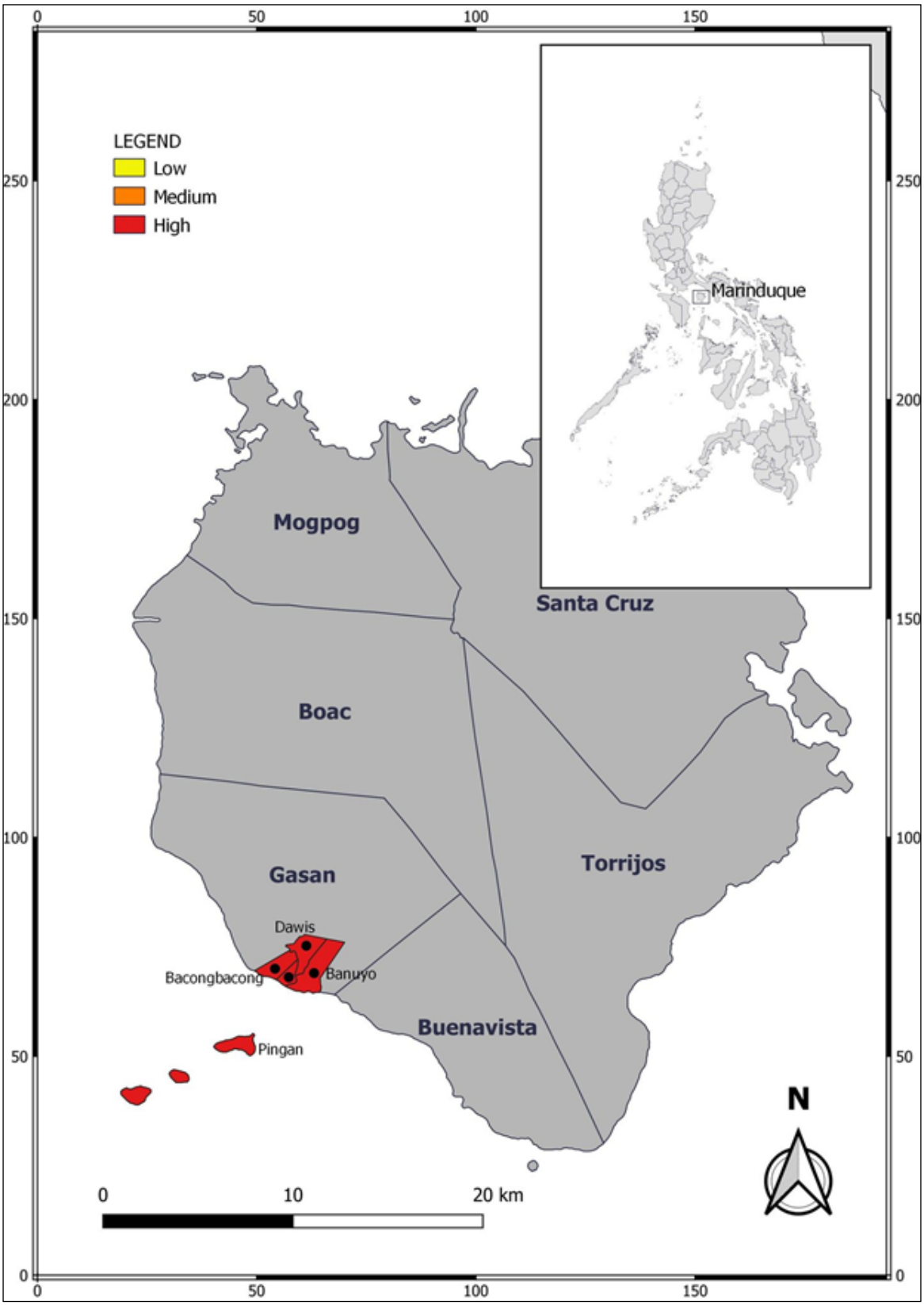


Figure 4. Climate change vulnerability map of "giant squid" squid fishery in Gasan, Marinduque

## 4. DISCUSSION

Marinduque is an island province consisting of six municipalities namely Boac, Buenavista, Gasan, Mogpog, Sta. Cruz, and Torrijos. It has the lowest income among the provinces in MIMAROPA, with almost 24% of the population under poverty, relying primarily on farming and fishing as sources of livelihood (Salvacion and Magcale-Macandog 2015). Per village, the average poverty incidence is around 46%, and the main determinant of poverty is agricultural productivity as dictated by slope and annual rainfall (Salvacion 2018).

One of the province's densely populated areas is in the coastal town of Gasan, a third-class income municipality with 11,930 ha of land area (Salvacion and Magcale-Macandog 2015). From the 37 Gasan "giant squid" fishers interviewed, most are 26-40 years old. Their level of education was moderate, most of whom are a non-graduated high school with no health benefits. They are highly dependent on "giant squid" fishing, basically catching for subsistence.

From this vulnerability assessment study, it was shown that the "giant squid" fishery is highly vulnerable to impacts of climate change because of the following drivers:

1. High exposure index brought about by frequent annual monsoons and tropical storms;
2. Medium sensitivity index due to declining catches and longer catching time coupled with increased fishing cost; and
3. Medium adaptive capacity index brought about by the community's high dependence on the fishery, low awareness, and limited sources of climate change-related information.

There is no published data particularly on "giant squid" catch production in the province. Still, the respondents strongly observed the decreasing catch volume and smaller-sized catch compared to past decades as they have spent half or more of their lives in fishing. They noted that in the past 5-10 years, they could catch "giant squid" at 1-2 hours after setting the squid jigger or multiple hook and line. But recently, it takes 8-10 hours or even longer, especially during strong winds and currents, to catch a "giant squid". This entailed a higher catching cost due to increased gasoline consumption as they go back 3-4 times to check on their hook and lines.

Most fishers catch fish for subsistence, and any income earned from the surplus is barely enough for the family to make both ends meet. With these scenarios, younger family members are compelled to join their fathers on fishing boats to increase the chances of catching more "giant squids," similar to Ferrer (2005) reports. In addition, artisanal fishers, in general, are poor and have low educational attainment, and lack technical skills. These prevent them from exiting the fisheries to look for other employment opportunities (Muallil et al. 2011).

There is a need for a more robust regulatory environment that protects both the fish and the fishers, especially since there are only a few livelihood alternatives to fishing, particularly in "giant squid" catching. Moreover, most of the younger fishers (sons of experienced fishers) likely follow their fathers' fishing livelihood given the minimal social and economic options available; otherwise, they would settle to exit the fishery and reduce fishing pressure (Muallil et al. 2011; Muallil et al. 2013). Therefore, climate adaptation strategies should also touch on the fisheries' socio-economic aspect, especially focusing on alternative livelihoods for the fishers (Muallil et al. 2013, Mamauag et al. 2013).

Overall, the assessment indicates that the "giant squid" fishery in Marinduque, considered long before as one of the primary resources and source of living in Gasan municipality, is highly vulnerable to climate change. The results are in line with the findings of Macusi et al. (2020), where based on interviews of various fishers and coastal communities in Cantilan, Surigao del Sur, and Mati, Davao Oriental, have reported that impacts of climate change are already evident. The study likewise reinforces the approach that local fisher's knowledge can be used to assess vulnerabilities to the fisheries sector's climate change.

Adaptation measures chosen will be critical to the future sustainability of the "giant squid" fishery and will need to consider strategies that are both beneficial to the community and the "giant squid" stocks in Marinduque, especially since the province is predicted to experience significant changes in its climate from 2020 to 2050 (DOST-PAGASA 2011). Based on the results of the VA, the local government unit (LGU) of Gasan, Marinduque, provided some climate change-related interventions. However, these are inadequate, as reflected in the low adaptive capacity scores looking at different parameters. Hence, additional strategies to lessen the vulnerability of the "giant squid" fishery could be pursued: 1) increase access to education among fishers (e.g. providing scholarships to their children), 2) increase programs related to climate change such as awareness and

capacity building, 3) modifying the existing fishing technology and innovating fishing techniques such as using milkfish as bait for catching giant squid, and 4) providing alternative livelihood following the socioeconomic approach such as access to education, modernization and improvement of fishing gears and boat, health systems, strict implementation of fishery laws and providing cash employment proposed by Muallil et al. (2013).

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## AUTHOR CONTRIBUTIONS

**De Chavez PD:** Writing-Original draft preparation; Investigation; Project Administration. **Santos SB:** Writing-Mapping. **Calderon GJA:** Writing-Analysis. **Vera Cruz EM:** Writing-Reviewing and Editing; Supervision. **Santos MD:** Conceptualization; Writing-Reviewing and Editing

## CONFLICTS OF INTEREST

We have no conflict of interest to declare.

## ETHICS STATEMENT

No animal or human studies were carried out by the authors.

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