DOI: 10.31398/tpjf/31.2.2024-0002

RESEARCH ARTICLE

Climate Change Vulnerability Assessment of Milkfish Fry Fishery in Selected Sites in Argao and Bantayan, Cebu, Philippines

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ABSTRACT

The province of Cebu is endowed with rich fisheries resources and is one of the known milkfish fry-producing areas in the Philippines. Milkfish fry fishery is one of the most critical industries in the country, and it provides livelihood to many coastal communities. However, with the global climate change threat, coastal areas serving as milkfish fry grounds are at risk. This study assessed milkfish fry fishery sites in Argao and Bantayan using a Fisheries Vulnerability Assessment Tool (FishVool). Vulnerability assessment tools aid in identifying risks, impacts, and possible climate change adaptation strategies. The results showed that the milkfish fry fishery sectors in Guiwanon, Argao, and Sungko, Bantayan in Cebu have a low- and medium overall vulnerability to climate change, respectively. In both sites, medium sensitivity and medium adaptive capacity were observed. However, the assessment also revealed different vulnerability variables responsible for the fishery's overall vulnerability index in each site. This could serve as a basis for identifying priority areas for localized and climate-resilient management plans for the milkfish fry fishery.

*Corresponding Author: *angelliasis@gmail.com*
Received: *January 2, 2024*
Accepted: *July 22, 2024*

Keywords: *Milkfish fry fishery, Climate change, Fish Vool, Vulnerability assessment, Cebu*

1. INTRODUCTION

The province of Cebu and many other provinces in the country rely on fisheries and fisheries-related livelihood as one of its main economic sectors. In Central Visayas, the fishing industry provides livelihood to more than 200,000 people and is the main source of income and food for many families living below the poverty threshold (Green et al. 2004). However, this heavy reliance on coastal systems connotes a high vulnerability to climate change since coastal areas in the Philippines are vulnerable to climate change hazards such as sea level rise, storm surge, monsoon rains, surface temperature changes, and tropical cyclones (Mamauag et al. 2013; Jacinto et al. 2015; Cruz et al. 2017; De Chavez et al. 2021) that cause flooding, erosion, salinization, siltation, and deterioration of coastal ecosystems as well as property damage (Cruz et al. 2017). These hazards affect not only the resource but also the ecosystem services that they provide.

With the increasing concentrations of greenhouse gases, carbon dioxide emissions scenarios have been developed to visualize a range of plausible future climates (Pielke Jr. et al. 2022). Here, the medium-range emission scenario is the most in line with recent observations and near-term carbon dioxide emissions projections (PAGASA 2011; Villarin et al. 2016; Pielke Jr. et al. 2022). Under this scenario, Cebu is projected to have changes in seasonal temperature, seasonal rainfall, and frequency of extreme events from 2020 to 2050 (PAGASA 2011). Climate projections for Cebu by the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) show a 1.03°C average increase in temperature from 28.9°C in 2020 to 29.9°C by 2050. It is also expected that there will be changes in seasonal rainfall from an average rainfall of 476 mm in 2020 to an average rainfall of 501 mm in 2050. Likewise, from 2020 to 2050, extreme events such as extreme temperature (> 35°C), dry days (rainfall ≤ 2.5 mm/day), and extreme rainfall (> 300 mm/day) will also occur. The days with extreme temperatures in Cebu will increase from 1,488 (2006-2035) to 2,463 (2036-2050). Meanwhile, the number of dry days will decrease from 5,720 days (2006-2035) to 5,693 (2036-2050), and the number of days with extreme rainfall will increase from 4 to 17 days. The expected impact of climate change is complex to determine, and its effects in intensity and characteristics vary per region (Barange et al. 2018). However, in general, the projected increase in temperatures will likely affect the growth rate, metabolism, reproduction, susceptibility to diseases and toxins, and spatial distribution of fishes (Santos et al. 2011; PAGASA 2011; Cruz et al. 2017; Barange et al. 2018; Macusi et al. 2021a). In addition, extreme events will not only affect the safety and efficiency of fishing operations during harsh weather conditions but also expose coastal communities to higher levels of threat to life and property depending on the exposure, vulnerability, and adaptive capacity of the fishing industry and community (Santos et al. 2011; PAGASA 2011; Cruz et al. 2017; Barange et al. 2018).

The use of vulnerability assessments (VAs) as tools for identifying risks, impacts, and possible adaptation strategies is included in the Philippines Climate Change Policy (Climate Change Commission 2011; De Chavez et al. 2021). Vulnerability assessment tools for coastal systems and fisheries, such as the Vulnerability Assessment Tool for Understanding Resiliency of Fisheries (VA-TURF) (Mamauag et al. 2013) and the Fisheries Vulnerability Assessment Tool (FishVool) (Jacinto et al. 2015) have been developed to assess vulnerability at the local setting and makes use of a participatory approach and commonly available data (MERF 2013; Mamauag et al. 2013; Jacinto et al. 2015). FishVool, in particular, has made revisions to VA-TURF to make it simpler and more convenient for use by Local Government Agriculture Offices (Macusi et al. 2021b). The use of FishVool has also been demonstrated in different fisheries sectors such as tuna and sardines (Jacinto et al. 2015), giant squid (De Chavez et al. 2021), and shrimp aquaculture (Macusi et al. 2022) in the Philippines. However, studies on the vulnerability to climate change of coastal systems and fisheries are only starting to emerge (Mamauag et al. 2013). At present, there is still no assessment of the vulnerability of the fry fishery sector to climate change, even though it may be one of the most vulnerable since fry fishery targets the early life stages of fish, which are not yet fully developed and are highly sensitive to environmental variation (Fuiman 2002; Chen et al. 2014).

Republic Act 8550 (as amended by Republic Act 10654) or the Philippine Fisheries Code only allows fry catching for aquaculture purposes. Caution is also advised since the use of non-selective gears in fry gathering can lead to large amounts of bycatch of postlarvae and juveniles of commercially important species (BFAR 2023) such as tunas, mackerels (Muallil et al. 2014), tarpon, glass perchlet, snapper, anchovy, shrimps, and others (Asis et al. 2016). One of the country's most essential fry fishery sectors is milkfish fry. Milkfish fry is used as seedstock for aquaculture to support the country's milkfish industry. It has an annual demand of 2.5 B milkfish fry (PHP 750 M) (BFAR 2023) and provides additional livelihood to thousands of coastal fishers and fish farmers (Smith 1981; Villaluz et al. 1983; Bagarinao 1998; Ahmed et al. 2001; Garcia et al. 2020). The national milkfish fry production in 2020 mainly came from private hatcheries (73.64%) and wild-caught fry gathering (21.39%) (BFAR 2023). According to the Bureau of Fisheries and Aquatic Resources (BFAR), the top wild milkfish fry-producing regions in 2020 were Western Visayas (44%), Central Visayas (26.37%), and Central Luzon (14.89%). However, the country is currently challenged with a shortage in milkfish fry supply—importing around 54% of the annual demand (BFAR 2023).

The province of Cebu produces up to 10 million pieces of milkfish fry (BFAR 2023) and has known wild milkfish fry grounds that could significantly contribute to the local milkfish fry production. Hence, this study aims to provide information on the vulnerability of the milkfish fry fishery in selected sites in Cebu to climate change. This information will aid in the development of climate adaptation strategies for the milkfish fry fishery in these sites and help sustain the fry supply in the country amidst climate change.

2. MATERIALS AND METHODS

2.1 Study site

The study sites are milkfish fry fishery grounds in Barangay Sungko, Bantayan and Barangay Guiwanon, Argao in Cebu (Figure 1). These municipalities were selected based on literature accounts of milkfish fry fishery in these areas (Llorca 1976; Encina and Gatus 1977; Bagarinao 1999; BFAR 2023) and in coordination with the Municipal Agriculture Offices (MAO) of Bantayan and Argao. The municipality of Argao is situated in the southeastern part of the province of Cebu. It is a first-class coastal municipality with a land area of 191.50 square kilometers. The climate category in Argao (and central and southern parts of Cebu) based on the Coronas classification is Climate Type III, where the seasons are not very pronounced but are relatively dry from November to April than the rest of the year (FAO 1980; PAGASA 2011; National Nutrition Council 2011). The municipality has 45 barangays and a population of 78,187, based on the 2020 census (Philippine Statistics Authority 2022a). The study site is in Barangay Guiwanon, a rural barangay with a population of 1,839 (2.4% of the total population) (Philippine Statistics Authority 2022a). The study site is a milkfish fry ground located on a sandy beach (09°57'55.88"N, 123°37'16.67"E) (Figure 2).

The other study site is in the municipality of Bantayan, near the northern tip of Cebu. It is a first-class coastal municipality with a land area of 81.68 square kilometers. The climate category here (and in northern parts of Cebu) is Climate Type IV, where rainfall is evenly distributed throughout the year (FAO 1980; PAGASA 2011; NNC 2011). The municipality has 25 barangays and a population of 86,247, based on the 2020 census (Philippine Statistics Authority 2022a). Here, the study site is in Barangay Sungko, a rural barangay with a population of 3,780 (4.3% of the total population) (Philippine Statistics Authority 2022a). The study site is a milkfish fry ground located in a tidal river near the mangrove forest landward zone (11°09'18.90" N, 123°44'03.44" E) (Figure 3).

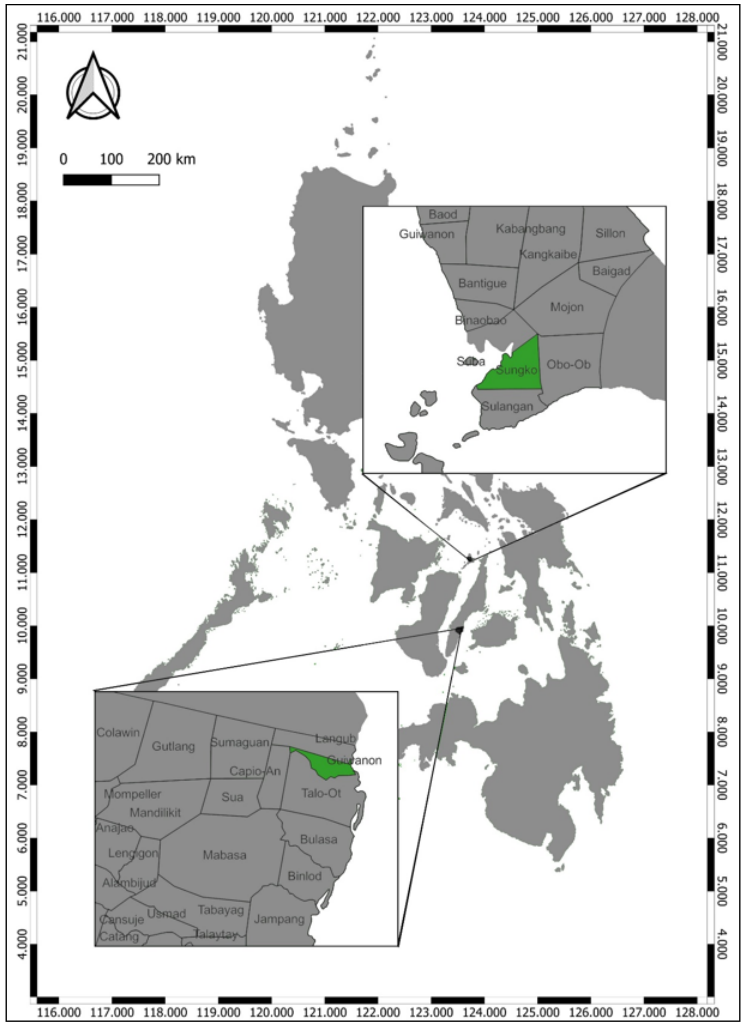

Figure 1. Milkfish fry fishery sites in Barangay Sungko, Bantayan and Barangay Guiwanon, Argao.

Figure 2. The milkfish fry ground in Barangay Guiwanon, Argao. Milkfish fry gatherers use a fry sweeper or "*trawl*" for fry gathering (right).

Figure 3. The milkfish fry ground in Barangay Sungko, Bantayan located near the mangrove landward area. The milkfish fry gatherer uses a skimming net or "*sahid*" for fry gathering.

2.2 Data collection and analysis

Key informant interviews were conducted using the FishVool questionnaire developed by Jacinto et al. (2015) with some modifications to adapt the tool to the milkfish fry fishery sector. The respondents were selected through a snowball sampling method or chain-referral sampling, and their consent was secured prior to the interview. There were 29 respondents (19 in Guiwanon, Argao, and 10 in Sungko, Bantayan) who were milkfish fry gatherers with at least six years of fry-gathering experience. The number of respondents represents 95% of milkfish fry gatherers in Guiwanon, Argao, and 50% of the milkfish fry gatherer population in Sungko, Bantayan. The scoring rubric for each variable in this study followed the FishVool rubrics by Jacinto and colleagues (2015) with some modifications (Table 1). The rubrics use a five-point, three-level scoring where the numerical score 1 to 2 signifies "Low," 3 to 4 signifies "Medium," and 5 signifies "High" (Mamauag et al. 2013; Jacinto et al. 2015). After scoring, a cross-tabulation (Punnett square) method was made, integrating the Sensitivity and Exposure to derive the Potential Impact of climate change; then, the Potential Impact was integrated into the Adaptive Capacity to determine the overall Vulnerability (Mamauag et al. 2013; Jacinto et al. 2013; Aguila et al. 2021). The category average score computation, vulnerability category translation, and cross-tabulation to get the Potential Impact and overall Vulnerability were made using the FishVool Excel Program (Aguila et al. 2021).

2.2.1 Vulnerability criteria variables

Exposure. The exposure (E) components are those that are known hazards to coastal areas in the country, namely increased temperature, typhoons, sea level rise, and unpredictable weather (Mamauag et al. 2013; Jacinto et al. 2015; Cruz et al. 2017; Macusi et al. 2021b) that could impact the milkfish fry fishery sector. The exposure variables were based on the criteria adapted from Jacinto et al. (2015), which are the frequency and severity of exposure of the fry gathering ground (E1), the fry gatherer household site (E2), and the coastal community site (E3) to extreme weather disturbances.

Sensitivity. The sensitivity (S) component is the present state of the fry resource and fishery in response to the exposure factors. The sensitivity variables for the fry resource include habitat quality (S1) or the condition of the milkfish fry ground (Mamauag et al. 2013) and the milkfish fry catch rate (S2) or the trend in milkfish fry catch rate over the years (Jacinto et al. 2015). For the fry gatherer, sensitivity variables include socio-economic conditions such as the fry gatherer's age (S3), household size (S4), and dependence on fry gathering (S5), which determines their capacity to cope with extreme weather conditions that could affect their health and disrupt the fry gathering activity, and their dependence on the fishery (Jacinto et al. 2015; Heenan et al. 2015). Finally, for the coastal community, sensitivity variables include the population density (S6) or the number of houses and other structures per square kilometer at the coasts, which may indicate the number of users or degree of utilization of coastal fishery (Mamauag et al. 2013); and community dependence on milkfish fry fishery (S7) or the proportion of fry gatherers relative to the total population (Jacinto et al. 2015). This indicates the importance of fry fishery in the community (Mamauag et al. 2013; Jacinto et al. 2015).

Adaptive capacity. The adaptive capacity (AC) component is the ability to cope with the

Table 1. Milkfish fry fishery vulnerability assessment scoring rubric

Components	Criteria		Score		
			Low (1-2)	Medium (3-4)	High (5)
Exposure	Fry ground exposure to climate change hazards (annually)	E1	(1) 0-1 weather disturbance; (2) 2 Weather disturbances	(3) 3-4 weather disturbances; (4) 5-6 weather disturbances	More than 6 weather disturbances
	Household site exposure to climate change hazards (annually)	E2	(1) 0-1 weather disturbance; (2) 2 Weather disturbances	(3) 3-4 weather disturbances; (4) 5-6 weather disturbances	More than 6 weather disturbances
	Coastal community site exposure to climate change hazards (annually)	E3	(1) 0-1 weather disturbance; (2) 2 Weather disturbances	(3) 3-4 weather disturbances; (4) 5-6 weather disturbances	More than 6 weather disturbances
Sensitivity	Habitat quality	S1	(1) Large contiguous habitat (2) Very large contiguous habitat	(3) Large but patchy (4) Small habitat	Small and fragmented habitat
	Target fry catch rate	S2	(1) 50-100% increased catch rate over the years; (2) 0-50% increased catch rate over the years	(3) Normal catch rate over the years (steady); (4) Normal catch rate over the years (fluctuating)	Decreasing catch rate over the years
	Age	S3	(1) below 26 years of age; (2) 26-40 years of age	(3) 41-55 years of age; (4) 56-65 years of age	Above 65 years old
	Household size	S4	(1) Fewer than 3 persons in the household; (2) 3 persons in the household	(3) 4 persons in the household; (4) 5 persons in the household	More than 5 persons in the household
	Dependence on fry gathering	S5	(1) Household income resource from fry gathering is less than 20%; (2) Household income resource from fry gathering is 20-40%	(3) Household income resource from fry gathering is 41-60%; (4) Household income resource from fry gathering is 61-80%	Household income resource from fry gathering is greater than 80%
	Population density	S6	(1) Less than 100 persons per square kilometer in a fishing village (not crowded); (2) 100-200 persons per square kilometer	(3) 201-300 persons per square kilometer; (4) 301-400 persons per square kilometer	More than 500 persons per square kilometer (very crowded)
	Dependence on fry fishery	S7	(1) Less than 10% of adult population dependent on fry fishery for livelihood; (2) 11-25% of the adult population are dependent on fry fishery for livelihood	(3) 26-35% of the adult population are dependent on fry fishery for livelihood; (4) 36-50% of the adult population are dependent on fry fishery for livelihood	Majority (>50%) of the adult population is dependent on fry fishery for livelihood
Adaptive Capacity	Fry temperature tolerance	AC1	(1) Very low abundance of temperature-tolerant fry (2) Low abundance of temperature-tolerant fry	(3) 50% non-tolerant fry species (4) Abundant temperature-tolerant fry	Highly abundant temperature-tolerant fry
	Presence of adjacent habitats (e.g., coral reefs, seagrass bed, mangrove forest)	AC2	(1) Absence of adjacent habitats; (2) extreme degradation of adjacent habitats	(3) Degraded adjacent habitat; (4) One adjacent habitat in good condition	Two or more adjacent habitats in good condition
	Alternative livelihood (fry gatherer)	AC3	(1) Less than 20% of fry gatherers have other sources of income; (2) 21-40% of fry gatherers have other sources of income	(3) 41-50% of fry gatherers have other sources of income; (4) 51-60% of fry gatherers have other sources of income	More than 60% have other sources of income
	Access to information (e.g., TV, radio, newspaper, internet, etc.)	AC4	(1) No sources of information; (2) 1-2 sources of information	(3) 3-4 sources of information; (4) 5-6 sources of information	More than six sources of information

Continuation of Table 1. Milkfish fry fishery vulnerability assessment scoring rubric

Components	Criteria		Score: Low (1-2)	Medium (3-4)	High (5)
	Fishing modification	AC5	(1) No modification and no resources (budget); (2) With some modification, no resources (budget	(3) With some modification and limited resources, unsuccessful (4) With some modification, limited resources; limited success	With modification and resources; successful
	Annual income obtained from fry fishery	AC6	(1) More than 80% of annual income generated from fry fishery; (2) 61-80% of annual income generated from fry fishery	(3) 41-60% of annual income generated from fry fishery; (4) 20-40% of annual income generated from fry fishery	Less than 20% of annual income generated from fry fishery
	Climate change support programs (e.g., seminars, workshops, trainings)	AC7	(1) No climate change support programs; (2) 1 program or support to climate change	(3) 2 climate change support programs; (4) 3 climate change support programs	More than 3 climate change support programs
	Adaptive strategies of community (e.g., knowledge on processing and storing of fry catch, and additional climate change knowledge or training)	AC8	(1) No adaptive strategies; (2) 1 adaptive strategy	(3) 2-3 adaptive strategies; (4) 4-5 adaptive strategies	More than 5 adaptive strategies

impacts of climate change (Licuanan et al. 2012). The adaptive capacity variables for the fry resource include the milkfish fry temperature tolerance (AC1) since fry are not yet fully developed and inherently sensitive to environmental variations (Fuiman 2002; Chen et al. 2014) and the presence of adjacent habitats (AC2), which enhances connectivity for survivorship and serves as refuge site (Mamauag et al. 2013). For the fry gatherer, adaptive capacity variables include alternative livelihood (AC3) or other sources of income, access to information (AC4) that enable fry gatherers to cope with disasters, and fishing modification (AC5) that ensures more effective fishing effort (Jacinto et al. 2015). Lastly, the coastal community adaptive capacity variables include annual income obtained from fry fishery (AC6), which describes the economic profile of a community dependent on fishing resources (Jacinto et al. 2015; Aguila et al. 2021), climate change support (AC7) or programs that create awareness and educate the community on climate change risks and adaptation measures (Jacinto et al. 2015), and adaptive strategies (AC8) such as knowledge on processing and storing of fry catch, and additional knowledge or training on climate adaptations (Macusi et al. 2021b).

3. RESULTS

3.1 Sungko, Bantayan

The sensitivity (S) analysis for Sungko, Bantayan showed an average score of 2.10 or a medium sensitivity score (Table 2). Here, the component parameters showed low scores for milkfish fry catch rate (S2), fry gatherer's age (S3), dependence on fry gathering (S5), the community's population density (S6), and dependence on milkfish fry fishery (S7). This is because the milkfish fry catch rate here is observed to be increasing (≤ 50%); the average age of milkfish fry gatherers is 26–40 years old; there was uncrowded and low utilization of coasts for milkfish fry fishery; less than 20% of the household income comes from fry gathering (majority of primary livelihood being fishing, farming, and trucking or driving); and less than 10% of the adult population depend on milkfish fry fishery for livelihood. Meanwhile, medium scores were noted for the habitat quality (S1) and household size (S4) since the milkfish fry ground is large and patchy, and the milkfish fry gatherers have big households with an average of four persons.

Table 2. Vulnerability indices of the milkfish fry fishery in Guiwanon, Argao and Sungko, Bantayan in Cebu.

Vulnerability Assessment (VA) Components	Parameters	Argao			Bantayan		
		Score	Average Score	Vulnerability Index	Score	Average score	Vulnerability Index
Sensitivity (S)	S1: Habitat quality	1.00	2.18	M	3.00	2.10	M
	S2: Milkfish fry catch rate	4.84			2.50		
	S3: Age	3.26			2.90		
	S4: Household size	3.00			3.20		
	S5: Dependence on fry gathering	1.16			1.10		
	S6: Population density	1.00			1.00		
	S7: Dependence on fry fishery	1.00			1.00		
Exposure (E)	E1: Fry ground	1.00	1.00	L	4.00	3.33	M
	E2: Household site	1.00			3.00		
	E3: Coastal community site	1.00			3.00		
Adaptive Capacity (AC)	AC1: Milkfish fry temperature tolerance	4.00	3.44	M	4.00	3.34	M
	AC2: Presence of adjacent habitats	4.00			5.00		
	AC3: Alternative livelihood	5.00			5.00		
	AC4: Access to information	2.89			2.80		
	AC5: Fishing modification	2.68			1.40		
	AC6: Annual income obtained from milkfish fry fishery	4.84			4.90		
	AC7: Climate change support programs	1.11			1.20		
	AC8: Adaptive strategies	3.00			2.40		

Exposure (E) analysis showed an average score of 3.33 or a medium exposure to climate threats such as increased temperature, typhoons, sea level rise, and unpredictable weather since these are experienced in the area about 3–4 times per year (Table 2). As for the Adaptive Capacity (AC), Sungko has a medium AC score of 3.34. Here, the component parameters showed high scores for the presence of adjacent milkfish fry habitats (AC2) and fry gatherer's alternative livelihood (AC3) since there are more than two adjacent milkfish fry habitats in good condition and because more than 60% of milkfish fry gatherers have alternative livelihoods. Medium scores were recorded for milkfish fry temperature tolerance (AC1) because milkfish fry can tolerate temperatures of up to 40°C (Villaluz and Unggui 1983; Astuti and Warsa 2020); and for the annual income obtained from milkfish fry fishery (20–40%) (AC6) since it means that their economic profile is not heavily dependent on the milkfish fry resource. Meanwhile, low scores were recorded for access to information (AC4) (e.g., newspaper, internet, radio, and others) to cope with climate disasters (1–2 sources); strategies to ensure more effective fishing effort (AC5); the presence of climate change support programs for fry fishery in the community (AC7); and other adaptive strategies (AC8) such as knowledge on processing and storing of fry catch, and additional climate adaptation seminars or training.

3.2 Guiwanon, Argao

The sensitivity (S) analysis for Guiwanon, Argao revealed a medium sensitivity score of 2.18 (Table 2). The component parameters showed low scores for milkfish fry habitat quality (S1), dependence on fry gathering (S5), the community's population density (S6), and dependence on milkfish fry fishery (S7). Here, the milkfish fry habitat is large and contiguous; the area was uncrowded with low utilization for milkfish fry fishery; less than 20% of the household income comes from fry gathering (majority of primary livelihood being fishing and construction work); and less than 10% of the adult population depend on milkfish fry fishery for livelihood. Meanwhile, medium scores were recorded for the fluctuating milkfish fry catch rate (S2), older age of milkfish fry gatherers (41–55 years old) (S3), and the big households of fry gatherers with an average of four persons (S4).

Exposure (E) analysis revealed a score of 1.00 or a low average exposure to climate hazards experienced in the area (0–1 time per year) (Table 2). As for the Adaptive Capacity (AC), Guiwanon has a medium adaptive capacity score of 3.44. The component parameters for AC showed a high score for alternative livelihoods (AC3) since more than 60% of fry gatherers only engage in milkfish fry gathering for supplemental income. Medium scores were recorded for milkfish fry tolerance (AC1); presence of one adjacent milkfish fry habitat in good condition (AC2); the annual income obtained from milkfish fry fishery (AC6) being around only 20–40% which means that their economic profile is not heavily dependent on the milkfish fry resource; and the climate adaptive strategies of the community (AC8). Meanwhile, there were low scores for access to information (AC4) (e.g., newspaper, internet, radio, and others) to cope with climate disasters (1–2 sources); strategies to ensure more effective fishing effort (AC5); and presence of climate change support programs for fry fishery in the community (AC7).

3.3 Overall vulnerability

The results show that climate change threats have a medium potential impact (medium exposure to climate threats x medium sensitivity) on the milkfish fry fishery sector in Sungko, Bantayan. With Sungko's medium adaptive capacity, the milkfish fry fishery sector showed a medium overall vulnerability to climate change (Table 3, Figure 4). For Guiwanon, climate change threats have a low potential impact (low exposure to climate threats x medium sensitivity) on the sector. With medium adaptive capacity, the sector in Guiwanon, Argao showed a low overall vulnerability to climate change (Table 3, Figure 4).

4. DISCUSSION

The vulnerability indices for the milkfish fry fishery sector in Barangay Guiwanon, Argao, and Barangay Sungko, Bantayan, showed that the fishery in these areas is vulnerable to climate change. Moreover, the milkfish fry fishery sector in Sungko, Bantayan, is seen to be more vulnerable to climate change, with a medium overall vulnerability. These results suggest the need for localized management and climate change adaptation strategies for each municipality, particularly because different variables were responsible for the overall sensitivity of the fishery in each site (Figure 5).

4.1 Sungko, Bantayan

The municipality of Bantayan is one of the two municipalities in Cebu Province with the highest number of fishers (Green et al. 2004). Barangay

Table 3. Overall vulnerability index of milkfish fry fishery in Guiwanon, Argao and Sungko, Bantayan.

Site	Vulnerability Index			Potential Impact (Sensitivity x Exposure)	Vulnerability (Adaptive Capacity x Potential Impact)
	Sensitivity	Exposure	Adaptive Capacity		
Argao	M	L	M	L	L
Bantayan	M	M	M	M	M

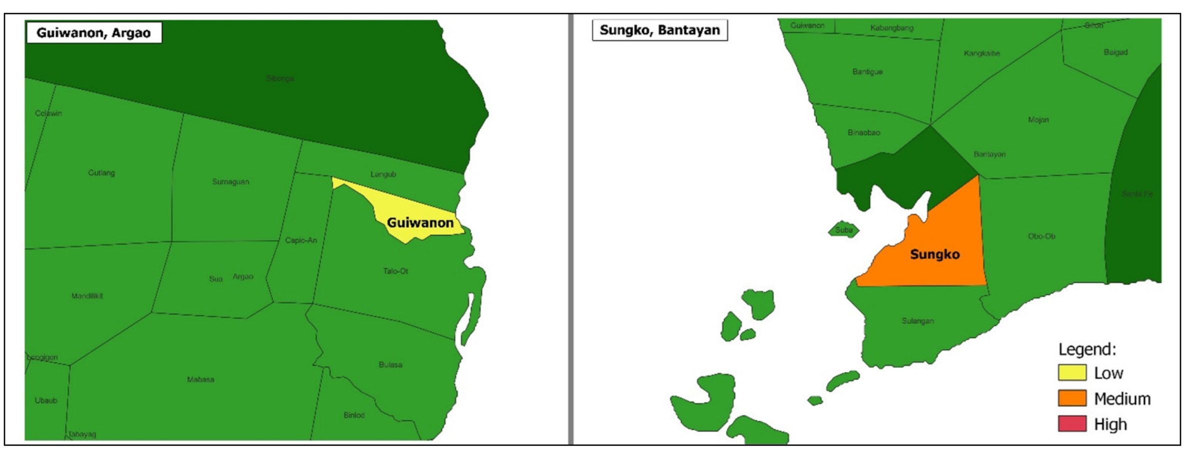

Figure 4. Vulnerability map of milkfish fry fishery sector in Barangay Guiwanon, Argao and Barangay Sungko, Bantayan.

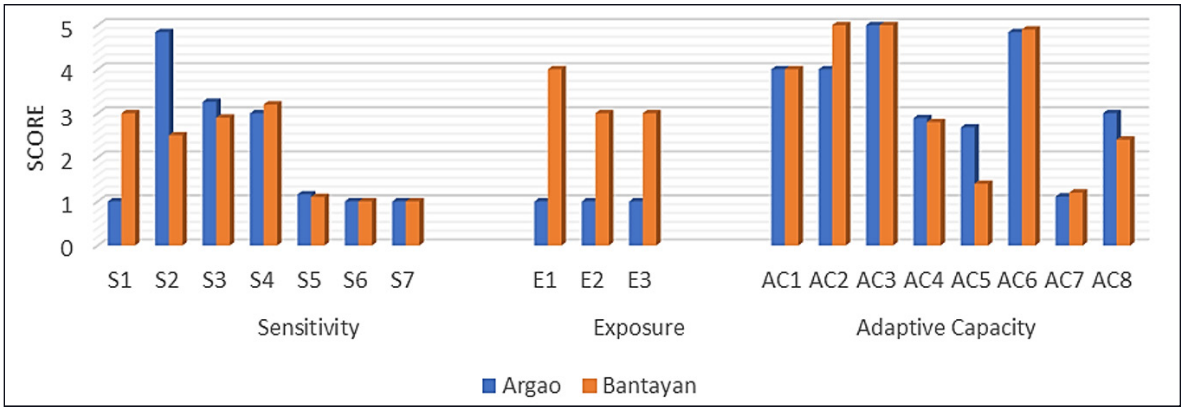

Figure 5. Comparison of vulnerability indices of the milkfish fry fishery in Guiwanon, Argao and Sungko, Bantayan. The vulnerability criteria variable scoring uses a five-point, three-level scoring where the numerical score 1 to 2 signifies "Low," 3 to 4 signifies "Medium," and 5 signifies "High."

Sungko is a rural barangay in the municipality that makes up 4.3% of its population (3,780 people). Milkfish fry gatherers here can catch an average of 2,600 milkfish fry in an hour during the peak season and around 300 milkfish fry per hour in lean seasons. The fry-gathering activity usually starts at 5 AM and lasts for at least two hours. The milkfish fry catch is then sold to fish cage operators in the municipality or nearby towns for 20 centavos per piece. On average, milkfish fry gatherers can earn up to PHP 1,500 per day during the milkfish fry peak season in May and about PHP 180 per day during the lean season from June to July.

From the vulnerability assessment, the milkfish fry fishery sector in Sungko, Bantayan, is more vulnerable to climate change impacts because of its medium exposure index. This may be due to its location since Bantayan is near the northern tip of Cebu. According to PAGASA (2023), nearly all typhoon landfalls track over Luzon and Samar Island and are generally oriented east-west or east southeast-west northwest from the Philippine Sea. Because of the climatological nature of tropical cyclone tracks, the northern end of Cebu Province is usually more affected by weather disturbances than its southern region. The annual average typhoon landfall in Bantayan is 1.9, and the area is known to be vulnerable to climate hazards brought about by high winds and storm surges (Brown et al. 1991; Cuadra et al. 2014). Inundation maps for storm surge simulations in Bantayan also show that Barangay Sungko is one of the two areas in the municipality that is prone to high surge levels (Cuadra et al. 2014).

Another contributing factor to the vulnerability of the milkfish fry fishery in Sungko, Bantayan, to climate change, is the medium sensitivity of habitat quality. The milkfish fry ground here is fragmented by a bridge and other structures in the barangay; hence, the habitat quality is patchy. Habitat fragmentation leads to both habitat loss and habitat disintegration (Datry et al., 2017). Since the milkfish fry ground here is dependent on the tidal motion, some areas can experience high surge levels (Cuadra et al. 2014) or dry up (as recounted by a respondent), affecting milkfish fry survival. In addition, the site is located near the mangrove forest landward zone, which is also threatened by anthropogenic pollution sources. Landward areas of mangrove forests are more polluted and retain more marine debris than seaward mangrove areas (Luo et al. 2022). However, based on the interviews, a current increase in milkfish fry catch (≤ 50%) is observed here, which they attribute to the operation of milkfish cages in the municipality starting in early 2023. However, further study and monitoring are still needed to confirm this.

There is also medium sensitivity in the socio-economic conditions, particularly in the household size of fry gatherers. Sungko, Bantayan has an average household size of 4.31, according to the 2020 population census (Philippine Statistics Authority 2022a). Since the poverty characteristics of a family are determined by dividing the total family income by the size of the family (Philippine Statistics Authority 2022b), larger households have higher risks of poverty. The large family size increases the risk of poverty due to higher financial and educational costs (Greenspan 1992; Orbeta 2005). The poverty incidence also increases as the household size increases, with four-member households having a 36.4 poverty incidence in 2000 (Orbeta 2005). This is also aggravated by the fact that Barangay Sungko is one of the poorest communities in Bantayan, with most families largely dependent on fishing for livelihood (Opdyke et al. 2016). Hence, although the respondents were not solely dependent on the milkfish fry fishery, most still take part in the fishery as an additional source of income for the family.

Regarding adaptive capacity, Sungko, Bantayan only has medium adaptive capacity because of the limited resources of milkfish fry gatherers and low awareness of climate change. The lack of resources due to their socio-economic conditions provides little access to information (i.e., TV, radio, newspaper, internet, and others), which may hinder their ability to cope with climate-related threats (Jacinto et al. 2015). Likewise, their limited financial resource only allows them to make very few modifications to their fishing gears to increase catch rates. Also, although the municipality of Bantayan has several programs and training for fisherfolks, the respondents do not recall attending any climate change-related events, so they have little to no awareness of the impacts of climate change on them and their livelihoods. This may be due to the municipality strictly regulating fry fishery to conserve fry resources. At present, the LGU's focus is to transition fishers into alternative livelihoods. The municipality conducts various training programs, such as milkfish post-harvest practices and fiberglass boat building, to name a few. In 2022, the municipality, together with the Department of Social Welfare and Development (DSWD) poverty alleviation program "Kapit-Bisig Laban sa Kahirapan-Comprehensive and Integrated Delivery of Social Services" (Kalahi-CIDSS), also conducted training for the operation and maintenance of fish cages for fishers associations in Bantayan. The municipality also assisted fishers by linking them to financial institutions and providing milkfish fry from the municipality's hatchery.

Currently, there is no data on wild milkfish fry production in Bantayan. It is also not listed in BFAR 7's database of milkfish fry fishery sites (BFAR 7, personal communication, November 21, 2023). However, based on the interviews conducted, there are about 20 milkfish fry gatherers in Sungko, Bantayan, and the number of wild milkfish fry caught by a fry gatherer during the peak season can go as high as 2,600 milkfish fry per hour and 14,000 milkfish fry per day. This suggests the municipality's potential to contribute to the country's required milkfish fry production. Hence, the adaptive capacity of the fishery should be increased by conducting climate change support programs, capacitating milkfish fry gatherers on how to ensure more effective fishing efforts, and enhancing their knowledge on other adaptive strategies such as storage and grow-out of milkfish fry catch due to more preference (and higher pay) for milkfish fingerlings.

4.2 Guiwanon, Argao

The municipality of Argao is in the southeastern part of the province of Cebu and has a low concentration of fishers (Green et al. 2004). Barangay Guiwanon is a rural barangay in Argao, making up to 2.4% (1,839) of the municipality's total population. It has an average household size of 4.48, according to the 2020 population census (Philippine Statistics Authority 2022a). On average, a milkfish fry gatherer here can earn up to PHP 1,200 per day during the peak season from April to June and about PHP 130 per day during the lean season from July to October. The milkfish fry catch is then sold to the sole buyer in the municipality for 20 centavos during the peak season and 15 centavos during the lean season.

Barangay Guiwanon, Argao's milkfish fry fishery sector, has low overall vulnerability to climate change mainly because of its low exposure index (0–1 annual weather disturbance). In terms of sensitivity, it has a medium sensitivity to climate change due to the average age of milkfish fry gatherers (41–55 years old) and their household size. The age and health of the fry gatherer can hinder their capacity to cope with extreme weather conditions during fry gathering. The fry-gathering activity can also be physically taxing since all the respondents have a different primary livelihood source. For example, fishers (39% of respondents) conduct the fry gathering activity after returning from fishing at dawn, usually starting at 5 AM and lasting for 2–8 hours. In addition, the higher risks of poverty in larger households, as previously discussed, hinder their access to healthcare services due to a lack of financial resources. This worsens their circumstances since old age and poor health may disrupt the fry-gathering activity and their dependence on the fishery. In the Philippines, although the national health insurance program (PhilHealth) has a special Indigent Program for indigent families, access to accredited healthcare remains a challenge for people with low incomes because of the high cost of medicine and remoteness of facilities for those living in rural areas (El Omari and Karasneh 2021).

Another contributor to the medium sensitivity to climate change here is the fluctuating milkfish fry catch rate. There is no published data on the number of milkfish fry gatherers and the wild milkfish fry production in Guiwanon, Argao. According to the BFAR regional office (BFAR 7, personal communication, November 21, 2023), there are eight milkfish fry gatherers in Guiwanon as of August 2023, with an average milkfish fry catch of 107-1,400 milkfish fry per operation. However, based on the interviews conducted, there are 20 milkfish fry gatherers in the barangay, with an average milkfish fry catch of 1,000 milkfish fry per hour during the peak season and around 300 milkfish fry per hour during the lean season. The respondents also said the milkfish fry catch has declined from an average catch of 5,000 per hour during peak seasons more than 20 years ago. The sole milkfish fry buyer in the municipality also observed a decrease in wild milkfish fry supply. According to the respondent, the total wild milkfish fry catches in the municipality (including other barangays with milkfish fry fishery) more than 10 years ago was above the present production of 300,000 during the peak season and 100,000 during the lean season. The perceived causes of the decline in wild milkfish fry supply in Guiwanon, Argao were increasing temperature and catching of "Sabalo" or the adult milkfish. These perceived causes were also similar to the survey results of the 1996 milkfish fry resource assessment conducted by Ahmed and colleagues (2001) at five important milkfish fry-producing regions in the country (Ilocos Norte, Palawan, Bohol, Antique, and Sarangani). Further studies are needed to confirm and address these perceived reasons for declining milkfish fry resources because milkfish fry gatherers consistently mention these.

Since the milkfish fry fishery sector in Guiwanon, Argao is still vulnerable to climate change threats, its adaptive capacity index should be increased through climate change support programs, capacity building, and enhancing the knowledge of milkfish fry gatherers on other adaptive strategies. Aside from enhancing the adaptive capacity of the milkfish fry sectors in both sites, the medium sensitivity index should also be lowered to lessen the potential impact of climate change on the fishery. At present, the municipality of Argao conducts seminars and training for fishers, such as financial literacy seminars, milkfish fry and fingerlings handling and production, and milkfish post-harvest practices, storage, and marketing. Some fishers are also involved in municipal fish cage operations that employ a sharing scheme after harvest.

4.3 Climate change mitigation and adaptation options

The Philippine Fisheries Code (Republic Act 8550, as amended by Republic Act 10654) allows catching wild milkfish fry for aquaculture, provided that fry gatherers are registered municipal fisherfolks. At the local government level, the Department of the Interior and Local Government (DILG) has also recently released guidelines for enacting and updating the municipal fisheries ordinance of coastal local government units (DILG Memorandum Circular No. 2023-012). This policy guides coastal LGUs, such as Argao and Bantayan, on enforcing and regulating the activities in their municipal waters. At present, both municipalities are updating their fisheries ordinance following the basic and comprehensive Fisheries Ordinance template contained in the guideline. The template includes the identification of production zones or fishing grounds, including fry-gathering areas. It also states the creation of a municipal or city fisheries development plan that will serve as the basis for the management, utilization, development, and conservation of its coastal and fisheries resources.

In enhancing climate change adaptive capacity, an ecosystems-based adaptation approach should be made. This approach uses biodiversity and ecosystem services and local traditional knowledge as part of the overall adaptation strategy (Baig et al. 2016; GIZ 2018). In the fisheries sector, some examples of this approach include the restoration of fragmented or degraded natural areas (e.g., mangrove rehabilitation and restoration) and management of marine protected areas (Baig et al. 2016), the establishment of biological reference points based on stock assessments (Talbot et al. 2024), and co-management of fisheries resources (Shelton 2014). In this study, the identified climate change vulnerability variables can serve as starting points for formulating climate change adaptation plans for milkfish fry fishery in the study sites. It is recommended that localized management plans and strategies are made for each site since there are different variables that are responsible for the overall sensitivity of the fishery in each area. In the study sites, the management of milkfish fry grounds should include programs for pollution control and fry resource assessment to identify other fry species threatened by milkfish fry fishery bycatch. The result of the assessment can also be used as a basis for conservation and management plans of different fry resources.

Likewise, aside from programs and policies that protect the resource, programs that address poverty and improve the welfare of fry gatherers are also needed because they are the primary stakeholders of the sector. The milkfish fry gatherers in both sites belong to the informal economy, the majority of whom are fisherfolks (36%), farmers (11%), truck drivers (11%), and construction workers (10%) (Figure 6). An overall average of 38% for both sites are also women. These socioeconomic groups, in terms of poverty incidence of basic sectors in the country, remain the

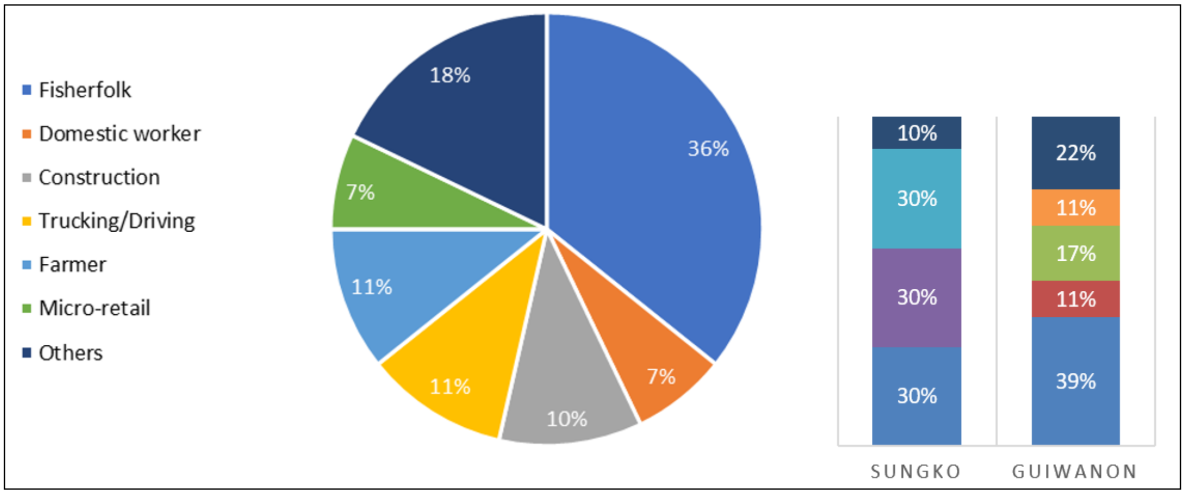

Figure 6. Primary livelihood of milkfish fry gatherers in Guiwanon, Argao and Sungko, Bantayan, Cebu, Philippines. The total percentage for both sites is shown in the pie chart, while the breakdown per site is shown on the labeled bars on the right. Other sources of livelihood include self-employed work, security guard, factory work, and wood gathering.

poorest individuals living below the poverty threshold (Philippine Statistics Authority 2023). Poverty increases vulnerability, especially in these groups, since they rely on coastal resources for livelihood and lack household resources (UNDRR 2019).

In the milkfish industry, climate change, disasters, and recent global uncertainties affect and disrupt the production cycle (BFAR 2023). Since milkfish fry gatherers are important primary input providers in the milkfish fry supply chain (Figure 7), other adaptation options that can also be considered by the local government and other concerned government agencies include training milkfish fry gatherers on milkfish fry storage and grow-out assistance for establishing milkfish fry holding facilities and linking them to milkfish growers to avoid multi-level marketing. Training on milkfish fry storage and grow-out is important since there is a preference for milkfish fingerlings. There are also instances when there is no immediate buyer, or there are weather disturbances like typhoons and heavy rains that affect trading. The establishment of fry holding facilities will also help address these problems since this will improve fry survival. Finally, linking the fry gatherers to milkfish growers will help avoid price manipulation due to multi-level marketing (BFAR 2023). This was observed in the study sites where the buyer dictated the price of the milkfish fry. In Guiwanon, Argao where there is a consolidator, the price of milkfish fry is relatively lower compared to Sungko, Bantayan.

This study has also made apparent the scarcity of data and the need for accurate data records on the milkfish fry fishery. This underscores the need for an updated and more comprehensive milkfish fry resource assessment, as well as the development of a reliable fry catch monitoring system. This will support not only milkfish research and development activities but also the goal of the National Milkfish Fry

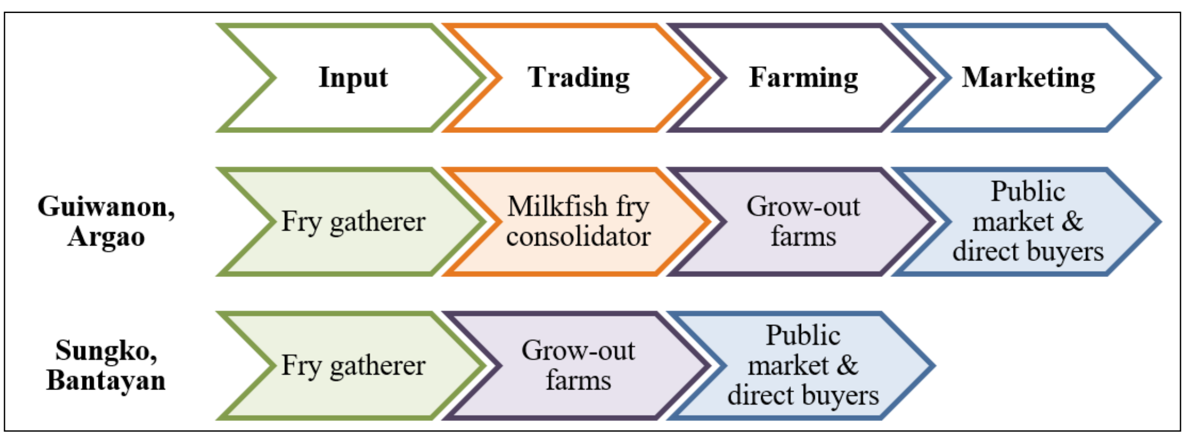

Figure 7. Generalized milkfish fry supply chain in Guiwanon, Argao and Sungko, Bantayan, Cebu.

Sufficiency Program by providing precise estimates of the country's wild milkfish fry resource.

5. CONCLUSION

The vulnerability assessment conducted showed that the milkfish fry fishery sectors in Guiwanon, Argao, and Sungko, Bantayan in Cebu, are vulnerable to climate change threats. The study revealed different causes of vulnerability of the milkfish fry fishery in each site, thereby suggesting that localized management interventions are needed to reduce the potential impact of climate change. These interventions should include policies and programs for the conservation of milkfish fry grounds and the reduction of socio-economic vulnerabilities of milkfish fry gatherers. In addition, the adaptive capacity of the milkfish fry fishery sector in the two sites should also be enhanced through climate change support programs that increase the milkfish fry gatherers resources and knowledge on climate change impacts; training on milkfish fry storage and grow-out; assistance in linking milkfish fry gatherers to buyers; and provision of livelihood support programs. Enhancing the sector's adaptive capacity will aid in improving the livelihood of milkfish fry gatherers and sustaining the fishery amidst climate change. It will also contribute to the goal of milkfish fry self-sufficiency in the country.

In this study, the use of FishVool proved to be a valuable tool in assessing the vulnerability to climate change of the milkfish fry fishery sector in the study sites. However, since the study was only limited to one barangay per municipality, it is recommended that VAs should also be conducted in other milkfish fry fishery sectors in the said municipalities, and in the province, for a more comprehensive milkfish fry fishery VA in Cebu.

ACKNOWLEDGMENT

The authors would like to acknowledge the Department of Science and Technology-Accelerated Science and Technology Human Resource Development Program-National Science Consortium (DOST ASTHRDP-NSC) for the dissertation and student research support grant. We would also like to express gratitude to the Municipal Agriculture Offices of Argao and Bantayan, Cebu, and BFAR 7 regional office for their help during the study; to Mr. Sherwin B. Santos for his assistance in the GIS mapping; and to the reviewers who provided valuable comments that further improved the manuscript.

AUTHOR CONTRIBUTIONS

Egar AMJA: Conceptualization, Investigation, Analysis, Writing-original draft, Writing- review and editing. **Geraldino PJL:** Writing- review and editing, Supervision. **Santos MD**: Conceptualization, Writing-review and editing.

CONFLICTS OF INTEREST

There is no conflict of interest.

ETHICS STATEMENT

No animal or human studies were carried out by the authors. The research protocol has been approved by the University of San Carlos Research Ethics Committee.

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