RESEARCH ARTICLE

Climate Change Vulnerability Assessment of the Eel Fishery in Aparri, Cagayan, Philippines

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ABSTRACT

The global glass eel population is continuously declining over the years. Apart from the anthropogenic factors, the global production decline suggests that the changing climatic condition may have influenced its downtrend. This study assessed the climate change vulnerability of the eel fishery in Aparri, Cagayan, being one of the major collection areas in the Philippines. Vulnerability assessment (VA) was conducted using the Fisheries Vulnerability Assessment Tool (FishVool) through focus group discussion (FGD) with 25 participants and key informant interview (KII) with 50 respondents whose experiences are up to 10 years. Results showed that the overall climate change vulnerability of the eel fishery in Aparri, Cagayan, Philippines is high due to high exposure (4.76) to extreme weather events but medium in sensitivity (3.35) and adaptive capacity (3.2). The results of this study provided valuable information to government fisheries planners, policymakers, and other fisheries stakeholders in developing policies and management plans that will reduce vulnerability and build climate-resilient eel fishery.

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1. INTRODUCTION

The declining catch of tropical *Anguillid* eel is drawing attention in East Asia due to seed supply insufficiency for farming (SEAFDEC 2019). The situation occurred when the population of the farmed eel, particularly *Anguilla anguilla*, a temperate species, decreased, which may be due to anthropogenic activities such as overexploitation, habitat loss, pollution, migration barriers, and global oceanic changes (Dekker and Casselman 2014; Muallil et al. 2014). Consequently, this species was placed under endangered status in Appendix II of the Convention on International Trade in Endangered Species of wild Fauna and Flora (CITES) (Crook 2014). Thus, eel farmers must resort to tropical species to fill the supply gap.

Studies show, however, that glass eel catch has been drastically declining over the last four decades (Crook 2014). This trend is similar to the general status of fisheries, where stagnation or decline in the total Philippine fish catch volume over the years of most captured fisheries is experienced (Anticamara and Go 2016). Mainly attributed to the direct impacts of human activities (Muallil et al. 2014), fish stock recovery may be possible through fisher's willingness to cooperate and support the closed fishing season policy (Macusi et al. 2021). The strategy should, however, be accompanied by cash incentives to help fishers exit from the fishery (Macusi et al. 2022).

The Philippines became an essential player in the eel industry because of its strategic location within the sphere of influence of Korushio current and North Equatorial Current (NEC). The two connecting currents transport the eel larvae, called leptocephali, via Kuroshio current near the eastern side of the Philippines and disperse them throughout their growth habitats in other East Asian countries such as Taiwan, China, South Korea, and Japan (Zenimoto et al. 2009; Shinoda et al. 2011). It was believed, however, that the bifurcation of the two current systems shifted the spawning area of *A. japonica* southward; thus, its population in East Asia decreased (Kimura et al. 2001; Kim et al. 2007; Zenimoto et al. 2009).

In 2012 and 2013, the country was the source of approximately 30% of all East Asian live eel fry imports (Crook 2014), sold from PHP 14,000 to PHP 50,000 per kilogram (Ame et al. 2013). The dramatic increase in the exploitation and trade of glass eel in 2011 (1.5 tonnes) and 2012 (3.8 tonnes) has alarmed authorities in the country; hence, Fisheries Administrative Order (FAO) 242 banning the export of elvers with size less than 15 cm was released as a precautionary approach to arrest further resource depletion (Crook 2014). Due to its increasing demand, the increasing illegal trade and export of glass eel in the Philippines are of growing concern. The situation was heightened when large quantities were traded, alarming authorities of its impact on the resources.

Most glass eel fishers are found in the northern part of the country, particularly Aparri, Cagayan (Cuvin-Aralar et al. 2014). A total of five species, namely *Bicolor pacifica, A. celebesensis, A.japonica, A. marmorata,* and *A. luzonensis* (Yoshinaga et al. 2014), are collected in Cagayan River, the longest river in the Philippines, and the principal collection area for glass eels. Around 10 fishing villages are engaged in glass eel gathering and consolidations in the area. The eel fishery provides livelihood to around 597 fishers dependent on these living resources (BFAR 2015). However, these fishers are vulnerable to climate disaster because they are marginalized geographically, socially, economically, and politically (Gaillard et al. 2009).

However, despite the importance of the fisheries sector, knowledge of climate-induced impacts and vulnerability on the local scale of fishery-based livelihoods still needs to be improved (Islam et al. 2014). Understanding climate change impacts and assessing vulnerabilities across different sectors are the first steps to preparing effectively for future risks imposed by climate change (GIZ 2014).

Vulnerability assessments (VAs) can be used for many different purposes, including improving adaptation planning, designing policies and interventions, raising awareness of risks and opportunities, and advancing scientific research (Barange et al. 2018). The National Fisheries Research Development Institute (NFRDI) developed the Fisheries Vulnerability Assessment Tool (FishVool) that measures the sensitivity, exposure, and adaptive capacity using interview survey metrics and analytics (Jacinto et al. 2015). Initial VA studies using the FishVool framework were conducted to assess the commercial fisheries' climate change vulnerability, particularly tuna and sardine sectors (Jacinto et al. 2015) in General Santos and Zamboanga City, which are the primary producers of the fish. Recently modified FishVool tool were also used to assess the vulnerability of Giant Squid in Marinduque, Region IV-B (De Chavez et al. 2021) and Penaeus vannamei in Davao (Macusi et al. 2022), both in the Philippines.

Other assessment models used by researchers to determine the perceived vulnerability and impacts of climate change on the community include the following: computable general equilibrium (CGE) model to elaborate impacts on the national economy (Suh and Pomeroy 2020); principal component analysis (PCA) to reduce the sources of vulnerability and the number of impacts of climate change by Macusi et al. (2022); time series analysis for the tropical cyclone (TC) data from 1951 to 2013 in the Philippines (Cinco at al. 2016); and impacts of climate change on flooding by Cabrera and Lee (2020). Local ecological knowledge (LEK) was also used in determining management strategies for adaptive measures and community resiliency (Kupika et al. 2019). Indigenous knowledge, culture, and tradition are key elements in sustainable development. The locals can provide the status of the biophysical environment and possible adaptation and mitigation strategies in the area (Kupika et al. 2019).

The study aimed to evaluate the climate change vulnerability of the eel fishery in Aparri, Cagayan. The output offers necessary inputs for government fisheries planners, policymakers, and other fisheries stakeholders in developing policies and management plans that will reduce vulnerability and build climate-resilient eel fishery. This study, however, used only the bottom-up approach of vulnerability assessment which is participatory in nature; hence, data were gathered based on the experience and perception of the local fisherfolk rather than on model-generated climate data.

2. MATERIALS AND METHODS

2.1 Selection of study sites

The study was conducted in six coastal barangays of Aparri, namely Bisagu, Dodan, Linao, Punta, Sanja, and Toran, the area's major glass eel collection sites. These barangays have been reported as the recruitment area of eel larvae, of which *Anguilla japonica* was one of the species identified (Yoshinaga et al. 2014).

The municipality is located at the northernmost tip of the island of Luzon (Figure 1). The delta at the mouth of the river is an estuarine

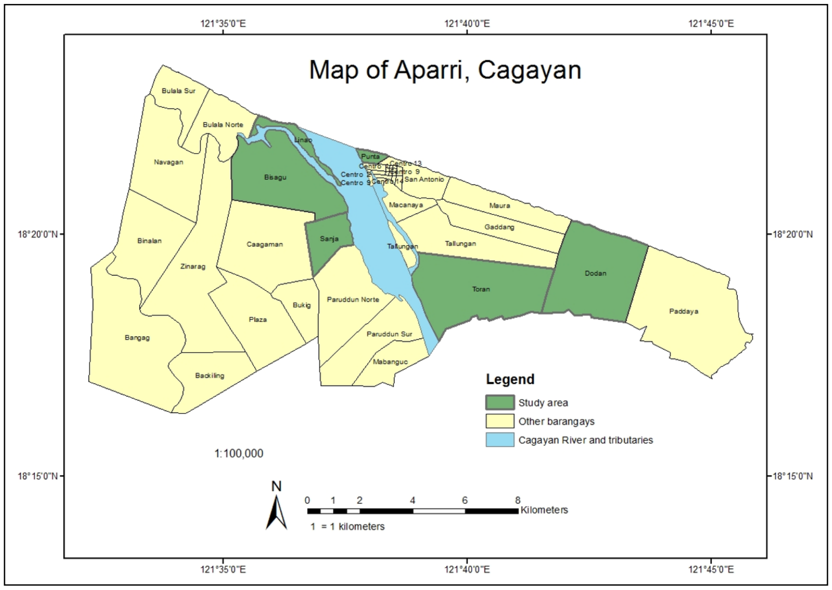

Figure 1. The study site

area where productive water from the upland and the seawater meets. It has a total area of 28,664 hectares, and the Cagayan River traverses its land mass. Out of the 42 barangays, 22 are coastal. Thus, 52% of the total population lives in the coastal barangays. Based on the Fisherfolk Registration (Fish R) of the Bureau of Fisheries and Aquatic Resources (BFAR) Region 2, the fishers' population in Aparri totaled about 11,515 as of 2021. Around 3,093 has been registered in the six targeted barangays.

Aparri falls under Type 3 climatic condition based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA). Under this category, the area experiences a short dry season from January to March and rainy for the rest of the year (Basconcillo et al. 2016). Therefore, tropical cyclones (TC) are most frequent during June, July, and August (JJA) and September, October, and November (SON) and less frequent in December, January, and February (DJF) and March, April, and May (MAM). However, it was observed that rainfall, humidity, and temperature do not have a regular pattern over the years to determine the wettest and driest part of the year.

2.2 Identification of respondents

Purposive sampling was used in this study, focusing on respondents with similar traits or specific characteristics. The 50 selected respondents are active glass eel gatherers with more than 10 years of experience in the industry. The group comprises fishers, barangay captains, fisherfolk associations leaders, and women in the community. They provided historical accounts of how climate and fish catch changed over the last 10 years based on their own experiences or perception. Due to limitations imposed on face-to-face encounters with the fishers because of COVID-19, especially in dealing with the elderly, respondents' years of experience were lowered to 10 years and above.

Key Informant Interview (KII) to 50 individuals using the same respondents stated above participated in the study using the FishVool tools. Twenty-five (25) fishers participated in the FGD. All participants were involved in eel fisheries. The questionnaire was designed to coincide with the rubrics that guide the assignment of scores for the three vulnerability components: exposure, sensitivity, and adaptive capacity. Scores of 1-5 were designated on each question, and explanations were provided during the FGD for the reasons corresponding to the scores. While attributing value to the different criteria, the fishers also provided explanations during the FGD as to the reasons corresponding to their scores.

2.3 Data collection and analysis

FishVool was used in data collection and analysis, considering its three components in measuring vulnerability: exposure, sensitivity, and adaptive capacity. Exposure (E) measures the intensity or severity of the physical environmental conditions that affect the present state of the biophysical system.

Sensitivity (S) is illustrated by the present state of the system based on the specific properties that respond to the exposure factors arising from climate change. Finally, adaptive capacity (AC) refers to the resiliency or the ability of the system to cope with the impacts associated with the changes in climate. The definitions of the major vulnerability components were adopted from Licuanan et al. (2012).

With the key concepts of vulnerability assessment, the framework in the development of FishVool was modified by Jacinto et al. *(*2015), incorporating three sub-components for the fisheries sector—fish, human, and community (Table 1). These three sub-components have corresponding criteria used to assess the sector's vulnerability. These criteria served as variables in the scoring system of the vulnerability assessment as outlined in the FishVool manual developed by NFRDI.

The rubrics guided the assignment of scores for exposure, sensitivity, and adaptive capacity. Scores were derived based on the information the key informants gave during the interview using the FishVool questionnaire. Ranking for each category vary depending on the average score obtained. For example, a score less than or equal to 2 corresponds to low vulnerability, while a score within the range of 2.001 to 4 corresponds to medium and a score greater than or equal to 4.001 corresponds to high (Table 2).

The vulnerability of the eel fishery in Aparri, Cagayan**,** was analyzed through the application FishVool V8.1, an MS Excel-based program developed in conjunction with the developed FishVool. This tool provided an automated and easy computational analysis in interpreting the data gathered from the key informants.

After analyzing the data gathered on the average score and category rank on the different indicators of sensitivity, exposure, and adaptive capacity, the results were presented in the form of an exposure map, sensitivity map, and adaptive capacity map with the help of Geographical Information System (GIS) tools.

Table 1. Parameters, elements and indicating factors

COMPONENT	SUB-COMPONENT	CRITERIA
	Fish	Fishing ground
Exposure	Human	Household site assessment
	Community	Records of weather disturbances occurrence
		Catch comparison
	Fish	Average length of fish catches
		Health conditions
Sensitivity	Human	Household age structure
	Community	Dependence on resource
	Fish	Gear modification
		Adaptive strategy
Adaptive Capacity	Human	Awareness
		Literacy
		Programs or support systems on climate change
	Community	Access to information
		Annual income from fishing

Table 2. Vulnerability category rank system

Vulnerability Category	Score
Low	<_2
Medium	2.001-4
High	>_4.001

3. RESULTS AND DISCUSSION

3.1 Respondents' socio-economic profile

The socio-economic characteristics of the eel fisher respondents are presented in Table 3. Male respondents constituted 90% and females with 10%. This shows that fishing is considered a male-dominated occupation while women take over postharvest activities and marketing, especially in developing countries (Kusakabe 2003). Results showed no relationship between the respondents' socio-economic standing and their responses on the occurrence of climate change. Fishers are aware of such a phenomenon and its impact on their livelihood.

The majority (40%) of the respondents belonged to the age groups of 46-55 years old. The average age of the respondents was 50 years old, with the oldest at 74 and the youngest at 37. This implies that most of the respondents are within the productive age, which agrees with the findings of Olaoye (2010) that most of the fishers are in their economically active ages to undertake strenuous tasks associated with the fishing enterprise. All the respondents have at least 10 years of experience in glass eel gathering as set criteria for selecting informants. Around 68% of the fishers had a household size of between 4-5 family members, which conforms with the average number of members per household in the municipality.

While several studies reveal that most fishers had no basic primary education (Factura et al. 2021; Mercado and Mercado 2016), this was not the case for respondents in Aparri, where 30% of the respondents attended secondary level, and 28% are high school graduates. In addition, 16% of the respondents reached college level while only 2% had

Table 3. Socio- economic profile of the respondents

Characteristics	Description	No. of Respondents	Percentage (%)
Gender	Male	45	90
	Female	5	10
Age	35-45 yrs old	18	36
	46-55 yrs old	20	40
	56-65 yrs old	11	22
	>65 yrs old	1	2
Household Size	2	5	10
	3	10	20
	4	20	40
	5	14	28
	6	1	2
Educational Attainment	Out-of School Youth	1	2
	Elem Level/ Graduate	12	24
	Non HS Graduate	15	30
	HS Graduate	14	28
	College Level/ Graduate/ Vocational	8	16
Monthly Household Income (PhP)	<2500	-	0
	2500-4500	3	6
	4600-6500	22	44
	>6500	25	50

no primary education level. The findings showed that education is accessible in all surveyed areas. Records from the Department of Education show that two schools offer college education in the municipality, the Cagayan State University and the Lyceum of Aparri. The former offers very low tuition fees and scholarship programs for deserving students. There are also 34 public primary schools, three secondary schools, and three private secondary schools in the area. According to the municipal profile, the literacy rate in Aparri, Cagayan, is 94%.

Regarding economic conditions, 50% of the respondents earn an average monthly household income of PHP 7,530.00 or an annual income of PHP 90,360.00. This indicates that the annual household income of fishers was notably lower than that of the national standard. The average annual household income reported by the respondents was below the PHP 132,204.00 annual income (PHP 11,017.00/month) per household in Aparri, Cagayan, as reflected in the 2018 municipal profile. Various factors can be attributed to this. Aside from climate change, fisherfolk reported that the present mining activities affected their capacity to fish, reducing their income.

Eel becomes an interesting target species of the fishers in the area because of the availability of the resources and its high market demand. Historically, global demand for eel has been driven by high consumption in East Asia, particularly Japan (Shirashi and Crook 2015). Since the Philippines has been recognized as an important source of alternative species for culture, fishers have been given a chance to derive income and livelihood from the resources.

3.2 Exposure of Aparri eel fishery to weather disturbances

The degree of the impact in terms of intensity or severity of climate change on the present state of the physical environment is termed exposure. This study measured exposure factors to weather disturbances in the fishing grounds, households, and communities.

3.2.1 Fishing ground (E1)

Respondents observed changes in the climate and extreme events over time. Around 80% or 40 of the 50 respondents claimed that more than six extreme weather disturbances, particularly frequent and intense typhoons and storms, affect the fishing ground yearly. In comparison, 20% reported four to six weather disturbances annually. Furthermore, the fishers observe the El Niño and La Niña phenomenon (https://www.meteoblue) every three to five years. In addition, tropical cyclones and TC-associated rainfall frequently hit this area compared to the southernmost part of the country, and consistent economic losses are experienced (Cinco 2016).

3.2.2 Household and community (E2 and E3)

The degree of exposure of a fisher's household or community to weather disturbances was also determined (Figure 2). The majority (78%) of the fishers' households and fishing community experienced more than six weather disturbances and climate-related incidents (typhoon, flood, sea level

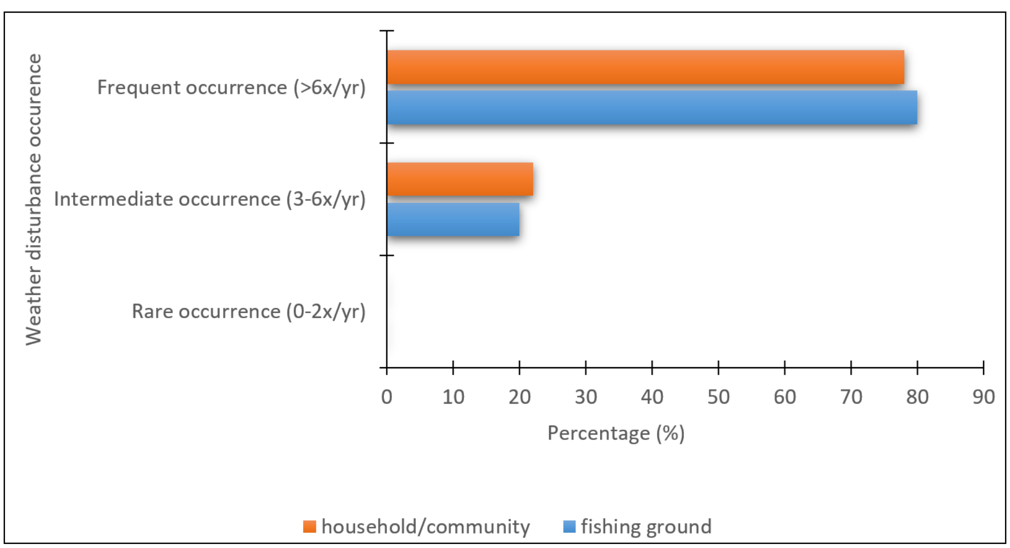

Figure 2. Exposure of fishing ground, household, and community to weather events

rise) annually. Households in low-lying barangays like Linao, Sanja, and Bisagu and those living along a river system and its tributaries like barangay Punta, Toran, and Dodan usually experience flooding brought by intense typhoons and heavy monsoon rains. In addition, respondents reported occurrences of coastal erosion from Punta and Dodan due to sea level rise and strong wave action during typhoon occurrence. The respondents also experienced saltwater intrusion from Barangay Dodan, affecting their crops. The perennial occurrence of these weather disturbances usually causes damage to their houses, fishing "bancas," and other properties. The inclement weather often disrupts their livelihood activities, especially fishing which prompted most households to seek an alternative source of income. Livelihood is a means of living in many poor communities. It is not just a salary or a job. It is about the various ways that individuals and communities sustain themselves. The money they earn makes them support their means of living. Hence, after calamities, the community needs to recover from stresses and shocks to continue living (Chambers and Conway 1992).

Results show that the overall exposure score of the eel fishery in Aparri, Cagayan was 4.760, which translated to high exposure of the fishing ground, household, and community to the impacts of climate change (Figure 3). In addition, the geographical location of Aparri, along the South China Sea and the Pacific Ocean, could have been attributed to its vulnerability to extreme weather events.

These findings were supported by the record of the PAGASA, stating that the Philippines is prone to tropical cyclones due to its geographical location, where heavy rains and flooding of large areas are commonly observed. Among the five provinces of the Cagayan Valley Region, the highest number of tropical cyclone occurrences is observed in the Province of Cagayan (PAGASA 2010).

Aside from typhoons and storms, seasonal extreme climate variability in the Philippines, including the Cagayan River Basin, is associated with the El Niño phenomenon. As the PAGASA records indicate, El Niño occurs almost every three years while the duration of the phenomenon varies. The climate in the Cagayan River basin, where glass eel abounds, consists of two tropical monsoons, i.e., the Southwest Monsoon and the Northeast Monsoon. Therefore, major storms that have struck the Cagayan River basin have resulted from typhoons and monsoons in the area. Typhoons usually strike from July to December about eight times a year on average. Studies show that weather perturbations, such as typhoons and storms, and increased sea surface temperatures in the fishing grounds act as physical stressors to fishes, which may result in disturbance and migration (IPCC 2007).

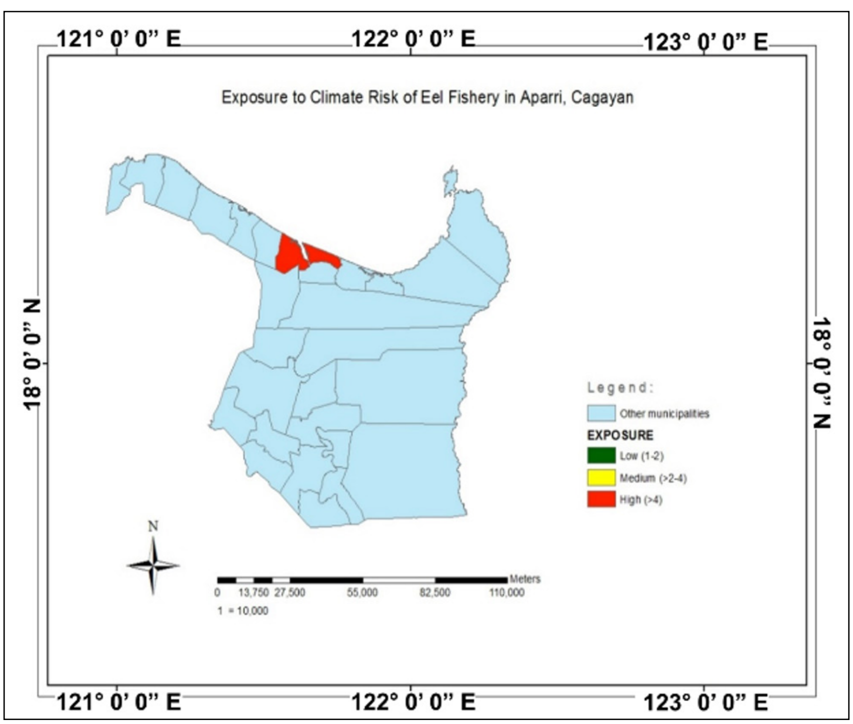

Figure 3. Exposure of fishing ground, household, and community to weather events

3.3 Sensitivity of the eel fishery in Aparri, Cagayan

To have an extensive understanding of the sensitivities for all sub-components (fish, human, community), the parameters used were catch comparison in terms of quantity and the average length of catch, dependence on the resource, household age structure, and health conditions.

3.3.1 Catch rate comparison (S1)

Of the 50 respondents, 56% said there was a decreasing trend or change in the catch rate over the years (Figure 4). However, it was not clear to the informants whether the decline was directly attributed to climate change or credited to the decrease in market demand and drop in the market price since both factors are impacting the catch of the fishers. Fishers can only go out to fish when there is good weather. Similarly, when there is no market for their catch, they cease to fish, considering that drying or processing is a problem in the area. Among the respondents, 42% claimed no observed change in the catch rate. Conversely, 2% said they observed an increase in the catch. In this variable, catch rate refers to the difference between the total catch by weight (kg) of the present catch of fishers and that from at least 10 years ago.

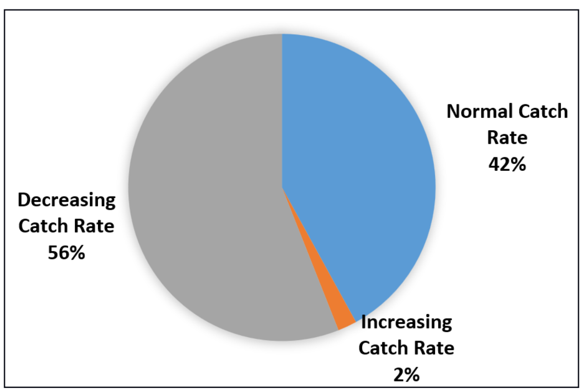

Figure 4. Catch comparison in 10 years (quantity)

The downtrend volume of catch reported by the eel fishers in Aparri was similar to the observed worldwide decline of different *Anguilla* species, commonly attributed to factors including overfishing, habitat loss, and global climate change (Dekker and Casselman 2014; Muallil at al. 2014). In addition, it was reported that the decrease in eastern Asian eel stocks might be influenced strongly by recruitment failure attributable to fluctuating oceanographic conditions associated with climate change (Kim et al. 2007).

It was said that the Philippines was the fourth greatest supplier of live eel fry over this period after Japan, France, and mainland China. East Asia reportedly imported nearly 120 tonnes of live eel fry from the Philippines between 2004 and 2013 (Crook 2014). The implementation of FAO 242 by BFAR in May 2012, which bans the export of juvenile eels ≤ 15 cm from the Philippines, affected live eel fry demand from the international market. In this case, it was difficult to isolate climate change among other causes of the perceived decreasing catch rate over the years.

Early records of the Municipal Agriculture Office (MAO) of Aparri and the Zoological Society of London (ZSL) show that there were 597 glass eel gatherers in Aparri, Cagayan in 2013-2015 (Gollock et al. 2017, unpublished). However, at the time of the study, there were only more or less 200 glass eel gatherers considered as active gatherers. Among them, only 50 were considered in the study due to restrictions imposed under COVID-19 to avoid spreading the disease. This number, however, changes as glass eel gathering is a market-driven industry. Household members, including wives and their children, often collect glass eels if the demand is high or with a lucrative price.

3.3.2 Length of fish catch (S2)

In terms of the average length of catch, 84% of the eel fishers believed that there was no observable change in catch size, contrary to the claim of 16% of the respondents that there was a decrease in size (Figure 5). For glass eels collected in the Cagayan River and other river systems draining into

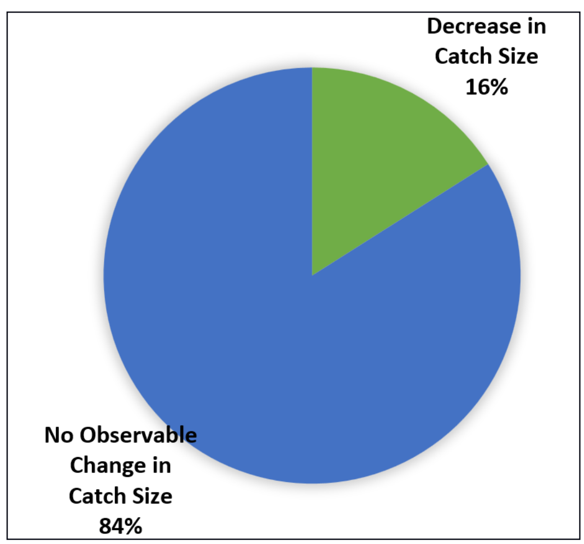

Figure 5. Catch comparison of glass eel in 10 years (average length)

the Babuyan channel, the size documented by BFAR Regional Office 2 ranges from 4.6 cm to 5.7 cm with 5,000–6,000 pcs per kg (0.17g–0.2g/pc). The results on catch comparison in terms of quantity and average length imply a sensitivity value of 4.460 (high) and 3.840 (medium), respectively.

3.3.3 Dependence on resource (S3)

As to the dependence on the resource, 28% or 56% of the respondents were said to be 61-80% dependent on fishing as their primary source of livelihood, 34% considered themselves to be 41-60% dependent on fishing, while 6% claimed that they were greatly dependent on fishing (> 80% dependence) and only 4% are less dependent to fishing activity as a source of livelihood (< 40% dependence) (Figure 6). This implies that fishing for income or subsistence maintained importance in most households. The eel fishers, however, acknowledged the importance of securing alternative sources of income aside from fishing activities, especially since their fishing grounds are frequently exposed to extreme weather events.

Aside from fishing, most respondents have other alternative sources of income, where 46% are involved as hired labor, 28% in farming, 6% in market trading/vending, and the rest have other income-generating activities (Figure 7). The majority (90%) had at least two additional sources of income apart from fish farming, with a combination of hired labor, farming, and trading/vending being the most common. Only 10% of respondents were full-time fishers. Also, a small number of respondents (12%) receive financial assistance from the government and their relatives working abroad. With the presence of supplemental livelihoods of most respondents, the dependence on the resource signifies a score of 3.220 or medium sensitivity.

The economic dependence of the eel fishers on the resource mainly influences sensitivity to climate change. The Food and Agriculture Organization of the United Nations pointed out that the populations at greatest risk are those dependent on agriculture and natural resources and whose livelihoods are highly exposed to climate change impacts. Small-scale fishers heavily dependent on coastal and inland fisheries are particularly vulnerable to climate change. Therefore, communities and households must be encouraged to maintain diverse livelihood portfolios, including the development of subsistence activities (Ellis et al. 2004).

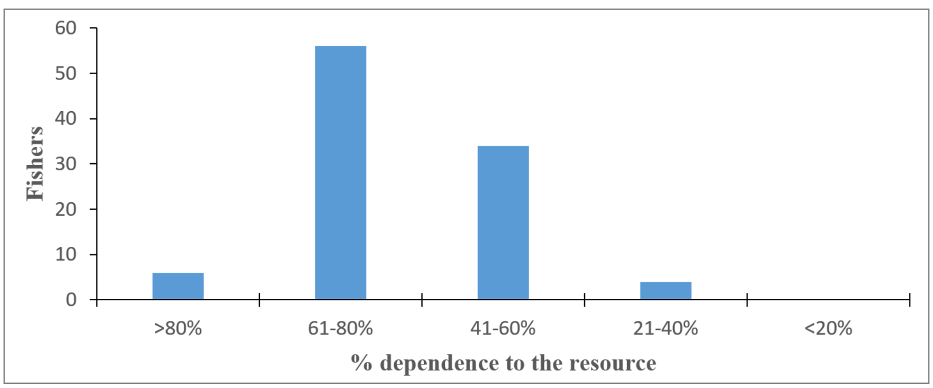

Figure 6. Dependence of eel fishers on the resource

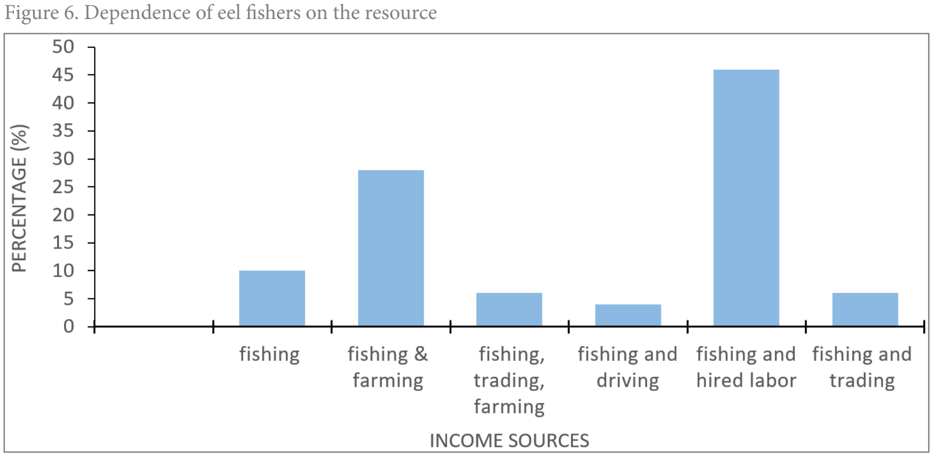

Figure 7. Household source of income of eel fishers

3.3.4 Household age structure (S4)

The household age structure was dominated by members with age groups 41–55 and 15–25 years old, or 25% and 24%, respectively. Results showed that 19% of the household members belong to the age group of <15 years old, 15% are in the age group of 26–40 years old, while only 2% belong to an age group of >65 years old (Figure 8). The score of 2.923 on household age structure translates to a medium sensitivity as most household members were in their productive years (15–55 years old).

Household age is an essential demographic factor in determining a household's vulnerability (Opiyo et al. 2014). A household with members primarily children and elderly are said to be more sensitive because these ages are among the most at risk of the adverse effects of climate change or any disasters. The elderly also haVE declining health conditions, while young children have less education. In addition, both have fewer financial resources and are frequently dependent on others for survival. These make the elderly and children less capable of adapting or surviving disasters.

3.3.5 Health condition (S5)

With regards to the overall health conditions of the eel fishers' household, 74% of the respondents claimed that their household members have no particular health needs, 22% have one or two members with symptomatic diseases, mainly respiratory diseases and hypertension, and 4% have a member with special health needs like a family member who was pregnant at the time of the survey or with disability (Figure 9). Thus, the health condition obtained a sensitivity score of 2.300 (medium).

The overall sensitivity score for eel fishery in Aparri, Cagayan, was 3.349, which indicates a medium sensitivity. This was attributed to no observable change in catch size, household age structure within the productive years, no serious health issues in most

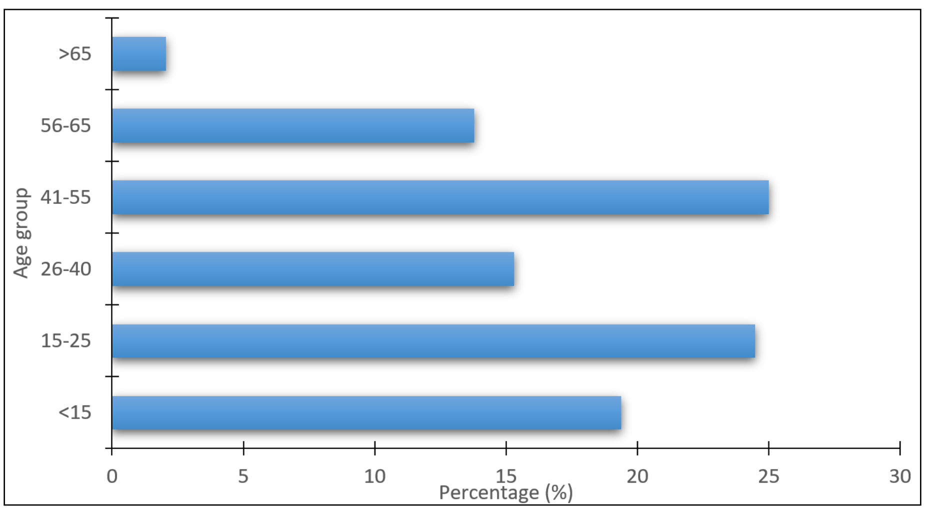

Figure 8. Household age structure of eel fishers

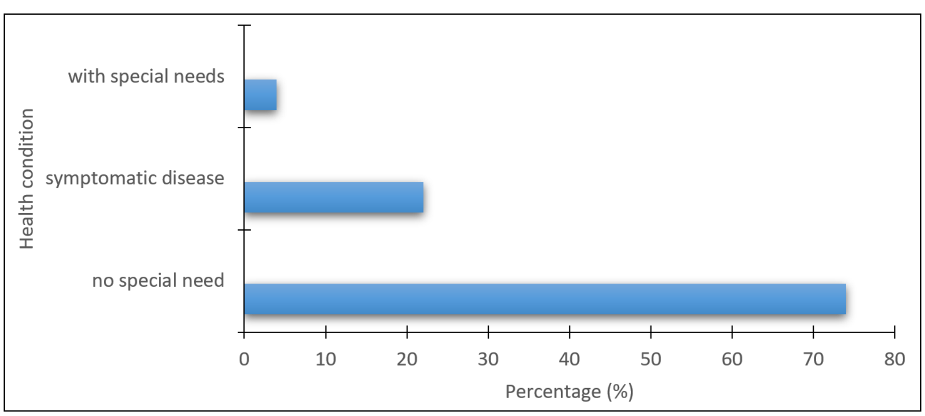

Figure 9. Household health condition of eel fishers

households, and medium dependence on the resource as a result of livelihood diversification. The climate risk sensitivity map of the eel fishery in Aparri, Cagayan, is presented in Figure 10.

3.4 Adaptive capacity of the eel fishers

Seven determinants were used to assess the adaptive capacity of the three sub-components based on the FishVool framework. Annual income from fishing, access to information, and programs or support systems on climate change are criteria under the community sub-component. The determining factors for the human sub-component are literacy (educational attainment), awareness of climate change, and adaptive strategy, while gear modification is the criterion under fish as a sub-component. These relate to the economic, social, institutional, and technological situations of the eel fisher communities that influence their adaptive measures.

3.4.1 Annual income from fishing (AC1)

At the time of the study, the average annual household income was PHP 90,360.00 (PHP 7,530.00 monthly), which was below the poverty line (Table 4). The contribution of fishing activities to the household's total income is 61.89% on average or an average of PHP 55,920.00 annually (PHP 4,660.00 monthly). While the major income source was from fishing, supplementary activities of most households earned an additional 38.11% or PHP 34,440.00 extra income. This result suggests that livelihood income from fishing as an indicator of adaptive capacity generates a score of 2.260 or medium adaptive capacity. This implies that diversified income sources are vital in improving their adaptive capacity. This allows the households to pursue various coping strategies. At the household level, a lack of financial resources will adversely affect a household's ability to recover from the impacts of extreme events (Koya et al. 2017). Furthermore, studies show that farmers and fishers who do not have supplementary income from other sources are less climate-resilient since both livelihoods are weather sensitive. Therefore, the economy of the fishery sector is an important parameter used to calculate the adaptive capacity of the sector (Koya et al. 2017).

3.4.2 Climate change vulnerability of eel fishery in Aparri, Cagayan

Table 5 shows the vulnerability indices of the Aparri, Cagayan eel fishery. All parameters under the exposure component (fishing ground, household, and fishing communities) have a score of 4.76, which

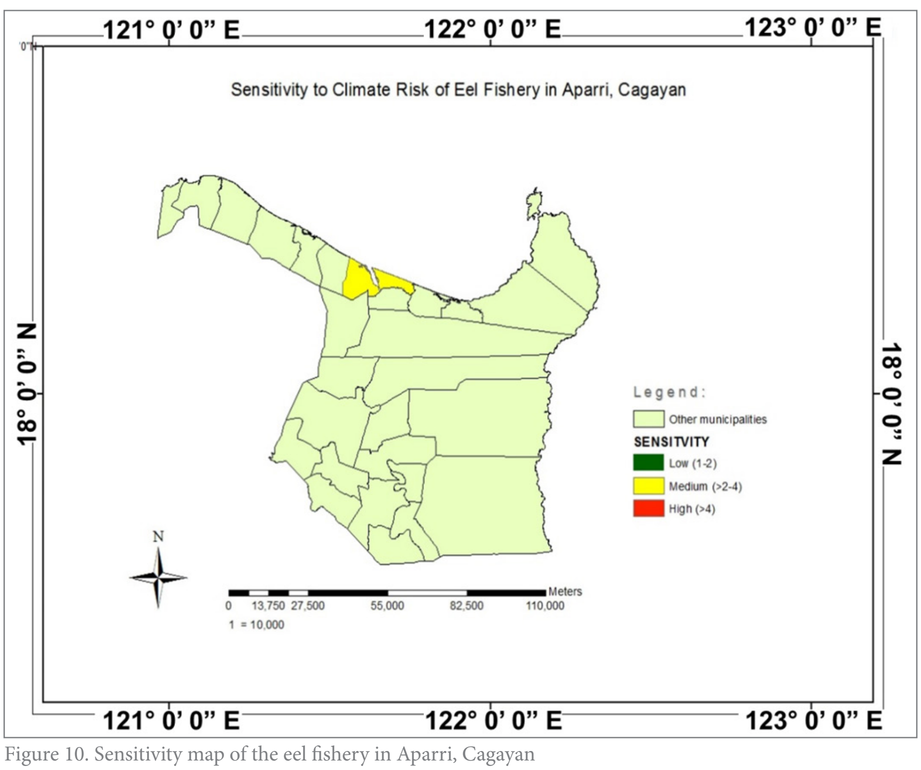

Figure 10. Sensitivity map of the eel fishery in Aparri, Cagayan

Table 4. Average annual household income from fishing and non-fishing and their contribution to the household income

Income source	Average annual income (PhP)	Contribution (%)
Fishing	55,920.00	61.89
Non-fishing	34,440.00	38.11
Total Income	90,360.00	

Table 5. Vulnerability indices of Aparri, Cagayan eel fishery

VA Component	Parameters	Scores	Average scores	Overall rank sytem
	Fishing Ground (E1)	4.760		
Exposure	Household/ Community (E2&E3)	4.760	4.760	H
	Catch comparison (S1)	4.460		
	Average length of fish catch (S2)	3.840		
Sensitivity	Dependence on resource (S3)	3.220	3.349	M
	Household age structure (S4)	2.923		
	Health conditions (S5)	2.300		
	Annual income from fishing (AC1)	2.260		
	Awareness (AC2)	3.760		
	Access to information (AC3)	2.700		
Adaptive Capacity	Adaptive strategy (AC4)	4.060	3.020	M
	Literacy (AC5)	2.920		
	Gear modification (AC6)	1.840		
	Pograms or support system (AC7)	3.600		

Legend: L – low, M-medium, H- high vulnerability

denotes high exposure. This could be attributed to Aparri, Cagayan's geographical location, which makes the eel fishery prone to various weather disturbances or high exposure to climate-related shocks and stresses. For the sensitivity component, most parameters obtained scores ranging from 2.30 to 3.84, indicating medium sensitivity except for catch comparison with high sensitivity. Most parameters for the adaptive capacity component had a score ranging from 2.26 to 3.76 (medium) except for adaptive strategy and gear modification, with 4.06 (high) and 1.84 (low) scores, respectively.

Table 6 shows the overall average score of the different components. Exposure yielded an average score of 4.76, which was translated to high exposure to weather disturbances, while sensitivity and adaptive capacity had an overall average score of 3.34 and 3.02, respectively, which indicate medium sensitivity and adaptive capacity.

Figure 11 shows the result of the vulnerability assessment using FishVool Excel V8. The medium sensitivity and high exposure yielded a high potential impact. Integrating high potential impact with medium adaptive capacity resulted in an overall high vulnerability of the eel fishery of Aparri, Cagayan, to the deleterious effects of climate change.

The findings of this study were similar to the observations of previous studies on the climate change vulnerabilities of fishing communities from a global aspect. Livelihoods of small-scale fish farmers and fishers in small island developing states, drought-prone countries, and developing countries in South and South-East Asia and Sub-Saharan Africa are likely to be vulnerable (Allison et al. 2009). It was reported that fisheries and fishing-dependent people are often located in places at exceptionally high risk of extreme

Overall Average Assessment Values		
Sensitivty	3.349	M
Exposure	4.760	H
Adaptive Capacity	3.020	M

POTENTIAL IMPACT

EXPOSURE \ SENSITIVITY	L	M	H
L	L	L	M
M	L	M	H
H	M	H	H

Potential Impact	H

VULNERABILITY

POTENTIAL IMPACT \ ADAPTIVE CAPACITY	L	M	H
L	M	L	L
M	H	M	L
H	H	H	M

Vulnerability	H

Figure 11. Overall average score on sensitivity, exposure, and adaptive capacity with the potential impact and overall vulnerability

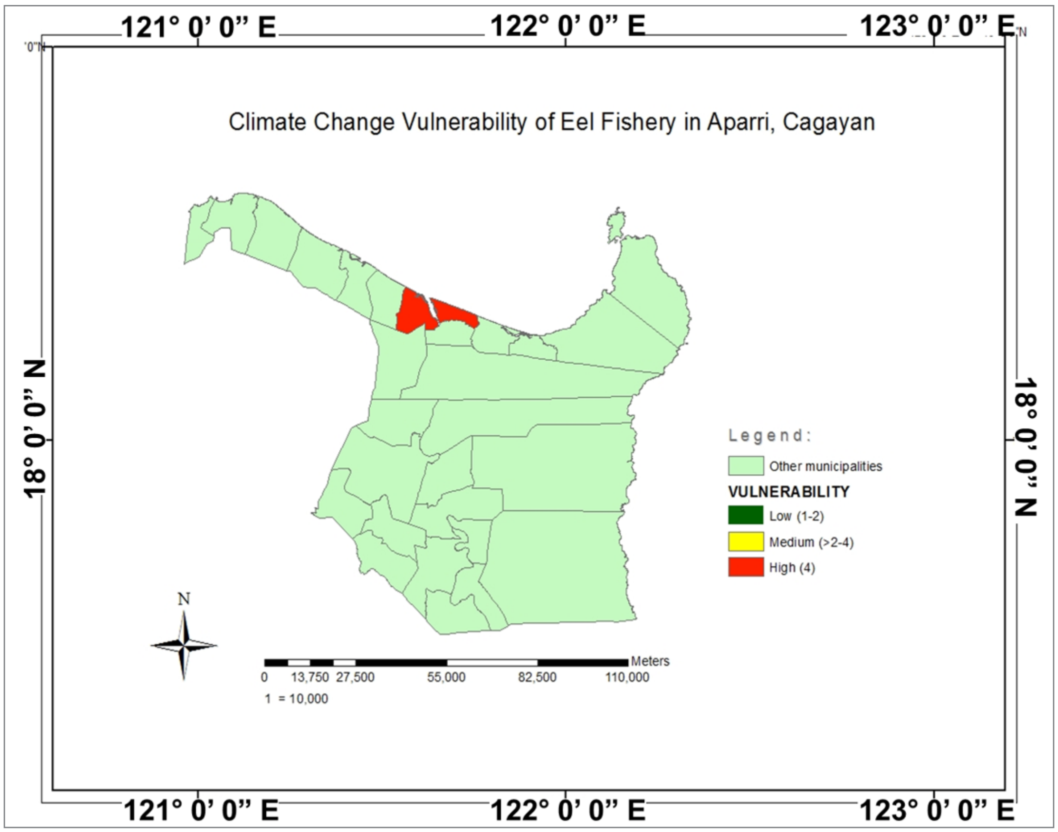

Figure 12. Vulnerability map of the eel fishery in Aparri, Cagayan

events storms, storm surges or tsunamis, and strong winds (FAO 2013). Fishing communities are highly affected by climatic events as fishers strongly depend on marine resources to maintain their livelihoods (Martins and Gasalla 2020). The presence of diversification of livelihoods, therefore, is significant as it is expected to increase the income of the fishing households and reduce the overall vulnerability (Brugere et al. 2008).

4. CONCLUSION

Eel fishers were dominated by males aged 40-55 years old, which was within the productive age. The average household size was between 4-5 family members. The average monthly household income of the respondents, mainly from fishing activities, was PHP 7,530.00 or an annual income of PHP 90,360.00, which was notably lower than the national monthly poverty threshold of PHP 10,481.00 in 2018.

More than six extreme weather disturbances, particularly intense typhoons and storms with accompanying secondary phenomena such as sea level rise, flooding, seawater intrusion, and soil erosion, affect the fishing ground, fishing community, and households yearly. Hence, the exposure of Aparri, Cagayan to weather disturbances is high.

The sensitivity of the eel fishery was moderate. Most of the glass eel gatherers were resource-dependent, as fishing is their primary source of livelihood. Decreasing fish catch was also observed over the years. The eel fishers had a medium adaptive capacity even with high adaptive strategies employed. This was attributed to the low average monthly household income of PHP 7,337.00, which was below the poverty threshold. Likewise, climate change awareness of the eel fishers, literacy, programs or support systems, and access to information were moderate.

High climate change exposure of the eel fishery in Aparri, Cagayan, but medium sensitivity resulted in high potential impacts to climate change. Therefore, the eel fishery can be said to be highly vulnerable to climate change. This also implies that all other fisheries in Northern Luzon may be affected by changes in the climatic condition and that they are also exposed to such phenomena, which will likely impact their livelihood. However, the impact of climate change on other areas in the country may vary since climate type varies from place to place.

5. RECOMMENDATIONS

The following are recommended to reduce vulnerability and build a climate-resilient eel fishery:

A. Intensify climate change awareness of the key players in the eel fishery. The fishers, Local Government Units, policymakers, and other stakeholders should increase awareness about climate change, its risks, vulnerability, and threat to the eel fishery. This is to properly integrate climate change into development policies, plans, and legislations to reduce climate change impacts on the industry, improve climate risk resilience, ensure sustainable eel fishery, and protect fisheries' livelihood.
B. Strengthen cooperation among relevant agencies and institutions to encourage knowledge and experience-sharing on climate change management, best practices on disaster risk reduction, and preparedness. Fisheries resource co-management and livelihood diversification should be encouraged to build the resilience of the vulnerable eel fishers.
C. Mainstreaming of Ecosystem Approach of Fisheries Management (EAFM), climate change adaptation and mitigation, and disaster risk reduction and preparedness into eel fishery management plans and policies. The scheme will provide a framework that will proactively address underlying issues in fisheries and aquaculture sectors, including the challenges brought by climate change.
D. Intensify capacity building of fisheries extension workers and fisherfolk. It is recommended to conduct capacity building for eel fisheries extension workers on EAFM and climate change adaptation and mitigation to strengthen their knowledge and advisory capacity for the effective delivery of services to vulnerable fishers communities. Through capacity building, fishers and fishing communities can build their climate risk resilience, thereby reducing their vulnerability, especially in eel collecting areas.

Implementation of climate change mitigation and adaptation programs may include but are not limited to: a) restoration or protection of eel habitats e.g., rivers and lakes and mangrove areas, and seagrass along the estuarine areas where glass eel are collected to reduce stress brought by climate change and act as a barrier from tropical cyclones and storm surges; b) open water stocking of glass eel in major production areas to enhance the depleted population of eel, which is a vulnerable fish species; c) implementation of regulations on fishing efforts and intensify maintenance of Marine Protected Areas and fish sanctuaries to improve fisheries productivity; d) diversification of source of income to reduce the dependence of the vulnerable communities on fishing and secure their means of livelihood; e) provision of life and property insurance; f) establishment of early warning systems to inform the community of impending calamities to protect lives and their source of livelihoods; g) provision of alternative livelihood by the LGU; and h) strengthen support system of the glass eel industry to include the provision of inputs or logistics, especially in cases where the area is stricken by of calamities.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in any way

ETHICS STATEMENT

The authors obtained prior informed consent from all participants included in this study.

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