RESEARCH ARTICLE

Assessing the Climate Vulnerability of Milkfish (*Chanos chanos*) Aquaculture in Cardona, Rizal, Central Bay of Laguna de Bay

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ABSTRACT

This study assessed the climate vulnerability of milkfish (*Chanos chanos*) aquaculture in Cardona, Rizal, located in the central bay of Laguna de Bay, Philippines, using the Fisheries Vulnerability Assessment Tool (FishVool). Focus group discussions were conducted with fourteen respondents, including fish pen caretakers, aquaculture operators, municipal agriculture officers, and members of the Municipal Fisheries and Aquatic Resources Management Council. Vulnerability was evaluated across three components: sensitivity, exposure, and adaptive capacity, using indicator scores translated into categorical ranks following the FishVool rubric. Results showed that sensitivity (mean score = 2.74), exposure (3.26), and adaptive capacity (3.37) were all classified as Medium, resulting in an overall Medium vulnerability classification for milkfish aquaculture in the study area. These findings indicate that while aquaculture households are not experiencing extreme climate stress, they remain subject to recurring environmental pressures and structural constraints that limit more robust adaptation. Although the assessment is site-specific to Cardona, the study demonstrates FishVool's utility as a practical framework for evaluating aquaculture vulnerability at the municipal level. The results provide locally relevant insights that may support broader discussions on climate adaptation and aquaculture resilience within Laguna de Bay.

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1. INTRODUCTION

Climate change has become one of the most pressing global challenges facing fisheries and aquaculture systems. More frequent and intense extreme weather events, shifting rainfall patterns, and rising temperatures alter aquatic ecosystems and undermine the livelihoods of communities that depend on aquatic resources (Brander 2010; Barange et al. 2018). In tropical countries such as the Philippines, aquaculture is highly vulnerable to these environmental fluctuations because it relies on open-water systems and has limited capacity for climate-resilient infrastructure (De Silva and Soto 2009).

Laguna de Bay, the largest freshwater lake in the Philippines, covers approximately 900 km² with a volume of 3.2 billion cubic meters. It is hydrologically complex, receiving inflow from around 100 tributaries and draining through the Napindan Channel into Manila Bay (Oledan 2001). The lake has long supported food security and livelihoods, including capture fisheries and aquaculture of commercially important species such as milkfish (*Chanos chanos*), tilapia (*Oreochromis* spp.), common carp (*Cyprinus carpio*), and bighead carp (*Hypophthalmichthys nobilis*) (BFAR 2023). However, climate variability, eutrophication, sedimentation, and competing uses, including navigation, water supply, and agriculture, are increasingly stressing the lake ecosystem (Santos-Borja and Nepomuceno 2006).

Milkfish aquaculture, in particular, plays a central role in the regional economy. In 2022, milkfish accounted for 16.5% of aquaculture production in CALABARZON, with a substantial portion coming from fish pens and cages in Laguna de Bay (BFAR 2023). Despite its economic importance, milkfish

production in the lake has declined markedly in recent years, falling from 29,725.29 metric tons in 2019 to 12,575.11 metric tons in 2022 (BFAR 2023). Contributing factors include fish kills associated with deteriorating water quality, storm-induced cage damage, and governance issues such as the implementation of feed bans and aquaculture zoning restrictions (Liu et al. 2021; Cuvin-Aralar 2016).

Fisherfolk from Laguna de Bay, especially those in its central bay, focus primarily on milkfish aquaculture. These communities are doubly vulnerable: first, to direct impacts of climate-related disturbances such as typhoons, flooding, and algal blooms; and second, to indirect socioeconomic stresses, including fluctuating income, limited livelihood diversification, and limited access to credit and technical support (Pham et al. 2021). Climate change adaptation, therefore, is not only about sustaining fish production but also about protecting community resilience.

Vulnerability assessments provide a structured way to evaluate how susceptible aquaculture systems are to climate impacts (Patt et al. 2009). Several vulnerability assessment frameworks have been developed for fisheries systems, including VA-TURF and other indicator-based approaches that integrate sensitivity, exposure, and adaptive capacity (Mamauag et al. 2013; Füssel and Klein 2006). In the Philippines, the National Fisheries Research and Development Institute (NFRDI) developed the Fisheries Vulnerability Assessment Tool (FishVool) to standardize vulnerability evaluations across fishery and aquaculture systems (Aguila et al. 2021). FishVool incorporates both biophysical and socioeconomic indicators, making it suitable for assessing the resilience of aquaculture-dependent communities in Laguna de Bay.

This study applies FishVool to assess the climate vulnerability of milkfish aquaculture in Cardona, Rizal, in the central bay of Laguna de Bay. The central bay includes six coastal municipalities, but this study focused on Cardona as a case study because of its extensive fishpen and fishcage operations, its representation of multiple lakeshore communities engaged in milkfish aquaculture, and its lakeshore coverage, which spans at least a third of the central bay. To do this, we used FishVool to assess the sensitivity of culture systems and households, their exposure to weather-related disturbances, and the adaptive capacity of aquaculture-dependent communities. The study provides a localized yet policy-relevant assessment of aquaculture vulnerability which aims to inform lake-wide adaptation strategies, guide resource managers and policymakers, and strengthen the resilience of fisheries-dependent communities in the face of climate change.

2. MATERIAL AND METHODS

2.1 Study site

The central bay of Laguna de Bay, located along the western and southern shoreline of Rizal province, is bordered by the municipalities of Cardona, Morong, Baras, Tanay, Pililla, and Jalajala. This portion of the lake is widely recognized as a primary aquaculture zone, supporting extensive fishpen and fishcage operations, particularly for milkfish (*Chanos chanos*). Since milkfish fishpens were established in the 1970s, the central bay has become a production focal area, with Rizal province consistently contributing the largest share of aquaculture yields in Laguna de Bay (Israel 2008; Liu et al. 2021; Cuvin-Aralar 2016). Despite this prominence, the fisheries of the central bay face persistent challenges from eutrophication, fish kills, aquaculture congestion, and climate-related disturbances, all of which undermine both production and fisherfolk livelihoods.

The decision to focus discussions on Cardona is justified by its geographic, economic, and institutional significance in the central bay of Laguna de Bay. Cardona encompasses nearly one-third of the central bay's coastal perimeter and supports extensive milkfish aquaculture through fish pens and cages. It is classified as a third-class municipality with a population of 50,143 (PSA 2020) and is historically recognized as one of the municipalities where milkfish aquaculture has been concentrated (Israel 2008; Liu et al. 2021).

Focus Group Discussions (FGDs) were conducted in Barangays Looc and Sampad, both of which host active milkfish aquaculture operations and represent distinct lakeshore settings within the municipality (Figure 1). Participants included leaders of the Rizal Province Fisheries and Aquatic Resources Management Council (FARMC), staff from the Cardona Municipal Agriculture Office, and milkfish aquaculture pen owners and caretakers. These barangays were selected to capture variation in aquaculture practices, livelihood dependence, and local governance contexts relevant to climate vulnerability assessment.

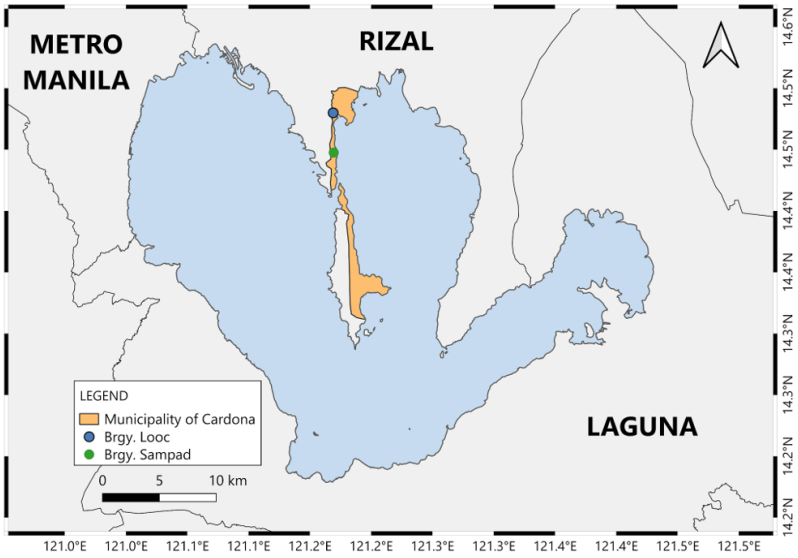

Figure 1. Map of Laguna de Bay showing the coastal coverage of the Municipality of Cardona (brown), Rizal, located in the central bay. The study sites include Barangays Looc (blue point) and Sampad (green point), where focus group discussions were conducted. Map prepared using QGIS 4.0.2.

2.2 Vulnerability assessment framework

This study employed the Fisheries Vulnerability Assessment Tool (FishVool), developed by the National Fisheries Research and Development Institute (NFRDI), to evaluate the climate vulnerability of milkfish aquaculture. FishVool has been previously applied to assess climate vulnerability in Philippine fisheries sectors, including tuna and sardine systems, demonstrating its applicability across diverse production contexts (Jacinto et al. 2015; Aguila et al. 2021). FishVool operationalizes vulnerability as a function of three components:

1. Sensitivity (S) – the degree to which the aquaculture system is affected by climate variability, including changes in fish mortality, growth, household reliance on fisheries, age structure, and health conditions.
2. Exposure (E) – the extent to which aquaculture systems, households, and communities are subject to weather disturbances and other climate-related hazards.
3. Adaptive Capacity (AC) – the ability of aquaculture-dependent households and communities to adjust, cope, or recover, measured through indicators such as income diversification, awareness of climate change, access to information, adoption of adaptive strategies, literacy, culture practice modifications, and availability of support systems.

Each sub-component is rated by stakeholders on a five-point scale (1–5), following the FishVool scoring system. Composite scores are then calculated for sensitivity, exposure, and adaptive capacity, which are further integrated to yield an overall vulnerability index (Aguila et al. 2021).

2.3 Data collection

Primary data were collected through focus group discussions (FGDs) and key informant interviews conducted from June to September 2024 (Figure 2). A total of fourteen respondents participated, including caretakers (7) of fish pens and cages, an aquaculture operator (1), members (3) of the Municipal Fisheries and Aquatic Resources Management Council (MFARMC), and staff (3) from the Municipal Agriculture Office. Respondents were selected purposively based on their direct involvement in milkfish aquaculture and decision-making within the local fishery sector. Their collective experience provided a diverse perspective on aquaculture operations and vulnerability in the central bay of Laguna de Bay.

Before the FGDs, the study objectives and the FishVool instrument structure were explained to participants. Informed consent was obtained from all respondents. The discussion covered each indicator under the sensitivity, exposure, and adaptive capacity components, with participants assigning scores based on their experience and community context.

Figure 2. Documentation highlights from a series of Focus Group Discussions (FGDs) as conducted by the (A) authors together with (B) members of Cardona Municipal Agriculture Office and Fisheries and Aquatic Resources Management Council. Shown as well are activities at a representative *bangus* fish farm (C) from the coastal community of Cardona (photo courtesy of John Albert Ponce).

2.4 Data analysis

The responses from focus group discussions were encoded into the FishVool Excel workbook (Aguila et al. 2021). The manual's rubric definitions were explained to respondents before scoring to ensure a shared basis for interpretation. For instance, a mortality rate of cultured fish below 20% was scored as "1" (low sensitivity), while a mortality rate above 80% was scored as "5" (high sensitivity). Similar structured scales were applied to growth rates, household dependence on fisheries, health conditions, and other indicators. The scoring process reflects consensus-based stakeholder perception, consistent with FishVool's intended application, and may therefore include the inherent subjectivity of expert judgment.

After all individual scores were collected, they were averaged across respondents to generate sub-component means. These means were then aggregated within each component (sensitivity, exposure, and adaptive capacity) by computing simple arithmetic averages across indicators. While numerical scores provided the basis for calculating component averages and vulnerability classifications, qualitative narratives from focus group discussions were used to contextualize and interpret these results. Participants' explanations and examples were not quantified separately but explained the conditions underlying assigned scores, such as reasons for observed mortality levels, flood exposure, or constraints on adopting adaptive measures. This combined use of descriptive statistics and qualitative insights follows the intended application of the FishVool framework, where stakeholder perceptions and experiences inform the scoring process and support interpretation of vulnerability outcomes. The resulting component scores were then translated into categorical ranks using the FishVool vulnerability rank system (Table 1) with the following thresholds: Low (≤ 2.00), Medium (2.001–4.00), and High (≥ 4.001).

To determine overall vulnerability, FishVool employs a cross-tabulation approach. First, sensitivity and exposure were integrated to produce a Potential Impact rating. This Potential Impact was then cross-tabulated with Adaptive Capacity to derive the final Vulnerability rating. This process ensures that vulnerability reflects both the combined pressure of sensitivity and exposure and the moderating effect of adaptive capacity. The results were then categorized into vulnerability levels (Low, Medium, High). Although focus group discussions were conducted in multiple barangays, results were analyzed collectively at the municipal level to reflect shared governance structures and aquaculture practices within Cardona.

Table 1. Vulnerability Category Rank System of the Fisheries Vulnerability Assessment Tool (FishVool) developed by DA-NFRDI.

Vulnerability Category	Ave. Score
Low	≤ 2
Medium	2.001 - 4
High	≥ 4.001

Qualitative narratives from respondents were used to interpret the scores, ensuring that numerical outputs were grounded in local context and experiences. Following the FishVool framework, sensitivity and exposure were first integrated to determine Potential Impact, which was then combined with adaptive capacity to derive overall vulnerability using a cross-tabulation approach.

3. RESULTS

3.1 Potential impact-

Milkfish aquaculture in Cardona, Rizal exhibited medium sensitivity based on the FishVool assessment (Table 2). Mean scores across sensitivity indicators ranged from 2.11 to 3.22, all falling within the Medium category under the FishVool rubric. Respondents reported mortality levels with a mean score of 2.14, while cultured milkfish growth performance received a mean score of 3.00, reflecting generally stable production conditions. Dependence on aquaculture as a household income source yielded a mean score of 2.11, indicating moderate reliance on fish farming relative to other livelihood activities. The average household age structure (3.22) and reported health conditions (2.44) also contributed to the overall Medium sensitivity classification.

Table 2. Vulnerability indicators (Sensitivity, Exposure, Adaptive Capacity) of milkfish aquaculture in Cardona, Rizal, of central bay of Laguna de Bay, expressed as arithmetic averages.

Vulnerability Component	Average Score
Sensitivity	
Mortality of cultured commodity (S1)	2.14
Growth of cultured commodity (S2)	3.00
Dependence on fishery resources (S3)	2.11
Household age structure (S4)	3.22
Health conditions (S5)	2.44
Exposure	
Exposure of culture system to disturbances (E1)	2.78
Household site assessment (E2)	3.22
Community site assessment (E3)	3.78
Adaptive Capacity	
Income from culture (AC1)	3.25
Awareness of climate change (AC2)	3.88
Access to information (AC3)	3.88
Adaptive strategies (AC4)	3.25
Literacy (AC5)	3.00
Modification of culture practices (AC6)	3.00
Community support systems and programs (AC7)	3.00

Milkfish aquaculture exposure in Cardona, Rizal was also classified as Medium (Table 2), with mean scores ranging from 2.78 to 3.78 across indicators. Culture systems' exposure to weather-related disturbances received a mean score of 2.78, while household site exposure received a mean of 3.22. Community-level exposure received a mean score of 3.78, reflecting more frequent or widespread impacts of weather disturbances at the community scale. When sensitivity (mean score = 2.74) and exposure (mean score = 3.26) were integrated using the FishVool framework, the resulting Potential Impact classification for milkfish aquaculture in Cardona, Rizal was Medium.

3.2 Overall vulnerability

Although respondents reported relatively strong awareness of climate change and broad access to information, the FishVool assessment (Table 2) found that the overall adaptive capacity of milkfish aquaculture households remained Medium (mean score = 3.37). The adaptive capacity of milkfish aquaculture households in Cardona, Rizal was classified as Medium, with indicator scores ranging from 3.00 to 3.88. Income derived from aquaculture contributed a mean score of 3.25, indicating moderate dependence supplemented by other livelihood activities. Awareness of climate change and access to information both received a mean score of 3.88, reflecting relatively strong awareness and multiple information sources, though both remained in the Medium category under the FishVool rubric. Adaptive strategies, including precautionary measures such as partial harvesting and stock management, were rated at a mean score of 3.25. Literacy levels and changes in culture practices both received a mean score of 3.00, while community support systems and climate change adaptation programs also averaged 3.00.

Integration of Medium Potential Impact with Medium Adaptive Capacity through the FishVool cross-tabulation approach resulted in an overall classification of Medium vulnerability for milkfish aquaculture in Cardona, Rizal (Table 3). This

classification reflects the combined effects of moderate sensitivity and exposure alongside a moderate capacity of households and communities to cope with and adapt to climate-related stressors.

4. DISCUSSION

Milkfish aquaculture in Cardona shows moderate vulnerability, as reflected in Medium rankings across the sensitivity, exposure, and adaptive capacity components. This profile indicates that while aquaculture households are not experiencing extreme climate stress, they remain consistently exposed to ecological and climatic pressures that challenge long-term sustainability. Similar vulnerability patterns have been documented in other Philippine aquaculture and fisheries systems, where production persists despite recurring environmental stress and institutional constraints (De Silva and Soto 2009; Macusi et al. 2021a; Egar et al. 2024). Comparable patterns have been synthesized across fisheries and aquaculture systems globally, where moderate vulnerability persists due to recurring climate exposure and uneven access to adaptation support (Shelton 2014).

The Medium sensitivity classification observed in Cardona is shaped by multiple interacting factors captured in the FishVool indicators. Respondents described recurring fish mortality events and episodic growth disruptions, which correspond to moderate scores for mortality and growth indicators. Although households reported continued engagement in milkfish aquaculture, reliance on fish farming as a sole income source was limited, resulting in a Medium dependence score. Age structure and generally stable health conditions further moderated sensitivity, preventing extreme vulnerability at the household level. These findings align with earlier assessments of Laguna de Bay, which document persistent ecological stress from eutrophication, fish kills, and aquaculture congestion that elevates sensitivity without rendering production systems non-viable (Santos-Borja and Nepomuceno 2006; Macusi et al. 2021b).

Milkfish aquaculture in Cardona was likewise classified as Medium, reflecting the combined effects of weather-related disturbances at the system, household, and community scales. Respondents reported periodic storm and strong-wind exposure of culture systems, while household-level impacts such as flooding were occasional rather than frequent. At the community level, respondents noted more regular disruptions linked to seasonal weather variability, resulting in relatively higher, but still Medium, exposure scores. Similar patterns have been observed in both inland and coastal aquaculture systems in the Philippines, where community-scale exposure often exceeds household-level impacts due to shared infrastructure and spatial concentration of production units (Roxas et al. 2017; Pham et al. 2021; Egar et al. 2024).

Adaptive capacity in Cardona remained Medium, reflecting a balance between relatively strong awareness of climate risks and persistent structural constraints. Respondents demonstrated broad access to climate-related information through multiple sources and reported several adaptive practices, such as partial harvesting and stock management. However, limited financial capacity constrained more capital-intensive adaptations, including cage reinforcement and major modifications to culture practices. Moderate literacy levels and the presence of a small number of community support programs further shaped adaptive capacity. Similar constraints have been documented in aquaculture value chain studies, where limited access to capital, services, and institutional support restricts small-scale producers' ability to translate knowledge and awareness into effective adaptive action (Kaplinsky and Morris 2000; German and Catabay 2018). This pattern mirrors findings from other Philippine aquaculture systems, where financial and institutional limitations prevent knowledge and awareness from automatically translating into action (Jespersen et al. 2014; Egar et al. 2024).

Beyond climate-related stressors, existing literature highlights pollution as an additional factor that may compound vulnerability in Laguna de Bay aquaculture systems. Recent studies have documented the presence of microplastics in lake waters and in milkfish production environments (Arcadio et al. 2023; Felicitas et al. 2025). While pollution was not

Table 3. Integration of sensitivity, exposure, potential impact, and adaptive capacity to derive overall vulnerability classification for milkfish aquaculture in Cardona, Rizal, central bay of Laguna de Bay.

Component	Ave. Score	Interpretation	Integration Step	Assessment
Sensitivity (S)	2.74	Medium		
Exposure (E)	3.26	Medium	S × E → Potential Impact (PI)	
Adaptive Capacity (AC)	3.37	Medium	PI × AC → Vulnerability	
Overall Vulnerability	—	—	Final classification	**Medium**

directly scored under the FishVool assessment in this study, these findings provide important context for understanding cumulative pressures on aquaculture sustainability and food safety (Lusher et al. 2017).

Social and gender dimensions represent another important contextual factor influencing aquaculture vulnerability. Previous studies indicate that women play significant roles in processing, net repair, and marketing within milkfish value chains, yet often face limited access to ownership, credit, and decision-making (Roxas et al. 2018; Jespersen et al. 2014). Although gender roles were not explicitly assessed through FishVool indicators in this study, integrating gender-responsive approaches into aquaculture adaptation planning may enhance household resilience and livelihood stability (German and Catabay 2018; Zapata et al. 2023).

Governance structures play a central role in shaping aquaculture vulnerability in Laguna de Bay. Multiple institutions manage the lake, including the Laguna Lake Development Authority (LLDA), municipal governments, and Fisheries and Aquatic Resources Management Councils (FARMCs). While these structures provide a framework for zoning, regulation, and stakeholder participation, previous studies and respondent narratives suggest gaps in enforcement, coordination, and access to technical and financial support. These challenges are consistent with broader findings on ecosystem-based adaptation, where fragmented governance, limited institutional coordination, and capacity constraints often hinder the implementation of locally appropriate adaptation strategies (Nalau et al. 2018). Strengthening alignment between local governance mechanisms and lake-wide management plans remains critical for translating climate awareness into effective adaptation.

The Medium vulnerability classification suggests that climate adaptation efforts should focus on reducing fish mortality risks, improving preparedness for extreme weather events, and strengthening institutional support for aquaculture households (Table 4). Priority interventions include establishment of fish kill early warning systems, routine water quality monitoring in major fishpen areas, development of pre-typhoon harvest and cage protection protocols, expansion of fisheries insurance and emergency assistance programs, and integration of climate adaptation measures into municipal fisheries development plans. Strengthening coordination among LGUs, FARMCs, BFAR, and LLDA may further improve the resilience of milkfish aquaculture systems in Laguna de Bay.

5. CONCLUSION

This study assessed the climate vulnerability of milkfish aquaculture in Cardona, Rizal, in the central bay of Laguna de Bay, using the Fisheries Vulnerability Assessment Tool (FishVool), with Cardona, Rizal, as the case study. Results indicate that milkfish aquaculture in the study area exhibits Medium vulnerability, reflecting moderate sensitivity and exposure to climate-related stressors, along with a moderate level of adaptive capacity among aquaculture-dependent households. While the findings offer valuable local insights, generalizing to other municipalities within Laguna de Bay should be done cautiously because ecological, socioeconomic, and governance conditions differ.

The findings show that while milkfish aquaculture in Cardona remains viable under current conditions, households and communities still face recurring environmental pressures and structural

Table 4. Recommended climate adaptation interventions for milkfish aquaculture in Cardona, Rizal, central bay of Laguna de Bay, based on FISHVOOL Results.

Findings	Possible Interventions
Moderate exposure to storms and strong winds	Develop municipal protocols for pre-typhoon partial harvest and fishpen reinforcement
Moderate mortality risk	Establish routine dissolved oxygen and water quality monitoring in major fishpen zones
Moderate adaptive capacity	Conduct annual climate adaptation workshops for fishpen operators and caretakers
Limited financial resources	Facilitate enrollment in fisheries insurance and emergency rehabilitation programs
Moderate dependence on aquaculture income	Support alternative lake-based livelihoods during periods of low production
Community-level climate impacts	Integrate climate adaptation actions into the Municipal Fisheries Development Plan

constraints that limit stronger adaptation. These results are consistent with previous assessments of tropical aquaculture systems, where production persists despite ongoing climate and ecological stress.

As a localized assessment, the findings are site-specific and reflect conditions in Cardona rather than the full range of aquaculture contexts across Laguna de Bay. Nevertheless, the study demonstrates FishVool's utility as a practical framework for identifying vulnerability patterns and informing municipal-level adaptation planning. Insights from this case study may support broader lake-wide discussions on strengthening governance, improving access to support mechanisms, and enhancing the long-term resilience of aquaculture livelihoods in Laguna de Bay. The study's recommended interventions may provide practical guidance for local government units and fisheries managers seeking to strengthen climate resilience in milkfish aquaculture systems within Laguna de Bay.

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AUTHOR CONTRIBUTIONS

Cinco MA: data gathering, data analysis, initial manuscript write-up. DietaJA: data analysis, initial manuscript write-up. **Esperanza J**: funding acquisition, initial document write-up. **Briones JC**: funding acquisition, conceptualization, data gathering, data analysis, initial manuscript write-up, and final revisions.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest relevant to this study.

ETHICS STATEMENT

All procedures followed in this study complied with institutional and national research ethics standards. The study involved consultations with adult stakeholders (fishpen owners, caretakers, and fisheries officers) who participated voluntarily in focus group discussions. The researchers obtained informed consent before interviews, and respondents were assured confidentiality and that their responses would be used in a non-attributable way. This study did not involve animal experimentation, handling of endangered species, or collection of protected organisms, and therefore did not require Institutional Animal Care and Use Committee (IACUC) approval.

REFERENCES

Aguila AAM, Calderon GJA, Santos SB, Santos MD. 2021. Fisheries vulnerability assessment tool (FishVool): instructional manual. Quezon City (PH): National Fisheries Research and Development Institute. http://hdl.handle.net/20.500.14310/4027.

Arcadio CGLA, Navarro CKP, Similatan KM, Inocente SAT, Ancla SMB, Banda MHT, Capangpangan RY, Torres AG, Bacosa HP. 2023. Microplastics in surface water of Laguna de Bay: first documented evidence on the largest lake in the Philippines. Environ Sci Pollut Res Int. 30(11):29824–29833. doi:10.1007/s11356-022-24261-5.

Barange M, Bahri T, Beveridge MCM, Cochrane KL, Funge-Smith S, Poulain F, editors. 2018. Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options. Rome (IT): Food and Agriculture Organization of the United Nations. 628 p. (FAO Fisheries and Aquaculture Technical Paper; no. 627).

Brander KM. 2010. Impacts of climate change on fisheries. J Mar Syst. 79(3-4):389-402. doi:10.1016/j.jmarsys.2008.12.015.

[BFAR] Bureau of Fisheries and Aquatic Resources.

2023. 2022 Philippine fisheries profile. Quezon City (PH): Bureau of Fisheries and Aquatic Resources. https://www.bfar.da.gov.ph/media-resources/publications/archives-philippine-fisheries-profile/.

Cuvin-Aralar MLA. 2016. Impacts of aquaculture on fish biodiversity in the freshwater lake Laguna de Bay, Philippines. Lakes Reserv Res Manag. 21(1):31-39. doi:10.1111/lre.12118.

De Silva SS, Soto D. 2009. Climate change and aquaculture: potential impacts, adaptation, and mitigation. In: Cochrane K, De Young C, Soto D, Bahri T, editors. Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. Rome (IT): Food and Agriculture Organization of the United Nations; p. 151–212. (FAO Fisheries and Aquaculture Technical Paper; no. 530).

Egar AMJ, Geraldino PJL, Santos MD. 2024. Climate change vulnerability assessment of milkfish fry fishery in selected sites in Argao and Bantayan, Cebu, Philippines. Philipp J Fish. 31(2):356–372. doi:10.31398/tpjf/31.2.2024-0002.

Felicitas G, Jumawan JC, Burdeos RCB, Delara RGD, Seronay RA, Vales TP, Latayada FS, Inocente SAT, Banda MHT, Capangpangan RY. 2025. Microplastics in surface water and gastrointestinal tracts of demersal fishes (*Oreochromis niloticus* and *Cyprinus carpio*) in the largest wetland of the Philippines. Int J Environ Res. 19(3):96. doi:10.1007/s41742-025-00768-w.

Füssel HM, Klein RJT. 2006. Climate change vulnerability assessments: an evolution of conceptual thinking. Clim Change. 75(3):301–329. doi:10.1007/s10584-006-0329-3.

German JD, Catabay MAG. 2018. Analysis of milkfish supply chain in the Philippines: a case study in Dagupan, Pangasinan. AIP Conf Proc. 2045(1):020047. doi:10.1063/1.5080860.

Israel DC. 2008. Fishpen and fishcage culture in Laguna de Bay: status, economic importance, and the relative severity of problems affecting its practice. Philipp J Dev. 35(1):55–92.

Jacinto MR, Songcuan AJG, Yip GV, Santos MD. 2015. Development and application of the fisheries vulnerability assessment tool (Fish Vool) to tuna and sardine sectors in the Philippines. Fish Res. 161:174-181. doi:10.1016/j.fishres.2014.07.007.

Jespersen KS, Kelling I, Ponte S, Kruijssen F. 2014. What shapes food value chains? Lessons from aquaculture in Asia. Food Policy. 49:228-240. doi:10.1016/j.foodpol.2014.08.004.

Kaplinsky R, Morris M. 2000. A handbook for value chain research. Brighton (UK): Institute of Development Studies, University of Sussex.

Liu JM, Borazon EQ, Muñoz KE. 2021. Critical problems associated with climate change: a systematic review and meta-analysis of Philippine fisheries research. Environ Sci Pollut Res Int. 28(36):49425–49433. doi:10.1007/s11356-021-15712-6.

Lusher AL, Hollman PCH, Mendoza-Hill JJ. 2017. Microplastics in fisheries and aquaculture: status of knowledge on their occurrence and implications for aquatic organisms and food safety. Rome (IT): Food and Agriculture Organization of the United Nations. 126 p. (FAO Fisheries and Aquaculture Technical Paper; no. 615).

Macusi ED, Camaso KL, Barboza A, Macusi ES. 2021. Perceived vulnerability and climate change impacts on small-scale fisheries in Davao Gulf, Philippines. Front Mar Sci. 8:597385. doi:10.3389/fmars.2021.597385.

Macusi ED, Geronimo RC, Santos MD. 2021. Vulnerability drivers for small pelagics and milkfish aquaculture value chain determined through online participatory approach. Mar Policy. 133:104710. doi:10.1016/j.marpol.2021.104710.

Mamauag SS, Aliño PM, Martinez RJS, Muallil RN, Doctor MVA, Dizon EC, Geronimo RC, Panga FM, Cabral RB. 2013. A framework for vulnerability assessment of coastal fisheries ecosystems to climate change: Tool for Understanding Resilience of Fisheries (VA-TURF). Fish Res. 147:381-393. doi:10.1016/j.fishres.2013.07.007.

Nalau J, Becken S, Mackey B. 2018. Ecosystem-based adaptation: a review of the constraints. Environ Sci Policy. 89:357-364. doi:10.1016/j.envsci.2018.08.014.

Oledan MTT. 2001. Challenges and opportunities in watershed management for Laguna de Bay (Philippines). Lakes Reserv Res Manag. 6(3):243–246. doi:10.1046/j.1440-1770.2001.00154.x.

Patt AG, Schröter D, de la Vega-Leinert AC, Klein RJT. 2009. Vulnerability research and assessment to support adaptation and mitigation: common themes from the diversity of approaches. In: Patt AG, Schröter D, Klein RJT, de la Vega-Leinert AC, editors. Assessing vulnerability to global environmental change: making research useful for adaptation decision making and policy. London (UK): Earthscan; p. 1–26.

Pham TTT, Friðriksdóttir R, Weber CT, Viðarsson JR, Papandroulakis N, Baudron AR, Olsen P, Hansen JA, Laksá U, Fernandes PG, et al. 2021. Guidelines for co-creating climate adaptation plans for fisheries and aquaculture. Clim Change. 164:62. doi:10.1007/s10584-021-03041-z.

[PSA] Philippine Statistics Authority. 2020. Philippine Standard Geographic Code (PSGC): Cardona, Rizal [Internet]. Quezon City (PH): Philippine Statistics Authority. https://psa.gov.ph/classification/psgc/barangays/0405806000.

Roxas AT, Guliman SDO, Perez ML, Ramirez PJB. 2017. Gender and poverty dimensions in a value chain analysis of milkfish mariculture in Misamis Oriental, Philippines. Asian Fish Sci. 30S:343-353. doi:10.33997/j.afs.2017.30.s1.021.

Santos-Borja A, Nepomuceno DN. 2006. Laguna de Bay: institutional development and change for lake basin management. Lakes Reserv Res Manag. 11(4):257–269. doi:10.1111/j.1440-1770.2006.00310.x.

Shelton C. 2014. Climate change adaptation in fisheries and aquaculture: compilation of initial examples. Rome (IT): Food and Agriculture Organization of the United Nations. 34 p. (FAO Fisheries and Aquaculture Circular; no. 1088).

Zapata NR Jr, Sarmiento JAC, Cruz MB. 2023. Development of smart food value chain intervention models for the milkfish industry in Region 1, Philippines. Asian J Agric Dev. 20(1):87–108. doi:10.37801/ajad2023.20.1.6.

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