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RESEARCH ARTICLE

Climate and Non-climate Related Hazards in Small Pelagic Fisheries and Milkfish Aquaculture: Expert Opinion Survey in the Philippines

Edison D. Macusi[1,*], Ivy M. Nallos[1], Mudjekeewis D. Santos[2], Rollan C. Geronimo[3]

[1] *Faculty of Agriculture and Life Sciences, Davao Oriental State University (DOrSU), Mati City, Davao Oriental, Philippines*
[2] *National Fisheries Research and Development Institute (NFRDI), Quezon City, Philippines*
[3] *Marine Environment and Resources Foundation (MERF), The Marine Science Institute, University of the Philippines, 1101 Quezon City, Diliman, Philippines*

ABSTRACT

Expert opinion surveys serve as a tool that collects perspectives from various experts, which can be used to enhance the reliability of a tool or study. This paper aimed to validate previously collected climate exposure factors currently impacting small pelagic fisheries and milkfish aquaculture farmers in the Philippines and to validate adaptation measures. The study was conducted through an online survey, where the questionnaire was emailed to experts from various segments of the academe, including non-government workers, and other government researchers, resulting in a total of N=22 respondents. These experts were also asked to rank the exposure factors and the adaptation measures that were taken previously from an online stakeholders' consultation workshop on small pelagic fisheries and milkfish aquaculture. The survey indicated that the top five exposure factors for small pelagic fisheries were coastal development (due to habitat destruction), water quality, temperature changes, typhoons, and declining catch. For milkfish aquaculture, the top five exposure factors were water quality (leading to fish stock depletion), fry source, temperature changes, typhoons, and salinity. As for adaptation measures, alternative livelihood, establishments of marine protected areas (MPAs), and financial access were identified for small pelagic fisheries, while the development of hatcheries, research, and development for feed formulation, and marketing support are the adaptations identified for milkfish aquaculture farmers. From the results, expert opinion on vulnerability assessments provides a valuable contribution by facilitating faster decision-making to address issues on climate change vulnerability and adaptation in coastal management and sustainable aquaculture.

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1. INTRODUCTION

Exposure refers to the degree to which a system, such as small pelagic fisheries or milkfish aquaculture systems, is affected by climate-related hazards. These hazards include rainfall variability, temperature changes, tidal fluctuations, and other environmental conditions influencing productivity, stability, and sustainability (Macusi et al. 2021). Small pelagic fisheries and milkfish aquaculture are vital to the economy and food security but face threats from overfishing, habitat loss, and climate change (Ojeda-Ruiz et al. 2022; Habib et al. 2025). Strategies like ecosystem-based management, seasonal closures, climate-resilient practices, and supportive governance aim to address these challenges (Holsman et al. 2019). However, limited resources and enforcement issues highlight the need for stronger governance, research, and local adaptation to ensure sustainability (Measham et al. 2011).

The Fisheries Vulnerability Assessment Tool (FishVOOL) is one of the most recent tools developed for evaluating the vulnerability of fisheries sectors to environmental and climate-related stressors. By utilizing empirical data, such as rainfall, temperature, and tides, in a modeling platform, FishVOOL offers projections that help identify exposure factors and potential impacts (De Chavez et al. 2021; Jacinto et al. 2015; Macusi et al. 2022). Additionally, proxy indicators, such as coral cover and fish catch, provide valuable insights for assessment. However, the accuracy of these projections often depends on the availability of comprehensive data, which can vary significantly across local government units (LGUs) and barangays (Tsehaye 2007; Mamauag et al. 2013). In some instances, even when mitigation measures like coastal defense structures and flood controls are in place, models may fail to accurately predict outcomes such as flooding (Miyamoto et al. 2022). This highlights the limitations of relying exclusively on quantitative models and underscores the importance of local validation to improve assessment accuracy.

In data-limited scenarios, expert opinion surveys offer a practical alternative (Ainsworth and Pitcher 2005). The Delphi technique, widely used in healthcare sciences for over 40 years, has been applied to forecast medium- (15 years) and long-term (30 years) vulnerabilities in fisheries. It provides reliable assessments at a lower cost, particularly in regions with scarce empirical data (Cuhls 2001; Hohmann et al. 2018). This method aggregates expert judgments to inform decisions on policies, practices, and management strategies (Fuentes and Cinner 2010; Ocampo et al. 2018; Flostrand et al. 2020). By engaging experts from diverse disciplines, the Delphi technique enhances the validity of recommendations, particularly when time-series data are unavailable (Mafi-Gholami et al. 2015; Flostrand 2017).

Scenario analysis using expert opinions has proven effective for addressing challenges in coastal and marine environments. This technique enables exploration of potential solutions for coastal management and has gained popularity across various academic fields (Green et al. 2007; Powell 2003). Complementing expert insights, local ecological knowledge from stakeholders offers context-specific perspectives based on daily resource use and experiences (Macusi et al. 2017; Mendoza et al. 2023; Ostrega et al. 2023). While expert opinions are rooted in scientific models and methodologies, stakeholders' knowledge provides practical insights into local realities, enhancing decision-making (Stocks et al. 2019). Integrating these perspectives leads to more robust and inclusive policies (Greenwood 2007; Winkler et al. 2019).

Despite challenges in integrating diverse perspectives, collaborative governance has emerged as an effective approach for managing coastal ecosystems. This approach facilitates shared decision-making and resource management by involving multiple stakeholders and experts, reducing risks and failures (Kujala et al. 2022; Walsh 2019). Adaptive management strategies focus on understanding factors that reduce system resilience and emphasize collaboration to address shared challenges and achieve sustainable outcomes (Berkes et al. 2003; Brunner et al. 2009).

Understanding the limitations of current tools like FishVOOL and incorporating diverse perspectives can improve vulnerability assessments and inform better adaptation measures. It is essential to consider different perspectives because they reflect various experiences of reality (Nadasdy 2003; Pomeroy and Douvere 2008), and it also becomes necessary to focus on gathering different perspectives and knowledge as an effective way of addressing numerous resource management issues to create policies that will promote sustainability (Linke and Bruckmeier 2015; Zukowski et al. 2011). For the successful implementation of policies, it is also essential to actively gather information from various stakeholders, and this also means establishing a broader knowledge base to ensure effective planning for any activities and interventions (Appleby and Jones 2012; Laya-og et al. 2024).

2. MATERIALS AND METHODS

2.1 Data collection

The desktop research began with drafting a letter containing a brief explanation of the provided tables in the questionnaire and the questions on climate change impacts, exposure factors, and adaptation measures. This study started in January 2021, with the letters being emailed containing an explanation and the questions to be answered by selected expert panels from May 26 to June 4, 2021. After that, a one-week follow-up was conducted to gently remind our respondents, and another two weeks were spent analyzing the data from the returned questionnaires. All the respondents sampled were marine science fisheries experts, practitioners, and conservation advocates. The expert panels comprised academics, practitioners, conservation advocates, and experts from marine science, fisheries, and aquaculture backgrounds. To get reliable results, a consistent result regarding indicators/factors being investigated should be elicited across spatial or geographic regions and among expert panels consulted. Thus, the main aim of this study was to validate previously collected climate exposure factors that were affecting small pelagic fisheries and milkfish aquaculture farmers in the Philippines and to validate adaptation measures that were applied in the present. The key question being investigated through the survey was: "What are the typical climate-related exposure factors affecting small pelagic fisheries and milkfish farming, and what are the potential adaptation measures to mitigate these challenges?"

2.2 Respondents

The study used purposive sampling to select 22 experts in marine science, fisheries, and aquaculture, with 15 holding doctoral degrees and 7 master's degrees. Respondents were chosen in various sectors, including academe (n=19), consultancy (n=1), and non-government organization (NGO) (n=2). The inclusion of experts with diverse backgrounds and experience enriched the study by incorporating both academic and practical perspectives. The study targeted a minimum of 20 experts and successfully collected 22 responses from the experts; the process took one week, and respondents were given another week as they asked for an extension to answer the emailed questionnaire.

2.3 The questionnaire

The study employed a modified technique, reducing the traditional three to four rounds of questioning to two rounds. This adjustment was implemented to gather expert opinions more efficiently on climate indicators and drivers identified through a literature review and a priori survey. These indicators were initially determined during an online stakeholders meeting (Macusi et al. 2021), and the approach aligns with methodologies outlined in previous works (Hasson and Keeney 2011; McKenna 1994). In the email and the questionnaire, we briefly explained our research in English, assuring the participants that the interview data were confidential before obtaining written consent to begin the interview. The questionnaire used to guide the interview mainly consisted of short questions about drivers of climate change and adaptation measures, followed by more open-ended questions about the future of these drivers regarding small pelagic fisheries and milkfish aquaculture. The first part of the questionnaire contained questions about their names, age, education, employment, study sites, number of publications and presentations, and membership in local and national civic and academic organizations to get their social profile. The questionnaire also contained a brief statement of their consent stating that this survey would only be used to enhance the FishVOOL tool of the National Fisheries Research and Development Institute (NFRDI). They were then presented with the previous results of exposure factors and adaptation measures from an earlier workshop, which they were asked to rank based on the probability of occurrence of these factors in the pelagic fisheries and aquaculture sector. Experts ranked key exposure factors and adaptation measures for small pelagic fisheries and milkfish aquaculture, building on the outputs of prior workshops. For small pelagic fisheries, exposure factors included coastal development, deteriorating water quality, temperature, typhoons, declining fish catch, siltation, change in fish distribution, strong winds/waves, quarrying and mining, sea level rise, unpredictable rainfall, coral bleaching, flooding, beach erosion, and pandemic. The corresponding adaptation measures comprised alternative livelihoods, establishment (MPAs), financial access, value-adding training for fish products, marketing support and link, fisherfolk clustering/organizing, R & D feed formulation, cold storage/ice making facilities, processing plants, implement patrolling, boat and crop insurance, develop monitoring stations and apps, IMTA, other fishing grounds, and reforestation. For milkfish aquaculture, exposure factors focused on deterioration of water quality, limited source of fry, temperature, typhoons, salinity, unpredictable rainfall, high mortality, siltation, tidal fluctuation, drought, flooding, strong winds/waves, sea level rise, invasive species, and COVID-19. Adaptation measures prioritized during workshops included more hatcheries, R&D feed formulation, marketing support, alternative livelihoods, cold storage, IMTA, value-adding trainings, proper handling, processing plants, financial access, reforestation, price control, reinforced dikes, developing monitoring stations, and renewable energy.

These various exposure factors and adaptation measures came from the previous results of an online stakeholder consultation in October 2020 (Macusi et al. 2021). They were also asked to provide a perceived confidence level for ranking their various exposure factors, whether low, medium, or high, in the medium (15 years) and long term (30 years). The 15-30 year timeline follows NEDA's medium-term Philippine Development Plan 2004-2010, which considers environmental changes and actionable strategies. While climate impacts may extend beyond this period, these time frames are suitable for addressing risks and enabling interventions. This was for both small pelagic fisheries and milkfish aquaculture. Finally, they were again asked to provide their final top five listing for their exposure factors and adaptation measures in the medium (15 years) and long-term (30 years), considering the relevance of the factors in those times. The authors then referred to various literature to help summarize and validate the multiple exposure factors and adaptation measures in the small pelagics and milkfish sectors (Efstathiou et al. 2008).

2.4 Data analysis

The responses were analyzed using descriptive statistics such as frequency counts and percentages, tabulated, and interpreted. The initial ranking of the factors and measures was based on frequencies from an earlier workshop of stakeholders (Macusi et al. 2021). The expert panel organized the expert ranking, counting which factors were most frequently considered by the experts. Whenever possible, all numbers with decimal places were rounded to the nearest whole number because these were based on individual respondents. Moreover, direct quotes from the respondents were explained whenever needed in the discussion. Themes and definitions based on the respondents' answers and results were created whenever appropriate for a better explanation.

3. RESULTS

3.1 Profile of respondents

Social and productivity profiles of experts elicited in this survey showed that they have an average age of 47 years and an age range of 26 to 63. Their education levels were primarily high; most were doctorate (15) and master's level (7) holders who have conducted research in the past 17 years. Their research record ranged from a minimum of 2 to 35 years, the most extended number. Their fieldwork ranged from one province to as many as the Philippines or more than 55 study sites logged to this day, and they have an average of nine study areas. In terms of scientific productivity, by publications and conference presentations, most of them averaged eight peer-reviewed journals in the past five years, with one related to climate change as a publication and one as a presentation. They have a scientific productivity of 182 publications and 156 presentations in the past five years, 20 publications on climate change, and 24 on climate change (Table 1).

3.2 Rank of various exposure factors for small pelagic and milkfish aquaculture

Based on **Table 2** below, coastal development was identified by respondents as the most critical exposure factor for small pelagic fisheries due to its significant impact on nursery grounds and fish habitats, driven by anthropogenic activities. Other highly ranked factors included deterioration of water quality, temperature—recognized for its long-term effects on phytoplankton, fish larvae, and their distribution—typhoons, and declining stock attributed to illegal fishing and encroachment. Although factors such as sea-level rise, quarrying, and mining were acknowledged, they did not rank among the top five. For milkfish aquaculture, respondents emphasized deteriorating water quality as the most pressing issue, affecting fish health and overall productivity. This was followed by concerns about the declining supply of fry and fingerlings, temperature, typhoons, and salinity. Additionally, unpredictable rainfall was noted for its

Table 1. Social and scientific productivity of expert respondents (N=22).

Variable	Description	Ave	Min	Max	
Age	Age of researchers	46.8	26	63	
Education	Seven master's holders, 15 PhD holders (in marine science, fisheries, and aquaculture)	18	16	19	
Years (Research)	Number of years in research	17.4	2	35	
Study sites	Field study sites	9.0	1	55	
Articles published	Articles published in the last five years	8.3	0	70	
Articles (climate change)	Number of articles on climate change published in the last five years	0.9	0	8	20
Conference presentations	Number of presentations in the last five years	7.8	0	40	156
Presentations (climate change)	Number of presentations on climate change in the last five years	1.1	0	6	24
Membership in organizations	Membership in academic and civic organizations	2.0	0	5	45

Table 2. Selected exposure factors for small pelagic fisheries and milkfish aquaculture.

Small-pelagic fisheries		Milkfish aquaculture	
Factors	**Rank**	**Factors**	**Rank**
Coastal development	1	Deteriorating water quality	1
Deteriorating water quality	2	Limited source of fry	2
Rising water temperature	3	Rising water temperature	3
Typhoons	4	Typhoons	4
Declining in stock	5	Salinity	5
Siltation	6	Unpredictable rainfall	6
Change in fish distribution	7	High mortality	7
Strong winds/waves	8	Siltation	8
Quarrying and mining	9	Tidal fluctuation	9
Sea level rise	10	Drought	10
Unpredictable rainfall	11	Flooding	11
Coral bleaching	12	Strong winds/waves	12
Flooding	13	Sea level rise	13
Beach erosion	14	Invasive species	14
COVID-19	15	COVID-19	15

association with increased mortality rates and nutrient overturning in mariculture and pond systems.

3.3 Rank of various adaptation measures for small pelagic and milkfish aquaculture

The adaptation measures suggested by respondents for small pelagic fisheries and milkfish aquaculture showed notable differences, as summarized in Table 3. For small pelagic fisheries, the highest-ranked measures included alternative livelihoods, the establishment of Marine Protected Areas (MPAs), improved access to financial resources, value-adding training for fish products, and market linkages and support. MPAs were particularly highlighted for their role in mitigating catch declines through spillover effects, while financial support was deemed essential for fishers affected by typhoons. Additionally, training programs to equip fishers with alternative livelihood skills or entrepreneurial opportunities were emphasized to address declining fish stocks and the impact of coastal development.

For milkfish aquaculture, respondents prioritized more hatchery, research and development (R&D) for improved feed formulations, marketing support, alternative livelihoods, and cold storage facilities. More hatcheries and R&D were considered crucial to addressing vulnerabilities such as degraded water quality, fry shortages, and unpredictable seasons. Cold storage infrastructure was also seen as critical to preserving fish products and maintaining market supply during disruptions caused by typhoons.

Other recommendations included regulating fishing activities through licensing, permits, and closed seasons, as well as managing coastal development, such as tourism. For milkfish aquaculture, one respondent suggested adopting sustainable aquaculture practices, including proper pond management, reduced pesticide use, and well-designed dikes. While ideas like reefer vans and reinforced dikes were mentioned, they were not prioritized as essential measures for milkfish adaptation.

3.4 Selected exposure factors for small pelagic fisheries and milkfish-aquaculture

The selected exposure factors for small pelagic fisheries and milkfish aquaculture, as predicted by respondents for the next 15 and 30 years, are presented based on their input and should not be viewed as

Table 3. Ranking of adaptation measures for small pelagic fisheries and milkfish aquaculture (N=22).

Small-pelagic fisheries		Milkfish aquaculture	
Factors	**Rank**	**Factors**	**Rank**
Alternative livelihoods	1	More hatcheries	1
Establish MPA'S	2	R & D feed formulation, breeding, spawning, biology	2
Financial access	3	Marketing support and link	3
Value-adding training for fish products	4	Alternative livelihoods	4
Marketing support and link	5	Cold storage/ice making facilities	5
Fisherfolk clustering/organizing	6	IMTA (shift to aquaculture)	6
R & D feed formulation, breeding, and biology	7	Value adding trainings for fish products	7
Cold storage/Ice making facilities	8	Proper handling and good storage	8
Processing plants	9	Processing plants	9
Implement patrolling	10	Financial access	10
Boat, gear, crop insurance	11	Reforestation (aquasilviculture)	11
Develop monitoring stations and apps	12	Price control	12
IMTA (shift to aquaculture)	13	Reinforced dikes, seawalls, storm breakers	13
Other fishing grounds	14	Develop monitoring stations and apps	14
Reforestation (aquasilviculture)	15	Renewable energy	15

Table 4. Factors relevant to affecting the small pelagic fisheries and milkfish aquaculture in the medium (15 years) and long-term (30 years) (N=22).

Small Pelagic Fisheries					
Factors (medium term)	**Frequency**	**(%)**	**Factors (long-term)**	**Frequency**	**(%)**
Temperature	9	14.8	Coastal development	10	14.5
Declining catch	8	13.1	Declining catch	9	13.0
Coastal development	8	13.1	Temperature	8	11.6
Quarrying and Mining	6	9.8	Coral bleaching	8	11.6
Typhoon	6	9.8	Typhoon	7	10.1
Strong winds/waves	6	9.8	Sea level rise	7	10.1
Water quality	6	9.8	Strong winds/waves	7	10.1
Coral bleaching	5	8.2	Water quality	5	7.2
Siltation	4	6.6	Unpredictable rainfall	4	5.8
Sea level rise	3	4.9	Quarrying and Mining	4	5.8
Milkfish Aquaculture					
Factors (medium-term)	**Frequency**	**(%)**	**Factors (long-term)**	**Frequency**	**(%)**
Water quality	15	24.6	Water quality	13	23.2
Temperature	7	11.5	Temperature	6	10.7
Source of fry	6	9.8	Typhoon	6	10.7
Siltation	6	9.8	Source of fry	5	8.9
Salinity	6	9.8	Siltation	5	8.9
Unpredictable rainfall	5	8.2	Tidal fluctuation	5	8.9
High mortality	5	8.2	Flooding	5	8.9
Typhoon	5	8.2	Unpredictable rainfall	4	7.1
Invasive species	3	4.9	High mortality	4	7.1
Flooding	3	4.9	Strong winds/waves	3	5.4

general conclusions. For small pelagic fisheries, the top five exposure factors in the first 15 years included temperature (15%), catch decline due to illegal fishing and encroachment (13%), coastal development (13%), quarrying and mining (10%), and typhoons (10%). After 30 years, coastal development emerged as the leading factor (15%), followed by catch decline (13%), temperature (12%), coral reef bleaching (12%), and typhoons (10%). Quarrying and mining were replaced by the increasing threat of coral bleaching.

In milkfish aquaculture, the most relevant exposure factors for the first 15 years were water quality (25%), temperature (12%), source of fry (10%), siltation (10%), and salinity (10%). After 30 years, water quality (23%), temperature (11%), and typhoons (11%) remained critical, while the source of fry (9%) and siltation (9%) persisted, with salinity being replaced by typhoons. The similar counts across several factors suggest that these issues are all viewed as important by respondents, though prioritization is needed for broader application, such as in Fisheries Management Areas (FMAs) 6 and 9, which mainly use earthen pond culture and semi-intensive farming systems. The persistence of water quality, temperature, fry supply, and siltation issues indicates a negative expectation that these challenges will continue to affect aquaculture in the next 30 years.

3.5 Confidence level on selected factors

In general, the confidence level of the exposure factors regarding small pelagic was higher both for the medium-term and long-term, around 50–60% for a high confidence level and around 30–45% for a medium confidence level (see Table 5). For small pelagic fisheries, the confidence level was relatively high, with around 50–60% of respondents indicating a high confidence level for both medium-term and long-term factors, and 30–45% expressing medium confidence. In contrast, for aquaculture, the high confidence level ranged from 35–45% for both medium-term and long-term factors, while medium confidence was more prevalent, ranging from 40–45% for these timeframes (see Table 5).

Confidence levels represent the respondents' certainty about the likelihood of a given event or outcome. For small pelagic fisheries, the higher confidence levels (55% for high confidence) suggest that addressing the challenges in this sector may be more complex, as factors such as bad weather, typhoons, and coral bleaching are beyond control. These changes, like temperature shifts, may require a broad, national approach rather than localized efforts, such as Marine Protected Areas (MPAs) or small-scale closures. For aquaculture, while the confidence level was lower, with about 40% expressing high confidence, this still indicates a possibility of change, suggesting that the challenges identified could potentially be addressed in the short term.

3.6 Selected adaptation measures for small pelagic and milkfish-aquaculture

The adaptation measures identified by respondents for small pelagic fisheries and milkfish aquaculture were attributed based on their input and should not be generalized. For small pelagic fisheries, the top five relevant adaptation measures for the next 15 years included providing alternative livelihoods for fishers and their families (18%), improving financial access or loans for livelihoods, fishing operations, or boat repairs (12%), establishing Marine Protected Areas (MPAs) and conservation areas (12%), research and development (R&D) on small pelagic spawning and biology (10%), and stricter implementation of coastal patrols by the navy, coast guard, and local barangays (10%). Marketing linkages for small pelagic products were also suggested (9%). For the next 30 years, respondents indicated a shift toward value-adding strategies for fish products (12%) and maintained the relevance of alternative livelihoods (19%), MPAs and conservation areas (17%), R&D for small pelagics (14%), and patrols (9%) (see Table 6).

For milkfish aquaculture, the primary adaptation measures for the next 15 years were the development of additional hatcheries (16%), market and support structures for aquaculture farmers (15%), R&D for feed formulation (13%), establishing

Table 5. Confidence level of respondents on their chosen exposure factors to be relevant in the medium (15 years) and long-term (30 years) (N=22).

Confidence level	Small Pelagic Fisheries		Milkfish Aquaculture	
	Medium-term	Long-term	Medium-term	Long-term
Low (<50%)	1 (5)	2 (10)	4 (20)	3 (15)
Medium (>50% but <90%)	9 (45)	6 (30)	9 (45)	8 (40)
High (>90%)	10 (50)	12 (60)	7 (35)	9 (45)

processing plants or canneries for value-added products (11%), and the creation of cold storage and ice-making facilities (9%). Looking ahead 30 years, respondents emphasized the importance of continued R&D for feed formulation (18%) and the development of integrated multitrophic aquaculture (IMTA) systems (16%) as sustainable methods for culturing multiple species. The need for value-adding strategies (12%), the establishment of advanced hatcheries (12%), and ongoing marketing support and linkages (10%) were also identified. For milkfish aquaculture, the economic aspects of market linkages and the development of hatcheries, feed technologies, and sustainable practices were seen as critical over the long term (see Table 6).

The exposure factors affecting small pelagic fisheries and milkfish aquaculture, as identified by the respondents, highlight the significant role that land-based activities play in impacting both pelagic fish populations and aquaculture operations. For example, quarrying, mining, and deforestation are linked to the clearing of mountains for infrastructure development, such as roads, and the extraction of valuable metals like copper and nickel. These activities leave the land vulnerable to erosion, particularly during heavy rainfall or typhoons, as tree roots, which normally absorb water, are removed. This results in increased runoff, bringing siltation, flooding, and potential contamination from toxic metals and pesticide residues. These factors degrade water quality, which is critical for pond culture in aquaculture and affects the health of fish larvae living in nearshore ecosystems, including seagrasses, mangroves, and coral reefs. Flooding caused by heavy rainfall or typhoons can further damage pond dykes, introduce invasive species, and lead to significant stock losses, increasing fish mortality.

Respondents noted that in the short term (15 years), land-based activities like quarrying and mining would result in erosion, siltation, and pollution, negatively affecting the water quality essential for small pelagic fisheries and milkfish aquaculture in coastal areas (Holden 2015; Rangel-Buitrago 2023). In the medium term (30 years), the impacts of these factors are expected to worsen, with more frequent and intense flooding, typhoons, and the continued loss of coastal habitats. This will make it increasingly difficult to sustain aquaculture, as the

Table 6. Relevant factors in the medium (15 years) and long-term (30 years) with regards to adaptation measures for the small pelagic fisheries and milkfish aquaculture (N=22).

Small Pelagic Fisheries					
Factors (medium-term)	**Frequency**	**(%)**	**Factors (long-term)**	**Frequency**	**(%)**
Alternative livelihoods	10	17.5	Alternative livelihoods	11	18.6
Financial access	7	12.3	Establish MPAs	10	16.9
Establish MPAs	7	12.3	R & D on spawning, biology	8	13.6
R & D on spawning, biology	6	10.5	Value adding for fish products	7	11.9
Implement patrolling	6	10.5	Implement patrolling	5	8.5
Marketing support and link	5	8.8	Processing plants	4	6.8
Cold storage/ice making facilities	5	8.8	Marketing support and link	4	6.8
Value adding for fish products	4	7.0	Cold storage/ice making facilities	4	6.8
IMTA (shift to aquaculture)	4	7.0	Reforestation (aquasilviculture)	3	5.1
Processing plants	3	5.3	IMTA (shift to aquaculture)	3	5.1
Milkfish Aquaculture					
Develop hatcheries	9	16.4	R & D feed formulation	9	18
Marketing support and link	8	14.5	IMTA (shift to aquaculture)	8	16
R & D feed formulation	7	12.7	Value adding for fish products	6	12
Processing plants	6	10.9	Develop hatcheries	6	12
Cold storage/ice making facilities	5	9.1	Marketing support and link	5	10
Value adding for fish products	5	9.1	Alternative livelihoods	4	8
Alternative livelihoods	4	7.3	Reforestation (aquasilviculture)	4	8
Proper handling and good storage	4	7.3	Price control	3	6
Boat, gear, crop insurance	4	7.3	Processing plants	3	6
IMTA (shift to aquaculture)	3	5.5	Cold storage/ice making facilities	2	4

larvae populations will decline, and infrastructure will be further damaged (Ahmed et al. 2019). Additionally, coastal development, particularly in tourist areas, was identified as another driver of environmental degradation. Improperly managed tourism, as well as unplanned urban growth in coastal regions, leads to pollution from plastics, wastewater, and increased fishing pressures due to higher populations of coastal dwellers and fishers. Respondents pointed out that the rising temperature caused by climate change would further affect small pelagic fish by altering their distribution and behavior, pushing them to deeper waters. Similarly, sudden temperature changes could impact milkfish fry and fingerling growth, leading to oxygen depletion and higher mortality rates.

These findings underscore the interconnectedness of land-based and marine activities and their cumulative effects on both small pelagic fisheries and milkfish aquaculture. Adaptation strategies, therefore, need to address these multifaceted challenges in both the short and long term to ensure the sustainability of these sectors (Table 7).

Based on the responses from the participants, several adaptation measures for small pelagic and milkfish aquaculture were identified as being relevant both today and in the future (15 to 30 years). For small pelagic fish, the need for research and development (R&D) in areas such as the biology of species like sardines, scads, mackerel, and rainbow runners was emphasized. Respondents also noted that the establishment of larger Marine Protected Areas (MPAs) and priority conservation zones could be a significant factor in preserving small pelagic fish populations. Furthermore, they highlighted the potential benefits

Table 7. Summary of the relevant exposure factors found in both 15 years and 30 years prediction of respondents and their possible impacts to fishing communities and fish farmers.

Relevant exposure factors	
Small pelagic fisheries	Impacts to fishing communities
Coastal development	Coastal developments without due regard to the environment can destroy marine ecosystem which are nursery grounds for various fish larvae
Declining catch	Because of the scarcity of fish in nearshores, fishers are forced to go farther offshore
Temperature	Weather can be too hot; summer season is hotter compared to previous years
Coral bleaching	High temperature essentially destroys the balance of symbiosis between the algae and its zooxanthelae in coral reefs causing bleaching. It reduces coral cover, diminishes habitat for fish and other marine species, and weakens the overall resilience of coral reef ecosystems.
Typhoons/strong winds and waves	Typhoons can damage boats and fishing materials and strong winds generate big waves preventing fishers from operating
Quarrying and mining	Quarrying and mining can dump heavy metals, silt rivers and destroy the habitat of nearshore fish including seagrass, mangroves, and coral reefs; they also affect water quality
Sea level rise	Highly exposed coastal areas where most population centers are located within 1 to 10 km from the shore are also affected by increased sea level due to ground subsidence, and melting of polar ice caps can lead to coastal flooding, erosion, saltwater intrusion into freshwater systems, and habitat loss
Milkfish aquaculture	Impacts of aquaculture operation to fish farmers
Water quality	Increasing anthropogenic impacts from river dumping, agricultural farm wastes, mining wastes and deforestation affects the health and survival of cultured fish
Temperature	Hot weather can affect the oxygen level of pond cultures, including mariculture sites affecting the survival of milkfish fries
Source of fry	Lack of fry in the wild has become problematic so that we continue to import milkfish fries from Indonesia
Siltation	Continued deforestation, quarrying and mining in nearby mountain ecosystems can dump silt and pollute rivers as well as coastal areas affecting their water quality
Salinity	Unpredictable weather can cause salinity levels to suddenly change or drop and impact the sensitive cultured species or fries
Typhoon	Bad weather due to typhoons can also affect pond dykes including destroying them
Flooding	A more frequent occurrences of flooding can happen if there are stronger typhoons due to increasing sea surface temperature. It causes stock losses, degrades water quality, and increase fish mortality.

of bank-facilitated loans, particularly those provided by the Department of Agriculture through the Bureau of Fisheries and Aquatic Resources (BFAR), to support fishers' operations and daily livelihoods. The idea of offering training on livelihood alternatives, value-adding processes, and market support was seen as vital for helping fishers improve their financial security. Respondents also pointed to micro-credit schemes as a possible solution to address the long-standing issue of insufficient capital for businesses, as these schemes would allow fishers to repay loans if their ventures succeed. However, concerns were raised about the reluctance of banks to invest in fishers' businesses due to perceived risks, and respondents emphasized the need for proper training and less risky environments to help fishers succeed in entrepreneurship (Table 8).

In the case of milkfish aquaculture, the need for research into feed formulation and the development of super spawners for milkfish fry was mentioned as crucial for the sector's future sustainability. Respondents suggested establishing a research center dedicated to overseeing these efforts, including potential advancements in genetic engineering or manipulation. Strategic hatchery and breeding center development was also identified as key to addressing the current lack of fry sources, which limits the industry's growth and forces reliance on external sources of milkfish fry. Multitrophic aquaculture, which involves farming multiple species, was proposed as a potential solution to diversify the sector. However, respondents noted that technical knowledge and training in multitrophic aquaculture could be a barrier for some fish farmers. Finally, the establishment of cold storage and ice-making facilities was seen as an important step in preserving fish products, preventing degradation, and ensuring they

Table 8. Summary of the adaptation measures found in both 15 years and 30 years prediction of respondents and their possible impacts to fishing communities and fish farmers.

Small pelagic fisheries	
Relevant adaptation measures	Impacts to fishing communities
Alternative livelihoods	Alternative livelihoods are essential given the declining catches of fishers
Establish MPAs	Because of the declining catches, a viable solution is the putting up of more MPAs and no fishing conservation areas
Implement patrolling	Although MPAs can be legally established, the lack of patrols and adoption of local governments of these conservation areas make it ineffective for its goal to replenish fish biomass
R & D spawning, biology	R & D of spawning, biology of fishes are essential for understanding their reproduction and biomass
Financial access	Financial access will allow fishers to change their fishing gears, operate as well as replace broken nets and damaged boats
Marketing support and link	Marketing support will help fishers to become traders
Value adding to fish products	Value adding of fish products will increase their profit margin and diversify their products
	Impacts to milkfish aquaculture
R & D feed formulation, breeding	With inadequate milkfish fry available, there is a need for continuous breeding and genetic manipulation of super spawners for stabilizing fry supply; Milkfish research centers should be established as there are Tilapia breeding centers
Develop hatcheries	State of the art hatcheries and milkfish research centers are needed to establish a sustainable milkfish aquaculture for years to come
IMTA (shift to aquaculture)	Multitrophic culture can be an alternative solution to culturing just one species, but the lack of technical knowledge could be a technology barrier to adopters
Value adding for fish products	Value adding of milkfish products will enhance and diversify their product portfolio especially for processed and export production
Marketing support and link	Marketing support will link fish farmers to markets locally and abroad, increasing their success and market penetration
Cold storage/ice making facilities	Lack of cold storage is a barrier to continuous production and processing because fish food products can easily degrade
Processing plants	In poverty stricken coastal areas, processing plants can be a boon especially to women's association and cooperatives as this technology increases their chances of being able to mass produce their products and do it under food safe standards.

can be marketed effectively (**Table 8**). These adaptation measures reflect the insights and priorities expressed by the respondents and provide a framework for addressing both immediate and long-term challenges in small pelagic fisheries and milkfish aquaculture.

4. DISCUSSION

Expert opinion enables individuals to collectively address a complex problem through group communication (Petrolia et al. 2020). This technique, as a process, involves an interaction between the researchers and the group of identified experts on a specified topic, usually through a series of questionnaires. A modified technique that used only two rounds of questioning may not indicate a consensus of opinions concerning the target issue on climate exposure factors and adaptation measures in small pelagics and milkfish aquaculture but can provide expert opinions that are crucial and approximates roughly the same contextual advice that can be given when evaluating factors that are influencing the fisheries and the aquaculture sectors (Green et al. 2007; Flostrand 2017).

Expert opinion provides valuable insights into climate exposure factors and adaptation measures in small pelagic fisheries and milkfish aquaculture, but the approach has limitations. The two-round questioning method may not achieve a consensus and could narrow the range of perspectives. Extending the number of rounds or broadening the respondent pool to include a more diverse group of experts could improve this. While purposive sampling ensures relevant expertise, it may exclude insights from non-experts, introducing potential bias. This method fosters focused discussions but may reduce the generalizability of the findings.

4.1 Small pelagic fisheries

By assessing several exposure and adaptation measures for the small pelagic fisheries and milkfish aquaculture, the study came up with several major factors, which included coastal development as a likely significant exposure factor for the small pelagic fisheries (Ma et al. 2024; Similatan et al. 2023). This is because modifying the coastline and replacing its natural features with artificial habitats, stones, or infrastructure can significantly disturb the surrounding environment by changing the sediment, water flow, noise, and chemical pollution (Rangel-Buitrago 2023). To mitigate the impact of coastal development, which destroys marine ecosystems and nursery grounds for fish larvae, establishing Marine Protected Areas (MPAs) and no-fishing zones is a key measure. However, their success depends on effective patrolling and strong local government engagement (McNeill et al. 2018). Moreover, human activities were likely to destroy and damaging native habitats, including mangrove forests and seagrass areas in coastal ecosystems, unintentionally affecting the small pelagic fisheries (Cuenca-Ocay et al. 2019; Cuenca et al. 2015; Primavera and Esteban 2008).

The current expert panel ranked adaptation measures for small pelagic fishery and milkfish aquaculture, and based on the opinion of respondents, the top adaptation measures for small pelagic fisheries were alternative livelihoods, financial access, and establishment of MPAs and conservation areas. Fisheries are a sector heavily impacted by climate change, and several adaptation measures have already been suggested and practiced. The most common adaptation measures for fishers were the diversification of livelihood due to the changing weather condition pattern and the frequency of typhoons especially in the Philippines (Galappaththi et al. 2022; Yumul et al. 2011), the fishers' ability to catch fish were hindered and so their capability to generate income and provide for their family's needs were negatively affected (Frawley et al. 2019; Malik et al. 2022). Due to inaccessible fishing grounds, time spent fishing will be converted to time spent at home, and alternative livelihoods should be available to fishers during these occasions to still support their families. Financial access through bank loans was also deemed an essential coping mechanism for fishers, allowing them to easily engage in other businesses such as vegetable and poultry production, or to have a starting capital if fishing resumes after a bad weather condition (Macusi et al. 2021). For declining fish catches in nearshore areas, alternative livelihoods provide diverse income opportunities for fishers, while financial access and marketing support enable them to adopt improved gear and fishing methods, reducing their reliance on shrinking fish stocks (Andrews et al. 2021; Gómez and Maynou 2021). These efforts enhance understanding of species resilience and guide strategies for habitat restoration. Similarly, the damage caused by typhoons, strong winds, and waves to boats and fishing operations is mitigated by providing financial resources for asset repairs and replacements (Heck et al. 2021). Coastal flooding and habitat loss from sea level rise are addressed by promoting alternative livelihoods that lessen dependence on vulnerable coastal resources (Haque et al. 2016).

Additionally, value-adding to fish products helps fishers offset income losses during periods of reduced fishing activity to create economic opportunities and enhance community resilience (Macusi et al. 2022). Climate change affects the marine resources targeted and harvested (Miller et al. 2018). To mitigate the impact of climate change on the aquatic environment, fisheries managers and conservation actors pushed for the establishment of MPAs or not take marine reserves to restock the ocean with fish, but these MPAs should be climate resilient by having proper size, spacing, shape, and connectivity (Cabral et al. 2014; Muallil et al. 2015).

The adaptation strategies aligned with the identified exposure factors, addressing short-term and long-term challenges—measures such as MPAs. Patrolling and R&D aim to mitigate environmental degradation and restore fish stocks, while financial access, marketing support, and value-adding strategies bolster socio-economic resilience. However, implementation gaps, including insufficient patrolling of MPAs and limited local government support, present significant challenges. Continuous monitoring and adaptive management will ensure their effectiveness and adaptability to future challenges.

4.2 Milkfish aquaculture

On the other hand, water quality for milkfish aquaculture was deemed the most significant exposure factor, resulting in potential human health risks and low product quality. This was supported by previous studies in the aquaculture sector, which state that maintaining a viable aquaculture production requires acceptable water quality (Mramba and Kahindi 2023; Macusi et al. 2024). Production can be hampered when the water contains contaminants that can impair development, growth, and reproduction or even cause mortality to the cultured species (Farrag et al. 2024). Milkfish aquaculture faces significant challenges due to environmental factors. Water quality is affected by river dumping, agricultural waste, mining, and deforestation, compromising fish health and survival. Integrated Multitrophic Aquaculture (IMTA), which utilizes species like shellfish and seaweeds to filter excess nutrients, improves water quality but requires technical training for adoption (Sasikumar and Viji 2015; Nissar et al. 2023). In milkfish aquaculture, the top three adaptation measures were the development of hatcheries, R and D for feed formulation, breeding, spawning, and biology, as well as marketing support and links determined by the respondents. Due to climate change impacts such as extreme temperatures, erratic rainfall, and frequent typhoons, the aquaculture industry greatly suffered, and hatchery operators have identified climate change-induced problems as exacerbating other existing problems (Cabrera and Lee 2018; Cheung et al. 2021; Macusi et al. 2021; Pelone and Arellano 2024), thereby influencing environmental changes, causing disease outbreaks and poor growth of broodstock that led to significant economic loss (Sen Gupta et al. 2020; Siddique et al. 2022). To cope with the problems caused by climate change, hatchery operators need to venture into and D to mitigate its impact; some studies were performed to change the reproductive timing of the fish to enhance adaptation to changing environmental conditions (Tillotson et al. 2019), selective breeding to reduce mortality due to disease outbreaks and changing ocean conditions and improvised genetic traits to be disease resilient and adaptive to environmental stressors to name a few breakthroughs in hatchery research and development (Nascimento-Schulze et al. 2021). In addition, alternative and sustainable feed formulation as an adaptation measure to climate change impacts can also greatly enhance cultured fish resilience (Macusi et al. 2023a; Macusi et al. 2023b).

However, poorly formulated diets can also expose fish to poor fish health because of reduced digestion, loss of appetite, and eating (mature and larvae), deterring fish growth and hatchery development (Ngoan 2018). Hot weather lowers oxygen levels in ponds, threatening milkfish fries. Advanced hatcheries with oxygenated systems and R&D in feed formulation can mitigate these effects (Araujo et al. 2022). The declining availability of milkfish fry, leading to reliance on imports, can be addressed through breeding research and establishing local hatcheries for a stable fry supply (Garcia et al. 2020). typhoons damage pond infrastructure, causing stock losses. Cold storage and decentralized processing plants enhance resilience and create alternative income sources (Amjad et al. 2023). Increased flooding from stronger typhoons exacerbates fish mortality and water degradation. IMTA improves resilience by integrating species that tolerate variable conditions, and flood-resistant hatcheries mitigate risks (Macusi et al. 2015; Custódio et al. 2017).

Adaptation strategies align with exposure factors but require robust implementation. R&D, hatcheries, infrastructure, and capacity-building investments for IMTA adoption are essential. Addressing root causes like deforestation and pollution through policy reforms complements these measures. An integrated approach combining technical, economic, and policy interventions will enhance the sustainability and resilience of milkfish aquaculture.

5. CONCLUSION

This study utilized expert opinion elicitation through an online survey to address gaps in the FishVool tool and validate climate exposure and adaptation measures. The findings highlighted critical exposure factors and adaptation measures for small pelagic fisheries and milkfish aquaculture. In small pelagic fisheries, coastal management emerged as a key exposure factor, emphasizing the importance of preserving marine ecosystems, with adaptation strategies such as alternative livelihoods, marine protected areas (MPAs), and financial access recommended to enhance resilience and sustainability. For milkfish aquaculture, deterioration of the water quality was identified as a primary exposure factor, with more hatchery, research on feed formulation, and market support prioritized as adaptation measures. However, the study's conclusions rely on the purposive identification of respondents and expert opinion, lacking robust quantitative analysis or a comprehensive literature review, which may limit the generalizability of the findings due to potential biases in respondent selection and the absence of broader stakeholder input. Future studies should integrate expert opinions with quantitative analyses, direct field observations, and systematic literature reviews to provide a more comprehensive understanding of climate change impacts and adaptation measures. Expanding the respondent pool to include diverse stakeholders and conducting multiple rounds of elicitation could also improve the reliability of the findings. Policy recommendations include strengthening coastal management through the enforcement of MPAs and promotion of alternative livelihoods, enhancing financial access to support fishers, addressing water quality issues in aquaculture with stricter pollution regulations and incentives for Integrated Multitrophic Aquaculture (IMTA), and supporting hatchery development and sustainable feed research. Governance efforts should prioritize multi-stakeholder engagement, stronger monitoring and enforcement, and increased R&D funding to create adaptive management schemes addressing both short- and long-term climate challenges. By integrating expert insights with robust methodologies and collaborative governance, fisheries and aquaculture management can better adapt to the impacts of climate change.

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AUTHOR CONTRIBUTIONS

Macusi ED: Conceptualization, Methodology, Data collection, Writing – original draft, Visualization, Analyses, Writing – review & editing, Supervision. **Nallos IM**: Conceptualization, Methodology, Visualization, Analyses, Writing – review & editing, Writing – original, draft, Supervision. **Santos MD**: Conceptualization, Methodology, Data collection, Writing – original draft, Supervision. **Geronimo RC**: Conceptualization, Methodology, Data collection, Writing – original draft, Supervision.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

DATA AVAILABILITY

Data are available upon request.

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