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Local Ecological Knowledge and Climate Change Perceptions among Mangrove Fishers in Masinloc, Zambales, Philippines

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Abstract

Small-scale fisheries (SSFs) are increasingly vulnerable to climate change, particularly in data-limited regions where scientific monitoring is scarce. Local Ecological Knowledge (LEK) offers valuable insights into environmental changes and adaptive practices. This study investigated the LEK of mangrove subsistence fishers in Masinloc, Zambales, Philippines, focusing on their perceptions of climate change impacts and the influence of demographic factors on LEK utilization. A structured survey was administered to 335 fishers across four barangays (villages), employing binary and open-ended questions to assess LEK related to climate indicators such as temperature fluctuations, rainfall patterns, typhoon occurrences, and flooding events. Quantitative data were analyzed using Pearson's chi-square tests, Bonferroni-adjusted post-hoc pairwise comparisons, and Cramer's V to identify specific associations between LEK and demographic variables. Findings revealed that while fishers possess substantial LEK pertinent to climate change, its application varies significantly with barangay, age, and educational attainment. Notably, these demographic factors influenced the depth and breadth of LEK used in predicting and responding to climate-related events. The study underscored the importance of integrating LEK into climate adaptation strategies, recognizing its potential to enhance resilience in SSFs. Although centered on a specific locale, the insights gleaned from this research contribute to the broader discourse on the role of indigenous knowledge systems in climate change resilience, offering a model for similar communities globally.

Keywords

Local Ecological Knowledge, Climate Change, Mangrove Stocks, Flooding, Typhoon, Social Impact, Mangrove Fishers

1. Introduction

Small-scale fisheries (SSFs) are vital for food security and livelihoods in tropical developing countries (Lam et al., 2020; Macusi et al., 2021; Porter et al., 2014). However, many SSFs struggle to provide enough catch and income to support their communities, often facing poverty and resource limitations (Bell et al., 2020; Islam et al., 2022). These challenges are further intensified by climate change, as the strong dependence of SSFs on local environments reduces their flexibility to adapt to shifting conditions (Hanich et al., 2017). Despite their central role and high vulnerability, SSFs are frequently underrepresented in climate change research, making it difficult to address their specific needs (Gianelli et al., 2021). This research gap is compounded by the lack of long-term scientific monitoring in many SSF communities, which limits our understanding of how climate impacts their fisheries over time (Inaotombi & Mahanta, 2018).

Local knowledge (LK) helps address the lack of scientific monitoring by providing both historical and current insights into environmental changes experienced by fishers (Galappaththi et al., 2019; Ullah et al., 2023). This knowledge is shaped and transmitted within communities through culture and social relationships (Collins, 2013). Recent studies highlight that fishers' local knowledge plays a key role in understanding and adapting to climate change, especially where scientific data are limited (Gianelli et al., 2021; Ullah et al., 2023). In many developing countries, local ecological knowledge (LEK) serves as a practical and reliable resource for interpreting changes in the environment. While combining LEK with scientific knowledge can be complex, such integration offers a more complete picture of environmental change (Gianelli et al., 2021). Many coastal communities recognize the value of blending both knowledge systems to improve resource management (Mateos-Molina et al., 2021). However, only a few studies have examined the practical benefits and challenges of this approach (Alexander et al., 2019). When scientists cannot monitor every ecosystem due to limited time and resources, relying solely on formal scientific data is often insufficient (Bélisle et al., 2018). Engaging local fishers and drawing on their experience has occasionally led to more successful management outcomes (Hiwasaki et al., 2014), which include community-based adaptation (CbA) practices. CbA is a method of adaptation that helps local people to decide the goals and methods of climate change adaptation to lessen the effects of climate change (storm surges, floods, and extreme weather events, typhoons) and taking actions to reduce vulnerability to climate change impacts (Alberto et al., 2022) and manage risks to protect communities and fortify the resilience of the economy (Paz-Alberto et al., 2021). By including local knowledge in climate change research, we gain vital site-specific context and a clearer understanding of how environmental changes affect communities over time. Recent global and regional syntheses sharpen this point, showing why LEK now sits at the centre of climate-adaptation debates.

Climate change presents a significant threat to ecosystems worldwide, and understanding its impacts requires integrating both scientific climate data and LEK

(IPCC, 2022). LEK, accumulated through generations of direct interaction with the environment, offers invaluable insights into environmental changes that might be missed by conventional monitoring systems (Berkes, 2018; Berkes et al., 2000; Reyes-García et al., 2019). Globally, studies have demonstrated the importance of LEK in identifying shifts in species distribution, phenological changes, and the impacts of extreme weather events (Fernández-Llamazares et al., 2015; Gadgil et al., 1993). Such knowledge is particularly crucial in regions where scientific data are sparse or unavailable, providing a more complete picture of climate-change impacts (Ford et al., 2016).

In Asia, the effects of climate change are keenly felt, with many communities relying directly on natural resources for their livelihoods (Asian Development Bank, 2021). For instance, in the Philippines, an archipelagic nation highly vulnerable to climate change, LEK plays a vital role in adapting to environmental shifts (Paz-Alberto et al., 2020b). Studies have shown that local fishermen possess detailed knowledge about the changing migration patterns of fish stocks and shifting coastal resources (Paz-Alberto et al., 2022b). Similar findings have been reported in Indonesia, where coastal communities use traditional knowledge to predict weather patterns and manage fisheries sustainably (Gunggut et al., 2024). In Bangladesh, local communities apply LEK to adjust cropping calendars and adapt to altered rainfall patterns (Sultana & Luetz, 2022). These practices not only enhance resilience to climate change but also contribute to biodiversity conservation and sustainable resource management (Berkes, 2018). Integrating LEK into climate-change policies and adaptation strategies is essential for ensuring effective and equitable outcomes at both regional and local levels (IPBES, 2019; Hiwasaki et al., 2014).

Comparing global and regional applications of LEK reveals nuanced approaches shaped by specific environmental and socio-cultural contexts. Globally, LEK is often used to validate or complement scientific findings, providing a broader understanding of climate-change impacts across diverse ecosystems (Reyes-García et al., 2019). For example, in Canada, Inuit communities have contributed critical observations on sea-ice changes that have informed scientific research (Beaulieu et al., 2023). In Australia, Aboriginal fire-management practices have been integrated into landscape management to reduce wildfire risk (Betigeri, 2020). Regionally, particularly in Asia and the Philippines, LEK plays a more central role in adaptation strategies, informing community-based resource management and disaster preparedness (Paz-Alberto et al., 2022b). This is partly due to the strong reliance on natural resources and the deep cultural connections to the environment in these regions (Asian Development Bank, 2021).

Given these considerations, research in Masinloc, Zambales, is crucial because it allows for a detailed understanding of how local communities are experiencing and responding to climate change in a specific ecological and socio-economic context (Paz-Alberto et al., 2022b). By documenting and analysing LEK in this area, we can identify effective adaptation strategies, inform policy decisions, and contribute to a more holistic and equitable approach to climate-change resilience (IPBES, 2019; Reyes-García et al., 2019). This research will not only benefit the local communities in Masinloc but also provide valuable insights for similar coastal communities facing climate-change challenges in the Philippines and beyond (Paz-Alberto et al., 2022b). Because LEK is socially produced, its generation and uptake depend on who holds what knowledge—an issue best understood through demographic lenses.

Demographic factors also play a key role in shaping how people understand and use environmental knowledge, including LEK (Adger et al., 2009; Maddison, 2007; Mandleni & Anim, 2011; Ullah et al., 2018). These influences are important to consider when designing climate change adaptation strategies that truly address community needs (Adger et al., 2009; Maddison, 2007; Ullah et al., 2018). For example, age and education can influence what people know about climate change and how they apply that knowledge (Jin et al., 2015). In fishing communities, these differences may affect how individuals observe, interpret, and respond to changing environmental conditions (Hopping et al., 2016; Sultana & Luetz, 2022). By recognizing how demographic factors impact the use and transmission of local knowledge, climate change initiatives can better harness existing strengths within communities and improve the effectiveness of adaptation efforts.

Understanding how climate change affects fishing communities requires more than just scientific monitoring—it calls for attention to how fishers themselves observe and interpret the changes around them (Saytarkon et al., 2025). Building on the idea that local and demographic factors shape both knowledge and adaptation, this study examined the LEK of mangrove-dependent subsistence fishers in Masinloc, Zambales, Philippines. While the research centers on a single community, its approach provided a practical model for other small-scale fisheries facing similar climate challenges. By highlighting the link between LEK and demographic characteristics, the study could offer insights that can help guide adaptation efforts in other vulnerable coastal regions.

Building on these foundations, these questions were posed to guide this study: "How do the perceptions of mangrove fishers of LEK about climate change affect their daily lives and relate to the demographic factors? Are there scientific bases for the identified LEK by the mangrove fishers in relation to climate change effects? This study had five main objectives. First, the study aimed to document the perceptions of mangrove fishers of LEK about climate change and how these could affect their daily lives and operations/activities. Second, to identify and categorize the specific LEK indicators that the fishers used to track changes in weather and climate. Third, to examine the influence of demographic factors, such as age or education, on the use of these knowledge systems. Fourth, to measure the association of the demographic factors with LEK. Finally, to explore the scientific basis for the most trusted cues, explaining why fishers expect these signs to signal rain, typhoons, or floods.

To achieve these objectives, the data were gathered through structured surveys and open-ended interviews with fishers. The survey used binary (yes/no), Likert, ranked, and open-ended questions, making it accessible for people with different literacy levels. Quantitative data were analyzed using chi-square tests, post-hoc comparisons, and Cramer's V to look into the links between demographics and LEK use. Meanwhile, qualitative answers were reviewed using thematic analysis to capture the broader context and meaning behind the cues fishers described.

These methods allowed us to better understand how local ecological knowledge works in practice and how it varies across different groups within the community. By highlighting the connections between LEK and demographic factors, this study can offer practical guidance for designing climate adaptation strategies that are both effective and locally appropriate. Ultimately, these findings can inform wider policy and planning, helping ensure that adaptation measures truly reflect the experiences and needs of the people most directly affected by climate change.

2. Methodology

Description of the Study Area

Study Area Profile of Masinloc, Zambales—Geographic, Socio-Economic, Ecological, and Climatic Setting

Masinloc, a municipality in the province of Zambales, Philippines, lies at approximately 15˚32'N, 119˚57'E on Luzon Island (**Figure 1**). At an elevation of 11.6 m above mean sea level, the municipality covers a land area of ~320 km^2, constituting 9% of Zambales's total area (PhilAtlas, 2024). With its 13 barangays (i.e., smallest administrative divisions), Masinloc had a population of ~54,500 in the 2020 Census, representing 8.4% of Zambales's total and 0.44% of Central Luzon's, for a density of ~170 inhabitants·km^{-2} (PhilAtlas, 2024). The community includes Sambal, Ilocano, and Tagalog speakers who are heavily reliant on fishing and agriculture (Masinloc CLUP, 2016).

Beyond these primary sectors, residents pursue a diverse mix of supplementary and alternative livelihoods. Participatory Coastal Resource Assessment interviews list farming (rice and vegetables), salt-making, seasonal mango spraying, seaweed farming, carpentry, sari-sari retail, small-scale food processing, livestock rearing, and wage work at the 1 GW Masinloc coal-fired power plant operated by Masinloc Power Partners (a San Miguel Corporation subsidiary) as common income sources. Roughly half of coastal households rely principally on fishing, ~40% on farming, and the remainder on these ancillary activities, with daily earnings ranging from PHP 300 to PHP 600 in peak seasons (Masinloc CLUP, 2016).

Masinloc possesses rich and diverse mangrove forests that play an essential role in coastal protection and provide critical habitat for marine life (CHED Dare TO Project 1, 2019; Paz-Alberto et al., 2020a). In 2005, the mangrove-covered area was ~177 ha. These mangroves thrive predominantly in western Philippine provinces such as Pangasinan, Bataan, and Zambales, as well as Palawan, where water temperature, pH, salinity, and seasonal wind patterns create ideal conditions (CHED Dare TO Project 1, 2019). The western coast of Masinloc is generally more sheltered, rich in mudflats and estuaries, and less exposed to Pacific currents, with frequent riverine input that maintains the brackish water ideal for mangroves (Salmo et al., 2014).

There are ten major mangrove species across five families—Rhizophoraceae, Sonneratiaceae, Avicenniaceae, Palmae, and Combretaceae—of which *Rhizophora* spp. Dominate, particularly in Inhobol (CHED Dare TO Project 1, 2019; Paz-Alberto et al., 2020a). Inhobol has ~95% mangrove cover and 153 individuals of *Rhizophora mucronata* across 15 ha, including plantations on Matalvis Island, whereas Taltal shows ~75% cover with lower diversity. A Zambales-wide assessment reports a species dominance index (SDI) of 1.57 in Inhobol versus 0.569 in Taltal (CHED Dare TO Project 1, 2019). Despite this ecological richness, mangrove cover declined from 261 ha in 1998 to 177 ha in 2005, partly converted to fishponds and residential areas (Salmo et al., 2014). The loss weakens natural defenses against climate-induced hazards and fragments habitat, adversely affecting biodiversity and the local fishing industry (Paz-Alberto et al., 2021).

Masinloc, like the rest of Zambales, experiences a PAGASA Type I climate with a dry season from November to May and a wet season for the remainder of the year. Instrumental normals (1991-2020) refine this picture: 31-day mean rainfall rises from ~5 mm in January to ~515 mm in August; the wet period spans late March to late December, with ~80% daily rain probability during the July-September typhoon corridor. Mean daily temperatures range from 25˚C in January to 31˚C in May, and prevailing winds shift seasonally (PAGASA, 2023; Weatherspark, 2023). This pronounced monsoon regime heightens vulnerability to typhoons—most frequent from May to September and peaking in July-October—causing heavy rainfall, storm surges, and flooding that threaten fisheries, agriculture, and infrastructure. Low-lying areas suffer frequent inundation from creek overflow and runoff, and combined coastal-fluvial hazards yield a storm-surge vulnerability index of 0.58 (CHED Dare TO Project 1, 2019). Moreover, Paz-Alberto et al. (2021) found that sea level rise happened at Masinloc, Zambales, as well as this municipality is vulnerable to flooding and storm surge. Consequently, Masinloc's unique climate and geography demand robust resilience measures to adapt and mitigate disaster impacts.

3. Methods

This study used a pragmatic, mixed-methods approach to capture both the breadth and depth of local ecological knowledge (LEK) among subsistence fishers facing climate change. By integrating structured quantitative surveys with open-ended qualitative questions, we systematically examined patterns in LEK use, while also exploring the nuanced, context-specific ways that fishers interpret and apply this knowledge. Special attention was paid to inclusivity and data reliability, given the rural setting, literacy levels, and ongoing COVID-19 restrictions. The methodological choices outlined below were guided by the need to balance scientific rigor with accessibility and community engagement.

Study design, instrument, and participants

A cross-sectional survey of 335 mangrove subsistence fishers in four barangays (villages), namely Baloganon, Bamban, Taltal, and Inhobol of Masinloc, Zambales, focusing on local ecological knowledge (LEK) and climate change perceptions, was conducted (**Figure 1**). Convenience sampling was used in the study. Participants were selected based on the nearby distance of their residence to mangrove areas and reliance on fishing primarily for subsistence, excluding those engaged in commercial, recreational, or distribution roles.

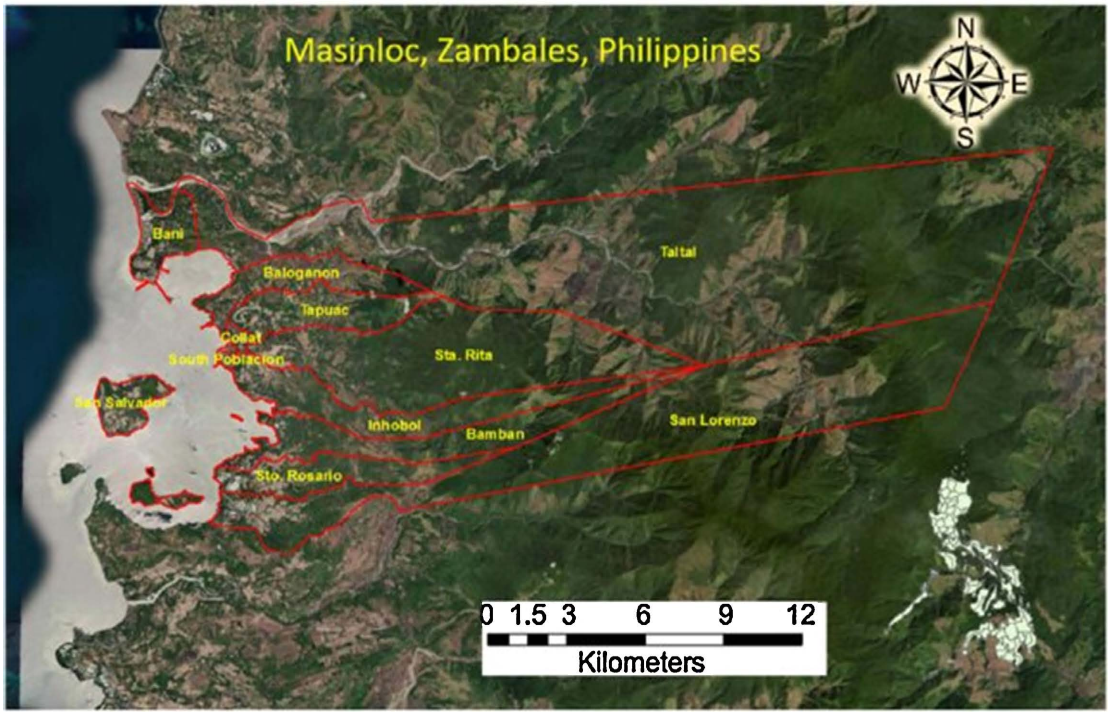

Figure 1. Map of Masinloc, Zambales showing the study areas (Balaganon, Bamban, Inhobol and Taltal) (Alberto et al., 2022).

To address rural literacy constraints, a structured questionnaire that could be administered orally by trained enumerators was designed. The instrument was based on established community survey frameworks (Aliyu et al., 2019; Hiwasaki et al., 2014; Ullah et al., 2018), which included four sections: demographic information, presence of LEK related to climate change, binary and ranked responses to 60 candidate LEK cues, and open-ended questions about how and when LEK cues are used.

Content validation was conducted by six experts, followed by pre-testing with 17 non-fisher volunteers and a pilot study with 35 fishers. This process ensured that the questionnaire was clear, accessible, and suitable for participants with varying literacy levels, resulting in simplified wording and binary or nominal responses.

The survey items were adapted from prior studies on climate change and local knowledge (Acharya et al., 2016; Reyes-García et al., 2016). Fieldwork took place from December 15, 2021 to January 14, 2022 in open barangay spaces under strict COVID-19 safety protocols, including mask-wearing, physical distancing, and full vaccination, as required by local regulations. Ethical clearance for the study was granted by the Central Luzon State University (No. 10347).

Data Collection

Data were collected using a mixed-methods approach, combining digital and in-person techniques to accommodate rural literacy and COVID-19 constraints. Enumerators used "Wix" and Google Form platforms to administer the survey, reading questions aloud and recording responses directly on tablets. Sessions were held twice daily (at 08:30 and 13:30) in open barangay gymnasiums to ensure ventilation and safety. Light snacks, water, and a brief quiz with small prizes were provided to maintain participant engagement and achieve a 100% response rate. Secondary demographic information was obtained from the Masinloc Comprehensive Land Use Plan (2016) and the Municipal Environmental and Natural Resources Office.

Data Analysis

All quantitative data were analyzed using R version 4.2.0 (R Core Team 2023), with the tidyverse and rcompanion packages. Descriptive statistics—including frequencies, means, and standard deviations—were first calculated for all survey items. Associations between binary LEK cues and socio-demographic variables (barangay, age group, education) were assessed using Pearson's chi-square test of independence (Bland et al., 2008; McHugh, 2013). For each significant association, post-hoc pairwise comparisons with Bonferroni adjustment were conducted to identify which specific groups differed (Kim, 2014; Weissgerber et al., 2018). The strength of these associations was quantified using Cramer's V (Cramer & Howitt, 2004). Statistical significance was set at $p < 0.05$ for all tests.

Qualitative data from open-ended survey responses were analyzed through inductive thematic analysis. Responses were coded to identify recurring themes and patterns describing how and why fishers use LEK in relation to climate change impacts. This qualitative analysis was used to provide context and depth to the quantitative findings, allowing for a more comprehensive understanding of the role and application of LEK among fishers. Qualitative themes derived from open-ended responses were summarized in the interpretation of key cues (see **Table 12**) and discussed throughout the results narrative.

4. Results

Fishers' Perceptions of Local Ecological Knowledge about Climate Change

Roughly three-quarters of respondents recognized the local ecological knowledge (LEK) in their community, while fewer than two percent denied its presence and about one-quarter were unsure (**Figure 2(a)**). Awareness of typhoon-related LEK was similarly high (≈75%), but recognition of flood-related LEK fell to just over half (≈56%), with denials and uncertainty each near 22% (**Figure 2(b)** & **Figure 2(c)**). For climate-change education, sea-based indicators were cited most often

(≈75%), whereas purely cultural practices were least mentioned (≈4%) (Figure 3(a)). The leading reservation about LEK effectiveness was site-specificity (≈56%), while the fewest respondents (≈24%) felt practices were confined to a single culture (Figure 3(b)). Timing data showed that the modal lead-time was less than one week (≈23% within 24 h, ≈23% within seven days), whereas only 13% of predicted events occurred one month after the climatic happenings (Figure 3(c)).

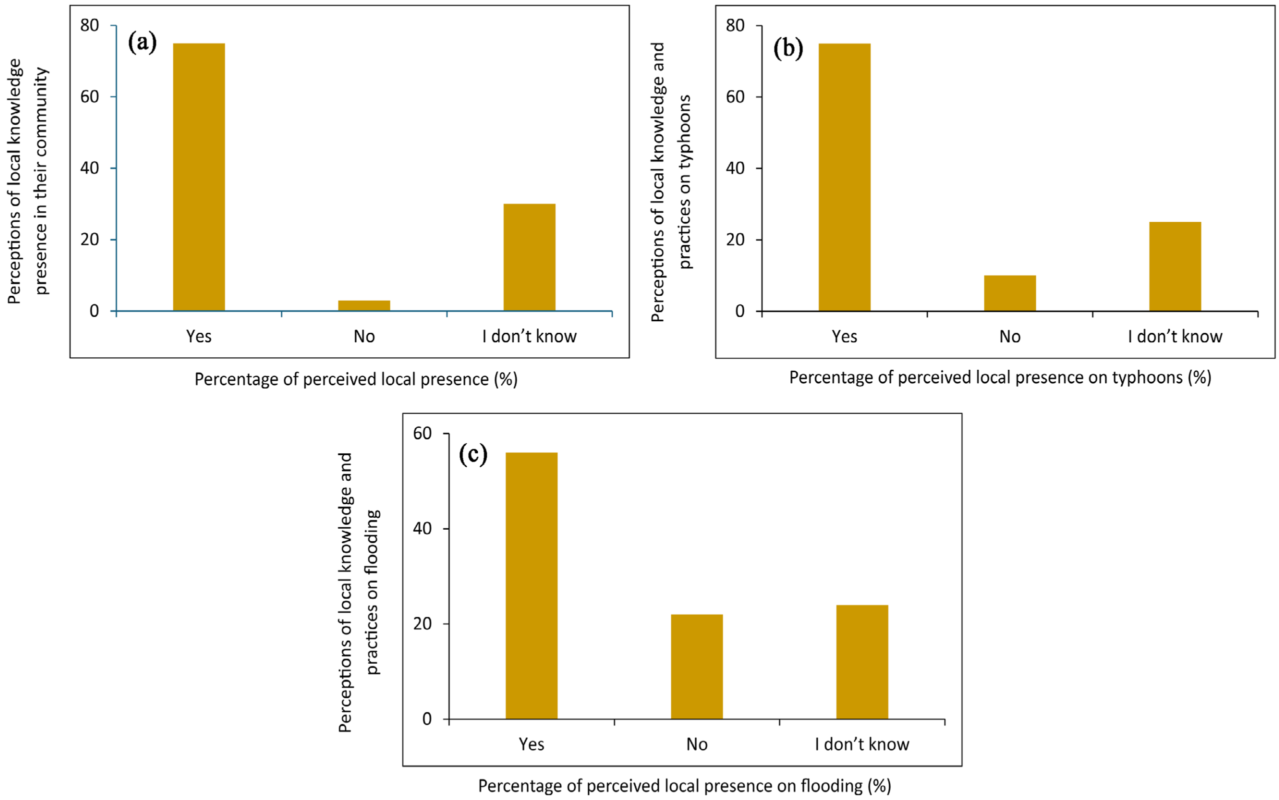

Figure 2. Recognition of local ecological knowledge (LEK) among Masinloc subsistence fishers (n = 335). (a) Overall awareness of LEK in their community; (b) Awareness of typhoon-related LEK; (c) Awareness of flood-related LEK. Bars give the percentage of respondents selecting “Yes”, “No”, or “I don't know”; totals equal 100% within each panel.

Demographic Factors Influence on Local Ecological Knowledge and Its Perceived Effectiveness

Chi-square tests assessed the influence of demographic characteristics on local climate knowledge and perceptions of its effectiveness.

Significant differences were observed for specific aspects about the association of local ecological knowledge and demographic factors among the Masinloc fishers (Table 1): 1) The use of animal or organism behaviors to understand climate events varied by barangay ($\chi^2 = 13.1217$, $p = 0.0044$); 2) the belief that local practices are geographically limited differed by barangay ($\chi^2 = 12.0312$, $p = 0.0073$); and 3) perceptions that local practices are culturally bound and limited in applicability varied by educational attainment ($\chi^2 = 21.2108$, $p = 0.0007$). No significant demographic differences emerged for items related to the usefulness of local knowledge or community practices on typhoons ($p > 0.05$).

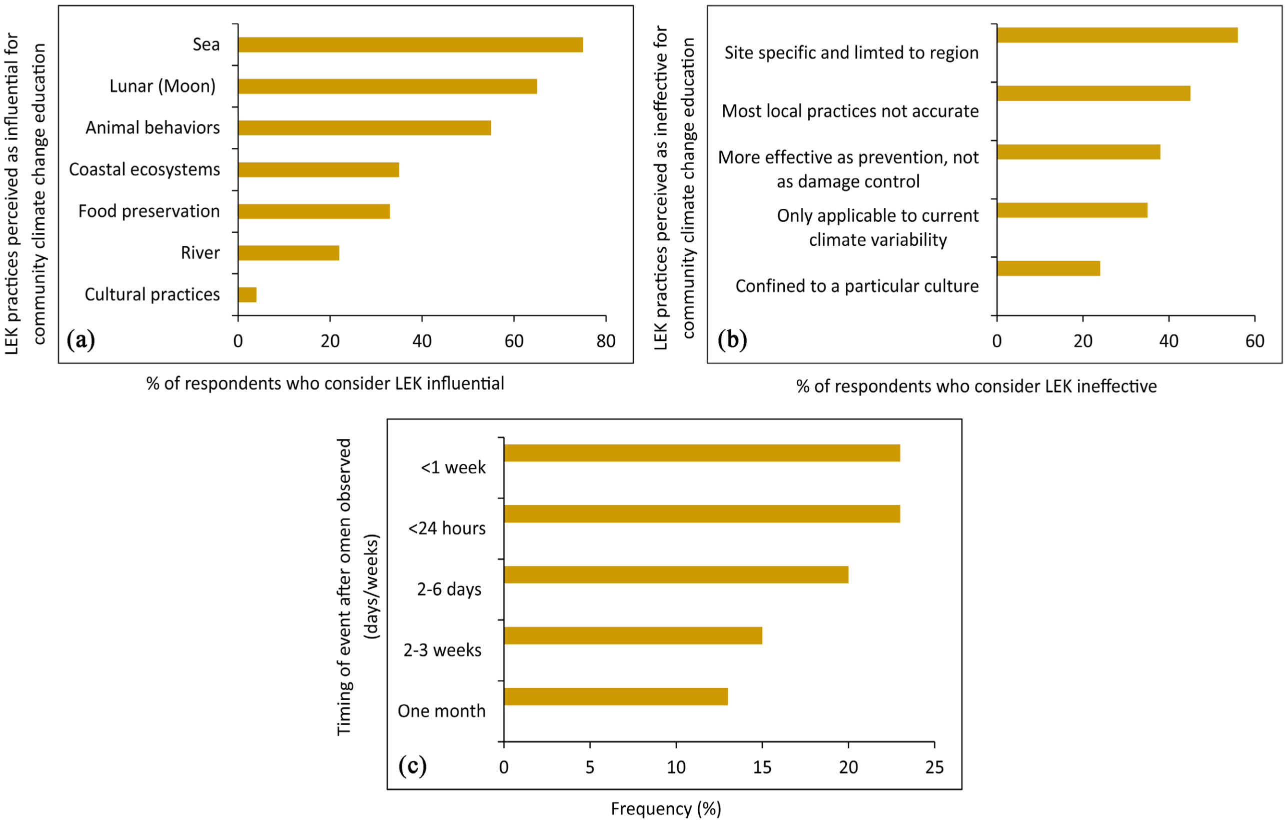

Figure 3. How fishers evaluate LEK for climate-change learning. (a) Practices judged influential for community climate education; (b) Main reasons some practices are viewed as ineffective; (c) Typical interval between observing a cue and the ensuing weather event. Bars represent percentage (a), (b) or frequency (c) of responses.

Table 1. Chi-square (χ^2) statistics and p-values for the association between various aspects of local ecological knowledge (LEK) and demographic factors among Masinloc fishers (n = 335).

Local Ecological Knowledge aspects	Demographic factors (*p-values*)					
	Barangay	Age Group	Civil Status	Gender	Educational Attainment	Monthly Income
Presence of Local Knowledge and Practices in the Community	7.9348 (0.2429)	3.4703 (0.9015)	7.5489 (0.6728)	4.6767 (0.5859)	4.1626 (0.9397)	1.4278 (1)
Usefulness of the Different Local Knowledge and Practices						
Acts as our first source of knowledge on weather predictions	12.0096 (0.0618)	10.4582 (0.2343)	2.6637 (0.9537)	8.9924 (0.174)	7.6623 (0.6618)	3.1821 (0.9941)
Acts as our early warning system against hazards	7.1758 (0.3049)	5.3528 (0.7193)	8.8742 (0.5441)	4.271 (0.6401)	10.3163 (0.2435)	9.8913 (0.6255)
Basis from which resources can be managed alternatively	12.7253 (0.0576)	5.3008 (0.725)	8.162 (0.613)	8.0354 (0.2355)	3.7635 (0.8778)	3.125 (0.9946)
Aids in protecting coastal ecosystem health	3.3211 (0.7676)	6.1707 (0.6281)	3.3587 (0.9099)	1.1679 (0.9784)	2.8081 (0.9856)	4.2168 (0.9792)

Continued

Aids in conserving our primary stocks	1.7266 (0.943)	3.0527 (0.931)	1.7369 (0.998)	1.4307 (0.964)	3.7548 (0.9577)	1.4576 (0.9991)
Helps in reducing conflicts within the community	4.2544 (0.6423)	3.7093 (0.8824)	3.7369 (0.9584)	0.1762 (0.9999)	0.5474 (0.9998)	1.6604 (0.9897)
Builds trust and cooperation within the community	7.4177 (0.2839)	2.2958 (0.9706)	1.2464 (0.9962)	5.0144 (0.542)	1.5343 (0.9921)	3.3573 (0.91)
Local communities knowledge and practices about typhoons	4.4954 (0.61)	1.7483 (0.9878)	7.8847 (0.6401)	3.1445 (0.7905)	2.6232 (0.989)	8.2729 (0.8746)
Local Communities knowledge and practices about flooding events	5.3416 (0.5008)	11.3732 (0.1814)	7.0277 (0.7228)	4.3663 (0.6272)	7.4186 (0.6854)	4.5883 (0.9908)
Local knowledge influence on the education and understanding of climate change, particularly typhoons and floods regarding environment and other aspects						
Lunar Observations (Moon)	2.1009 (0.5517)	5.4301 (0.2459)	4.3938 (0.4942)	1.5027 (0.6816)	2.1639 (0.826)	3.2257 (0.8634)
Observation of Animal/Organisms Behaviors	**13.1217 (0.0044)***	4.5332 (0.3386)	3.5846 (0.6106)	0.1475 (0.9856)	7.1011 (0.2132)	2.8318 (0.9001)
Observation of the coastal ecosystems	0.604 (0.8955)	7.6103 (0.1069)	4.1841 (0.5232)	1.3466 (0.7181)	3.723 (0.59)	10.4163 (0.1662)
Observation of the sea	1.1507 (0.7649)	8.614 (0.0715)	8.0336 (0.1544)	6.3081 (0.0975)	3.9537 (0.5561)	2.7596 (0.9063)
Observation of the rivers	7.1278 (0.0679)	4.6631 (0.3236)	3.3893 (0.6402)	3.5647 (0.3125)	13.5199 (0.1900)	3.1562 (0.8702)
Food Preservation Mechanisms	5.0519 (0.168)	2.6344 (0.6207)	1.5203 (0.9107)	1.4082 (0.7036)	2.5612 (0.7673)	8.8493 (0.2637)
Important Cultural Practices	5.2014 (0.1576)	0.0799 (0.9992)	1.5414 (0.9082)	2.6621 (0.4467)	0.2252 (0.9988)	0.0641 (1)
Reasons for believing their local climate knowledge and practices are ineffective						
Local practices are site specific and limited to a specific geographical region.	**12.0312 (0.0073)***	4.0154 (0.4039)	2.6097 (0.7599)	1.9344 (0.5861)	5.2813 (0.3825)	2.427 (0.9325)
Local practices are confined in a particular culture, and are applicable to that area only.	0.5421 (0.9096)	3.9507 (0.4127)	3.6974 (0.5937)	1.6567 (0.6466)	**21.2108 (0.0007)***	4.213 (0.7549)
Most local practices are not accurate in anticipating typhoons.	3.0769 (0.3799)	3.8953 (0.4204)	4.3618 (0.4986)	2.7878 (0.4255)	2.7604 (0.7369)	4.2576 (0.7497)
Local practices are only applicable to current climate variability and not in addressing the future impacts.	1.3806 (0.7101)	2.3989 (0.6628)	0.7899 (0.9777)	3.0787 (0.3796)	5.2781 (0.3829)	2.9454 (0.89)

Continued

Local practice are more effective as preventive measures, rather than as tools to repair extreme damages.	2.6932 (0.4414)	7.0257 (0.1345)	2.1799 (0.8237)	5.7002 (0.1271)	0.367 (0.9962)	4.5677 (0.7126)

Note: Cells show the χ^2 statistic, with *p*-values in parentheses. Bold values indicate statistically significant associations at the 5% significance level ($p < 0.05$), suggesting that the relevant demographic category has a significant effect on the corresponding aspect of local ecological knowledge or perception. All other results are not statistically significant and are shown for completeness. "—" indicates that a variable was not tested or is not applicable for that particular combination. The table provides a comprehensive overview to support transparency and facilitate further interpretation of demographic influences on LEK.

Barangay-Level Contrasts in Perceived Usefulness and Site-Specificity of Local Ecological Knowledge

Following the significant differences found in the chi-square analysis (Table 1), a post hoc analysis was conducted to further examine pairwise differences among barangays. A post hoc test was performed to pinpoint exactly which barangays differ significantly from each other. This step was necessary because the initial chi-square test (Table 1) only indicated general differences, not specific pairwise contrasts. Thus, Table 2 presents the results of this pairwise comparison among the four barangays (Baloganon, Bamban, Taltal, and Inhobol) specifically regarding their perceptions on 1) the usefulness of observing animal/organism behaviors and 2) the perception that local knowledge is ineffective due to site-specific limitations.

The analysis revealed significant contrasts in perceptions of animal/organism behavior observations between Baloganon and Bamban ($p = 0.0017$) and between Bamban and Taltal ($p = 0.0015$). Similarly, significant differences were found regarding the perception that local practices are ineffective due to being site-specific, notably between Baloganon and Bamban ($p = 0.0217$) and Bamban and Taltal ($p = 0.0122$). These specific pairwise differences showed that respondents from Bamban differed significantly from those in Baloganon and Taltal in their views on local knowledge's usefulness and geographic applicability (Table 2).

Table 2. Pairwise contrasts among barangays in terms of the perceived usefulness of local ecological knowledge (LEK) and the reasons for viewing such knowledge as ineffective.

Local Ecological Knowledge aspects for barangay differences	CONTRASTS (*p-value*)					
	Baloganon vs Bamban	Baloganon vs Inhobol	Baloganon vs Taltal	Bamban vs Inhobol	Bamban vs Taltal	Inhobol vs Taltal
Observation of animal/organisms behaviors	**0.0017***	0.1083	0.0524	0.1189	**0.0015***	0.4988
Local practices are site specific and limited to a specific geographical region	**0.0217***	0.0997	0.2134	0.5008	**0.0122***	0.1513

Note: *p*-values are shown for each barangay comparison for two significant key items. Bold values with an asterisk (*) indicate statistically significant differences at the 5% level (*p*-value < 0.05). Only the barangay pairs with significant differences are highlighted, suggesting these locations differ meaningfully in their perceptions of local knowledge's usefulness and applicability. Non-significant contrasts are presented for completeness.

Perceived Cultural Specificity of Local Ecological Knowledge across Educational Levels

The chi-square test (χ^2) confirmed that opinions about whether local ecological knowledge (LEK) is "confined to a particular culture and applicable only locally" varied by educational attainment ($\chi^2 = 21.21$, $p < 0.001$). Post-hoc pair-wise contrasts (Table 3) showed that the difference was driven entirely by the college-educated group: their views diverged significantly from both elementary graduates ($p = 0.0054$) and secondary-school graduates ($p = 0.0005$). No other educational pairing differed at the 5% level. College-educated respondents were less likely to view LEK as culture-bound, while those with only primary or secondary schooling were more likely to regard such knowledge as exclusive to their own community.

Table 3. Pairwise contrasts among educational attainment groups in relation to the perception that local ecological knowledge (LEK) is "confined to a particular culture and applicable only locally."

Local Ecological Knowledge aspects for education differences	**CONTRASTS (*p-value*)** *Local practices are confined in a particular culture, and are applicable to that area only.*
Elem. Graduate vs College	**0.0054***
Elem. Graduate vs Vocational	0.6702
Elem. Graduate vs Secondary School	0.3486
Elem. Graduate vs Masters	0.9826
Elem. Graduate vs Prefer not to say	0.9883
College vs Vocational	0.1405
College vs Secondary School	**0.0005***
College vs Masters	0.9808
College vs Prefer not to say	0.9776
Vocational vs Secondary School	0.3328
Vocational vs Masters	0.9822
Vocational vs Prefer not to say	0.9861
Secondary School vs Masters	0.9831
Secondary School vs Prefer not to say	0.9912
Masters vs Prefer not to say	0.9814

Note: *p*-values are shown for all possible educational group comparisons. Bold values with an asterisk (*) indicate statistically significant differences at the 5% level (p-value < 0.05). Only educational group pairings with significant differences are highlighted, suggesting that college-educated respondents view the cultural specificity of LEK differently compared to other groups. All other contrasts are presented for reference.

Strength of Demographic Associations with LEK Perceptions

Cramer's V confirmed that all earlier significant χ^2 findings involved at least a "strong" relationship ($V \geq 0.16$). Barangay where the fishers reside showed strong associations with reliance on animal/organism behaviour ($V = 0.2159$) and the perception that practices are site-specific ($V = 0.1732$). The single "very-strong" association ($V = 0.2838$) appeared between educational attainment and the view that local practices are confined to one culture and applicable to that area only (Table 4).

Table 4. Cramer's V values for the strength of significant associations between socio-demographic factors and key aspects of local ecological knowledge (LEK) and practices.

Local Ecological Knowledge aspects	Barangay	Educational Attainment
Observation of animal/organisms' behaviors	0.2159	—
Local practices are site specific and limited to a specific geographical region.	0.1732	—
Local practices are confined in a particular culture, and are applicable to that area only.	—	**0.2838**

Note: Cramer's V interpretation: 0 - 0.05 = no or very weak; 0.06 - 0.10 = weak; 0.11 - 0.15 = moderate; 0.16 - 0.25 = strong; >0.25 = very strong. Bold values denote "very strong" associations. Dashes (—) indicate no significant association was found for that factor. Only associations reaching statistical significance in the prior chi-square analyses are presented (Tables 1-3. Among the significant results, the highest V values represent the strongest observed associations.

The chi-square tests (Tables 1-4) showed that barangay where the fishers reside, age group and educational attainment are the only demographics that shape how respondents judge the overall usefulness and scope of LEK. Therefore, the data were re-examined at the level of each individual warning cue to see which specific LEK cue vary by those same three factors; the five cues that cleared this stricter χ^2 screen are listed in Table 5.

Table 5. Chi-square test results for traditional warning cues used in predicting typhoons and coastal floods, by demographic factor (barangay, age group, education, civil status, gender, monthly income) among 335 Masinloc fishers.

Local knowledge and practices that could aid in prediction of typhoons and coastal floods		Demographic Factors					
		Barangay	Age Group	Civil Status	Gender	Educational Attainment	Monthly Income
Color of the sky and clouds	Typhoon	2.4185 (0.4902)	2.2832 (0.6838)	3.2687 (0.6586)	1.4421 (0.6957)	1.6929 (0.8898)	5.2573 (0.6286)
	Coastal Flooding	6.7086 (0.0818)	3.0638 (0.5472)	4.8133 (0.4391)	0.4385 (0.9322)	1.9074 (0.8618)	3.143 (0.8715)

Continued

Movement of winds	Typhoon	0.9992 (0.8015)	3.6253 (0.4591)	0.6516 (0.9855)	1.1587 (0.7629)	1.0621 (0.9574)	5.5274 (0.5959)
	Coastal Flooding	**10.2705 (0.0164)***	1.1666 (0.8836)	3.8613 (0.5696)	0.2492 (0.9693)	6.3009 (0.278)	1.7358 (0.973)
Smell of the sea	Typhoon	2.2939 (0.5137)	2.2649 (0.6872)	5.606 (0.3465)	3.8886 (0.2737)	3.8702 (0.5682)	4.6053 (0.708)
	Coastal Flooding	5.0809 (0.166)	1.4899 (0.8284)	3.7925 (0.5797)	4.6793 (0.1968)	8.3749 (0.1368)	3.6075 (0.8237)
Branches of trees	Typhoon	2.7187 (0.4371)	3.8782 (0.4227)	7.0023 (0.2205)	4.4276 (0.2188)	1.0656 (0.9571)	0.8948 (0.9964)
	Coastal Flooding	2.5345 (0.4691)	**14.1019 (0.007)***	9.416 (0.0936)	3.257 (0.3537)	**11.2474 (0.0467)***	3.2442 (0.8615)
Behavior and movement of the waves	Typhoon	1.1049 (0.7759)	**9.992 (0.0406)***	4.5454 (0.4738)	1.412 (0.7027)	1.8697 (0.8669)	1.1713 (0.9916)
	Coastal Flooding	5.1476 (0.1613)	**14.2611 (0.0065)***	2.3933 (0.7925)	1.7572 (0.6243)	2.9972 (0.7004)	2.779 (0.9047)
Appearance of sea grasses	Typhoon	0.5168 (0.9152)	4.609 (0.3298)	2.0823 (0.8376)	2.4383 (0.4865)	4.1541 (0.5275)	2.8199 (0.9011)
	Coastal Flooding	4.0957 (0.2513)	3.2791 (0.5122)	2.5195 (0.7736)	2.3158 (0.5095)	1.9831 (0.8515)	2.1528 (0.9509)
River sound	Typhoon	3.2546 (0.354)	6.634 (0.1565)	7.2371 (0.2036)	1.6446 (0.6493)	9.8691 (0.079)	2.173 (0.9496)
	Coastal Flooding	4.8384 (0.184)	0.5817 (0.9651)	2.567 (0.7664)	0.371 (0.9462)	6.6909 (0.2447)	2.0957 (0.9544)
Fish and other organisms' behavior	Typhoon	6.8467 (0.0769)	3.3925 (0.4944)	7.7089 (0.3033)	3.7254 (0.2927)	6.0067 (0.3056)	2.492 (0.9277)
	Coastal Flooding	3.7949 (0.2845)	5.3317 (0.2549)	6.2175 (0.2856)	1.1242 (0.7712)	5.2282 (0.3887)	2.0965 (0.9543)
Solunar Cycle and Illumination (Sun and Moon)	Typhoon	0.9164 (0.8215)	8.4665 (0.0759)	0.6981 (0.9831)	2.3474 (0.5035)	3.2996 (0.6539)	7.0251 (0.4263)
	Coastal Flooding	1.9936 (0.5737)	1.4409 (0.8371)	2.6521 (0.7534)	3.5964 (0.3085)	6.0027 (0.306)	3.8083 (0.8016)
Movement of leaves	Typhoon	2.5133 (0.4729)	7.327 (0.1196)	5.2274 (0.3888)	1.4188 (0.7011)	0.8843 (0.9713)	6.2231 (0.514)
	Coastal Flooding	6.4744 (0.0907)	1.1685 (0.8832)	4.1588 (0.5268)	2.7643 (0.4294)	4.9029 (0.4278)	4.0093 (0.7787)
Tide movement	Typhoon	1.1716 (0.7598)	6.121 (0.1903)	1.24 (0.941)	3.3282 (0.3437)	1.5798 (0.9037)	0.2867 (0.9999)
	Coastal Flooding	**8.0133 (0.0457)***	6.4307 (0.1692)	1.3061 (0.9343)	5.694 (0.1275)	3.2974 (0.6542)	2.335 (0.939)

Continued

Presence of fog	Typhoon	3.2044 (0.3612)	1.4994 (0.8268)	7.916 (0.1609)	0.3417 (0.952)	4.8926 (0.4291)	2.2603 (0.944)
	Coastal Flooding	**8.9374 (0.0301)***	1.459 (0.8339)	1.9096 (0.8615)	3.9662 (0.2651)	4.7702 (0.4446)	2.8939 (0.8946)
Others	Typhoon	0.0285 (0.9987)	0.0802 (0.9992)	0.0008 (1)	0.0015 (1)	0.0634 (0.9999)	0.0654 (1)
	Coastal Flooding	0.0954 (0.9924)	0.3675 (0.9851)	0.1517 (0.9995)	0.0431 (0.9977)	0.427 (0.9946)	1.6505 (0.9766)
Prediction on typhoon and coastal flood occurrence from local knowledge		10.6367 (0.1003)	15.1031 (0.0572)	7.6729 (0.6608)	3.0553 (0.8019)	12.5331 (0.251)	6.0109 (0.9662)
Time periods that depict the occurrence of the predicted events once local typhoon knowledge and practices have been observed		12.693 (0.3004)	13.7488 (0.145)	14.8166 (0.7868)	2.9871 (0.9956)	11.8114 (0.9224)	21.9788 (0.7823)

NOTE: p-values are given in parentheses below the chi-square statistic for each indicator-demographic pairing. Bolded p-values with an asterisk indicate statistically significant differences at the 5% level ($p < 0.05$). Only cues and demographic factors with significant differences are highlighted in the results narrative; all tested indicators are shown for completeness.*Significant at the 5% level (two-tailed).

Demographic Contrasts in Individual Typhoon- and Flood-Warning Cues

Among the thirteen traditional indicators tested, only five showed statistically significant variation across demographic groups (**Table 5**). Movement of winds, tide movements and the presence of fog as coastal flood sign differed by barangay, while branch movement and wave behaviour differed by age group, with branch movement also varying by educational attainment. No significant differences were detected for civil status, gender, or monthly income.

Barangay-Level Contrasts in Flood-Warning Cues

Pairwise comparisons of barangays for each flood-related warning cue (movement of winds, tide movements, and presence of fog) that reached statistical significance in the chi-square test in **Table 5** was done to compare the four barangays for LEK flood related warning signs. Pairwise post hoc comparisons among the four barangays revealed significant differences for several flood-related LEK indicators (**Table 6**). For the movement of winds, Baloganon differed significantly from Inhobol ($p = 0.0073$) and Taltal ($p = 0.0149$). Regarding the presence of fog, significant differences were found between Baloganon and Bamban ($p = 0.0031$), Baloganon and Taltal ($p = 0.0150$), and Bamban and Taltal ($p = 0.0171$). For tide movements, only Inhobol and Taltal differed significantly ($p = 0.0085$). No other barangay pairings reached statistical significance for these cues.

Table 6. Pair-wise barangay contrasts for LEK flood-related warning cues.

Local Ecological Knowledge aspects	CONTRASTS (*p-value*)					
	Baloganon vs Bamban	Baloganon vs Inhobol	Baloganon vs Taltal	Bamban vs Inhobol	Bamban vs Taltal	Inhobol vs Taltal
Movement of winds (coastal flooding)	0.3808	**0.0073***	**0.0149***	0.0652	0.2949	0.0501
Tide movements (coastal flooding)	0.9888	0.0887	0.8901	0.0903	0.9066	**0.0085***
Presence of fogs (coastal flooding)	**0.0031***	0.0929	**0.0150***	0.2009	**0.0171***	0.7412

Note: *p*-values are provided for each barangay pair. Only barangay pairs with statistically significant differences are emphasized in the results text. Bold values with an asterisk (*) indicate statistically significant differences at the 5% level ($p < 0.05$) between barangay pairs for each specific warning cue. "—" indicates a non-significant or untested contrast. All pairwise comparisons are shown for completeness. No multiple testing adjustment was required as each indicator involved only six pairwise comparisons.

Age-Group Contrasts in Typhoon- and Flood-Warning Cues

Because Table 5 indicated that branch movement and wave behaviour differed by age, the five age classes were compared pair-wise (Table 7). The 35 - 44 year cohort (code 3) emerged as the pivot: it relied on branch-drop signals for coastal-flood timing far more than both the youngest (18 - 24 y) and the 45 - 54 y groups, and invoked wave behaviour for typhoon prediction more than 18 - 24 y respondents (all Bonferroni-adjusted $p < 0.05$). For coastal-flood waves, the same mid-career fishers differed from every younger class (codes 1 - 2) but not from older cohorts, confirming that practical experience rather than sheer seniority shapes cue selection. No other age pairing reached the 5% threshold, underscoring that age affects only this narrow subset of highly kinetic indicators.

Table 7. Pairwise comparisons of age groups for warning cues that showed significant overall age-group differences in the chi-square test in Table 5: branch movement (coastal flooding) and wave behavior (typhoon and coastal flooding).

Local Ecological Knowledge aspects	CONTRASTS (*p-value*)									
	1 vs 2	1 vs 3	1 vs 4	1 vs 5	2 vs 3	2 vs 4	2 vs 5	3 vs 4	3 vs 5	4 vs 5
Branches of trees (Coastal flooding)	0.1765	**0.0304***	0.695	0.2851	0.1566	0.1201	0.1747	**0.0054***	**0.0012***	0.3678
Behavior and movement of the waves (Typhoon)	0.0579	0.1655	**0.0294***	0.9793	0.47	0.6391	0.09736	0.2563	0.9734	0.9805
Behavior and movement of the waves (Coastal flooding)	**0..0014***	**0.0010***	**0.0020***	0.9788	0.7699	0.7309	0.9819	0.9527	0.9755	0.9818

Note: *p*-values (Bonferroni-adjusted, two-tailed) are presented for each age-group pairing. Age group codes: 1 = 18 - 24 years; 2 = 25 - 34 years; 3 = 35 - 44 years; 4 = 45 - 54 years; 5 = 55+ years. Only significant differences ($p < 0.05$) are marked with an asterisk (*). Asterisk (*) indicates a statistically significant difference at the 5% level (Bonferroni-adjusted). Only pairwise comparisons with $p < 0.05$ are highlighted; blank cells indicate non-significant differences. The table shows which age groups differ in their use of specific LEK warning cues.

Educational Contrasts in the "Branch-Movement" Flood Indicator

Building on the chi-square χ^2 test in Table 5, which showed that educational attainment affects reliance on the branch-movement cue for coastal-flood prediction. Pair-wise post-hoc tests (Table 8) show that the divergence centered on the college-educated group. College graduates relied on branch fall or swaying significantly less than respondents with vocational training ($p = 0.0037$) and, to a lesser extent, those with secondary schooling ($p = 0.1139$, n.s.). Conversely, vocational respondents differ from secondary-school fishers ($p = 0.0299$), suggesting that practical, skills-based training sustains trust in this arboreal omen, whereas university exposure may steer fishers toward instrument-based forecasts. No other educational pairing reached the Bonferroni-adjusted 0.05 threshold, reinforcing the conclusion that branch cues are the sole warning sign shaped by schooling and that the split lies chiefly between hands-on vocational and academically oriented cohorts identified earlier in Table 5.

Table 8. Pairwise comparisons of educational attainment groups for reliance on the "branch-movement" cue as a predictor of coastal flooding.

Educational Pairing	CONTRASTS (*p-value*) Branches of trees (Coastal flooding)
Elementary vs College	0.0652
Elementary vs Vocational	0.0502
Elementary vs Secondary School	0.6633
Elementary vs Masters	0.9866
Elementary vs Prefer not to say	0.9853
College vs Vocational	**0.0037***
College vs Secondary School	0.1139
College vs Masters	0.9875
College vs Prefer not to say	0.9905
Vocational vs Secondary School	**0.0299***
Vocational vs Masters	0.9854
Vocational vs Prefer not to say	0.9142
Secondary School vs Masters	0.9779
Secondary School vs Prefer not to say	0.9861
Masters vs Prefer not to say	0.9869

Note: p-values are shown for all possible educational group contrasts. Bold values with an asterisk (*) indicate statistically significant differences at the 5% level (Bonferroni-adjusted p-value < 0.05). All educational pairings are displayed for transparency. Educational group labels are as follows: "Elementary" (elementary graduate), "Secondary School" (high school graduate), "Vocational" (vocational/technical graduate), "College" (college graduate), "Masters" (postgraduate), "Prefer not to say" (did not disclose educational attainment).

Effect-Size Strength of the Demographic Contrasts

The final step converts each significant χ^2 result from **Tables 6-8** into Cramer's V to gauge practical importance (**Table 9**). All barangays or age-related associations fall in the "strong" band (V ≈ 0.18 - 0.21), confirming that location chiefly was associated with wind, tide and fog cues, while age was related to the branch- and wave-based signs; the lone education effect (V = 0.186 for branch movement) had a strong association. Only the barangay influence on tide movement registered with "moderate" association (V = 0.124), and with no association with other demographic factors. Thus, demographic impacts on specific warning indicators are consistent but limited in magnitude, reinforcing earlier findings that most cues are widely shared across the fisher population.

Selective Sensory Cues That Directly Shape Climate-Impact Perceptions

Having identified which warning cues vary by demography (**Tables 1-9**), assessment whether any of those cues actually drive fishers' perceptions of climate impacts was performed (**Table 10**). Only two local ecological knowledge (LEK) indicators showed a statistically meaningful link with specific climate-change impacts. A thunder-like roar (*balkak*) at the river mouth, long regarded locally as the sound of on-rushing floodwater, was strongly associated with the belief that sudden rainfall is imminent (Cramer's V = 0.1734). Likewise, a pungent "fishy" sea odour—interpreted as fish becoming confused by heavy surf—was strongly linked to the perception that stronger typhoons are now more frequent (V = 0.1644). No other cue-impact pairing reached the "strong" threshold (V ≥ 0.16), confirming that only a very small subset of traditional observations actively shapes climate-impact perceptions.

Table 9. Cramer's V effect-size values for demographic factors (barangay, age group, education) that showed a significant chi-square association ($p < 0.05$) with individual typhoon- and flood-warning cues among Masinloc fishers.

Warning cue (hazard context)	Barangay	Age group	Education
Movement of wind (coastal flood)	0.187	—	—
Branches of trees (coastal flood)	—	0.200	0.186
Wave behaviour (typhoon)	—	**0.210**	—
Wave behaviour (coastal flood)	—	**0.202**	—
Tide movement (coastal flood)	0.124	—	—
Presence of fog (coastal flood)	**0.201**	—	—

*Effect sizes (V) are interpreted as follows: 0 - 0.05 = very weak, 0.06 - 0.10 = weak, 0.11 - 0.15 = moderate, 0.16 - 0.25 = strong, >0.25 = very strong associations. Dashes (—) indicate that no significant association was found for that pair. All values reported here are at least in the "strong" range (V ≥ 0.16). The highest V values in the table denote the strongest associations observed among the significant results. Only cue-demographic combinations with significant associations in previous analyses are included.

Table 10. Cramer's V effect sizes for the only two local ecological knowledge (LEK) indicators that correlate significantly ($p < 0.05$) with specific climate-impact perceptions among 335 Masinloc fishers.

Climate impacts	Local Knowledge and Practices	
	Fishy smell of the sea as the fishes don't know where to go due to the strong waves *—Local knowledge (LK) on oceans and the sea*	*A roar (Balkak) sound is coming from the river's mouth* *—Local knowledge (LK) on rivers*
Sudden rainfall and onset of rain	—	0.1734
Stronger typhoons are becoming more frequent	0.1644	—

Note: Cramer's V interpretation: 0 - 0.05 = no or very weak association; 0.06 - 0.10 = weak; 0.11 - 0.15 = moderate; 0.16 - 0.25 = strong; >0.25 = very strong. Only significant associations reaching the "strong" threshold (V ≥ 0.16) are shown. All values are based on results that achieved statistical significance in chi-square analyses. Empty cells indicate non-significant associations for that pairing. No "very strong" associations (>0.25) were observed in this analysis; the table highlights only those that are at least "strong."

Sensory Local Ecological Knowledge and Perceived Climate-Driven Disruptions to Fishing Operations

The earlier discussion (Table 10) dealt with LEK cues that help fishers *anticipate climate hazards* (rain burst, stronger typhoons). The present section focuses on *livelihood consequences*—how those cues trigger decisions about boats, gear, and fishing effort. Overlap is minimal: wind, odour, and river sound are mentioned in both contexts, but here they are linked to operational responses rather than hazard recognition, so the narrative adds distinct value without duplicating the previous analysis.

Table 11 summarizes the associations between specific sensory LEK cues and fishers' perceptions of climate change impacts on fishing operations, as measured by Cramer's V. Among the 30 cues examined, 18 showed statistically significant associations ($p < 0.05$) with at least one aspect of fishing, including changes in catch, vessel or gear replacement, repair, or modifications, and fishing trip frequency, timing, or area.

Abnormal winds exhibited a very strong association with boat replacement after typhoons (V = 0.353), while sudden leaf-fall demonstrated a very strong association with gear modification (V = 0.330). Fishy sea odor was strongly associated with lower typhoon catches (V = 0.289) and urgent gear replacement (V = 0.262). The a roar (*balkak*) sound from the river was strongly linked to flood-time changes in species richness (V = 0.266) and rainfall-related catch decline (V = 0.191). Tall/foaming waves were associated with emergency boat repairs (V = 0.280) and changes in fishing areas and times (V ≈ 0.26). Other strong associations were observed for lunar illumination, leaf-fall, and cloudy water cues across various fishing domains. Most reported Cramer's V values were in the strong range (0.16 - 0.25), with the strongest associations highlighted in the table.

Table 11. Cramer's V effect sizes showing statistically significant associations ($p < 0.05$) between local ecological knowledge (LEK) sensory cues and fishers' perceptions of climate-driven impacts on fishing operations.

	Local Ecological Knowledge Cues					
Affected Fishing Aspects	Fishy sea odor	Tall/foaming waves	River roar (*balkak*) sound	Lunar illumination	Sudden leaf-fall (no wind)	Abnormal winds/cloudy water
			Organisms and Stocks			
Distribution of species on flooding	0.1620	—	0.1607	—	—	—
Number of catch on typhoons	—	—	0.1910	—	**0.2507**	**0.2889**
Number of catch on Rainfall	—	—	0.1613	—	—	—
Species richness on typhoons	—	—		—	—	0.1913
Species richness on flooding	—	—	0.1541	**0.2660**	—	—
Presence of invasive species on typhoons	—	—			0.2287	—
			Boats and Vessels			
Vessels and Boat repairs on Typhoons	0.1666	0.1377	0.1598		—	**0.2796**
Vessel and boat repair on rainfall	—	—	—	**0.2766**	—	—
Vessel and boat replacement on flooding	—	—	—	—	0.2233	—
Vessel and boat replacement on typhoon	—	—	—	—	—-	**0.3529**
			Fishing Gear			
Gear repair on typhoon	—	—		—	—	0.2264
Gear replacement on typhoon	—	—	0.1419	—	—	**0.2616**
Gear modifications on typhoon	—	—	—	—	—	**0.3304**

Continued

			Fishing trips			
Time for fishing on typhoons	—	—	—	—	0.2238	**0.2691**
Time for fishing on rainfall	—	—	—	—		—
Time for fishing on floods	—	—	—	—		—
Fishing areas on typhoons	—	—	—	—	0.2482	**0.2587**
Fishing areas on rainfall	—	—	—	—	—	—
Fishing areas on flooding	—	—	0.1818	—	—	—
Frequency of fishing trips on typhoons	—	—	0.1804	—	—	**0.2616**
Frequency of fishing trips on rainfall	—	—	—	—	0.2029	—
Frequency of fishing trips on flooding	—	—	—	—	—-	—

Note: Rows indicate LEK cues, while columns represent affected fishing aspects—organisms/stocks, boats/vessels, gear, and fishing trips. Values denote the strength of association (Cramer's V) for each cue-impact pair. Only statistically significant relationships are shown; cells with "—" indicate non-significant associations. 0 - 0.05 = no or very weak, 0.06 - 0.10 = weak, 0.11 - 0.15 = moderate, 0.16 - 0.25 = strong, >0.25 = very strong.

Having shown that just a handful of vivid cues govern day-to-day safety and income, the next logical step is to ask *why these cues, and not the dozens of others once recorded, have survived*: Table 12 addresses that question by tracing each signal to a concrete atmospheric, oceanographic or ecological mechanism.

Physicochemical Foundations of High-Trust LEK Cues

Most statistical contrasts in Tables 1-11 showed either no demographic effect or only "strong" (not "very-strong") associations, underscoring how selective the Masinloc collection already is. Table 12 documents the outcome of that selectivity: just fourteen cues, shared across all four barangays, meet the combined criteria of statistical significance and unanimous key-informant endorsement. Sky-optic signs dominate—darkening nimbostratus and the "black" 22˚ lunar halo—followed by sea-state indicators such as a pungent ozone-like odour, fast-rising foaming swell and increasingly turbid waves. One hydrological cue, the thunder-like roar (*balkak*) from the river mouth, is universally linked to flash-flood onset, while only three biological omens—restless fish, inshore fish (*taburdik*) schools and wind-free leaf-fall—make the final list. Respondents agreed that these fourteen cues give practical warning windows ranging from a few hours (river roar, leaf-drop) to two or three days (halo, swell, ozone smell). No additional indicators reached group-consensus, confirming the repertoire's tight focus.

Table 12. Physicochemical rationale for the 14 "high-trust" local ecological knowledge cues retained by Masinloc fishers. Each cue that remained statistically significant through Tables 1-11 is paired with (a) its locally understood meaning and (b) the atmospheric, oceanographic, or ecological mechanism that makes the cue reliable. Superscript numbers point to primary technical references.

Local cue	Local meaning	Scientific note
Dark/black cloud base	↑ rain/typhoon	A thickening nimbostratus holds larger droplets that absorb more light, darkening the cloud base and heralding heavy rain or a typhoon (Houze, 2010).
Whistling wind	Impending typhoon	High-speed flow around obstacles creates aero-acoustic tones; friction rises rapidly before cyclones (Blake, 1986; von Kármán, 1954).
Fishy sea odor	↑ rain / typhoon	Ozone and volatile organics are forced earthward by downdrafts ahead of squalls, producing a pungent smell (Ajmani et al., 2016; Zhang et al., 2020a, 2020b)
Foaming tall waves	Storm swell → typhoon	Long-fetch winds during storms generate swells by transferring energy to the ocean surface. As wind speed and fetch distance increase, waves grow taller and break as foaming, towering waves typical of typhoons (Komen et al., 1994)
River roar (*balkak*)	Sudden flood	Squall rainfall accelerates discharge; turbulence at the mouth produces a loud roar (Diedhiou et al., 2024; Garstang et al., 1994; Greco et al., 1994).
Appearance of school of fish (*Taburdik*)	Storm coming	Fish detect barometric drop and wave-orbital velocity; migrate to shallows before storms (Bacheler et al., 2019).
Fish restless / hiding	Impending storm	Behavioural change triggered by falling pressure and increasing orbital velocity of waves (Burkholder, 2021; Hammerschlag et al., 2019; Johnson, 2021)
Moon halo (*kubkob*)	Rain in 1 - 3 d	22˚ halo forms in cirro-stratus ice clouds that precede frontal rainbands; inner sky looks darker (Greenler, 2020; Minnaert, 1993; van Diedenhoven, 2014).
Dark/blackish halo (*kubkob*)	Severe rain likely	Dense ice crystal population absorbs more moonlight, yielding a darker halo that folklore links to heavier rain (Hurt, 2021; Lea, 2022)
Full/new moon	↑ rain	Perigean spring tides raise the water table; rainfall peaks in days after full or new phases (Avila-Carrazco et al., 2024; Kohyama & Wallace, 2016; Minogue, 2010).
Quarter/full moon → big waves	Larger swell	During quarter and full moons, the alignment of the Earth, moon, and sun causes stronger tidal forces (spring tides), which amplify storm-generated waves and increase swell height and surf energy (NOAA, 2025; Ross, 1995; Sumich, 1996).
Sudden leaf drop (no wind)	↑ typhoon/rain	Humidity and pre-storm water stress hasten senescence; chlorophyll loss causes premature abscission (Inagaki et al., 2010; Meir et al., 2022)
Abnormal north winds	Typhoon exiting West Phillipine Sea	Most Philippine cyclones curve N-NW; strong northerlies in Masinloc mark rear flank (Cayanan et al., 2011; Kubota & Chan, 2009).
Faster waves, cloudy water	Harsh weather	Stronger winds raise wave celerity; turbulence resuspends sediment, clouding water (Kundu et al., 2015; Wright & Short, 1984).

*Cue meanings are the community's wording; scientific notes are condensed from peer-reviewed publicaions. All cues listed here reached $p < 0.05$ somewhere in Tables 1-11.

5. Discussion

Local ecological knowledge (LEK) is not a uniform set of traditional beliefs (Marquez & Olavides, 2024; Reyes et al., 2021). Instead, it is shaped by social factors such as age, education, and community position (Brook & McLachlan, 2008; Mateos-Molina et al., 2021). Fishers rely on a select group of trusted warning cues, using these signals to make practical decisions for their livelihoods (Berkström et al., 2021; Castro et al., 2020). To make the progression of the discussion clear, each subsection builds on the previous one. Section A examines how social factors influence general confidence in LEK. Section B explores how these same factors affect which warning signs fishers' trust. Section C considers whether any of these cues shape how fishers perceive climate trends. Section D links these findings to daily decisions about boats, gear, and catches. Finally, Section E explains why only certain cues persist, connecting them to fundamental physical and biological principles.

1) ***Influence of Demographic Factors on Perceptions and Effectiveness of Local Ecological Knowledge***

Local ecological knowledge (LEK) remains an important part of coastal life in Masinloc. About three-quarters of fishers recognize its value, especially for predicting typhoons, but see it as less reliable for floods. This pattern is similar to findings from other studies in the Philippines, where fishers rely most on sea conditions, moon phases, and animal behavior for immediate risk awareness for strong typhoons and flooding (Farr et al., 2018; Reyes et al., 2021; Ruzol et al., 2021; Schafer & Reis, 2007).

Chi-square tests show that only barangay, age group, and educational attainment shaped how fishers view and use LEK. Gender, civil status, and income did not have a significant effect (**Table 1**). Barangay-level comparisons confirmed that perceptions vary even within a single municipality. For example, fishers in Bamban trusted animal behavior cues less than those in Baloganon and Taltal, which is consistent with studies showing that local geography and mangrove cover influence what signs are considered useful (Carrasquilla-Henao et al., 2019; Majesty et al., 2019; zu Ermgassen et al., 2024).

Education also plays a key role. College-educated fishers were much less likely than those with only elementary or secondary schooling to believe that LEK is limited to their own culture. This agrees with international findings that formal education broadens people's views of nature and knowledge (Erdogan, 2013; Kopnina, 2019). The strength of these demographic influences, as measured by Cramer's V (0.17 - 0.28), is strong but not absolute. This means that LEK can be integrated with, rather than replaced by, scientific knowledge (**Table 4**).

To keep LEK relevant, communities can document their LEK cues sets through workshops and digital archives, while schools and universities can include these cues in science and social studies classes, allowing students to compare them with data from instruments (Lucero-Sanico, 2019; Pariscal & Aboy, 2022). These actions support the Disaster Risk Reduction and Management (DRRM) Act's mandate to preserve local knowledge and help strengthen Local Climate Change Action Plans, keeping LEK a living system. Understanding who trusts LEK is only the first step. The next question is which specific signs these groups actually use in daily practice.

2) *Demographic Selectivity in Typhoon- and Flood-Warning Cues*

After identifying which groups value local ecological knowledge (LEK), the next step is to determine which specific warning cues are most influenced by these differences and what these mean for community preparedness.

Of the thirteen warning cues tested, only five—wind shifts, unusual tides, fog, wave behavior, and sudden branch-fall—showed significant variation by barangay, age, or educational background (Cinner & Huchery, 2014; Mcmillen et al., 2017). For example, fishers in Baloganon relied more on wind and fog signals than those in Bamban or Taltal. Inhobol differed from Taltal in their focus on tide height. These contrasts suggest that even within the same municipality, slight differences in geography can change which cues are trusted (Alberto et al., 2024; Calzeta et al., 2014; Rodriguez-Ramirez et al., 2020).

Age is also a key factor: mid-career fishers depended more on branch-fall and wave-steepness than younger fishers, similar to findings from West Africa where those with the most experience used the richest set of cues (Berkström et al., 2021; Mbaye et al., 2021). Education mainly affects the use of the branch movement. College graduates were less likely to trust this cue compared to those with vocational or secondary schooling, which mirrors international research showing that more formal education could shift reliance toward instrument-based forecasts (Cinner et al., 2012; Islam & Nursey-Bray, 2017; Okeke-Ogbuafor et al., 2022). Most of these demographic effects had a "strong" association with LEK based on Cramer's V, except for the barangay difference in tide height, which had a moderate association (**Table 5**).

Communities can put these high-trust cues into practice by setting simple rules. For example, a barangay could decide to act when two trusted signals—like Baloganon's fog and wind—or one local cue plus a PAGASA advisory, are observed. Actions might include hauling boats inland, securing nets, or preparing for evacuation. Mid-career fishers, who are the most experienced with these cues, can guide younger crew members through "knowledge walks" that connect traditional signals to data from barometers and tide gauges (Ens et al., 2015; Puspita, 2017).

At the regional level, an ASEAN coastal risk group could provide basic hydrophones, anemometers, and tide sensors, combining local knowledge with modern monitoring. Piloting these approaches through micro-grants would allow communities to test and adapt the system, while giving donors a model for integrating indigenous practices with early-warning science (ASEAN Secretariat, 2024). Pinpointing the cues people trust leads naturally to the deeper issue of whether any of those cues shape fishers' sense of a changing climate itself.

3) *Selective Sensory Cues That Directly Shape Climate-Impact Perceptions*

Among all the warning cues influenced by demographic factors, only two showed a strong association with fishers' perceptions of climate impacts. The first is a thunder-like roar (*balkak*) at the river mouth, which signals that heavy rainfall is about to begin (**Table 10**). The second is a strong fishy smell from the sea, which is linked to the belief that stronger typhoons are becoming more common (**Table 3**). Both of these cues are multisensory and are trusted by the community because they have been repeatedly proven reliable. Research in cognitive ecology shows that such vivid, repeatable signals are especially valuable when the weather is unpredictable.

These connections are not unique to Masinloc fishers. For example, Ilocano farmers read river turbulence in a similar way (Galacgac & Balisacan, 2001), while communities in Ghana treat a rising river roar as a warning for floods (Macnight Ngwese et al., 2018). Sa'ban fishers notice a sulphur-like smell from the surf before cyclones (Hosen et al., 2019), and Alaska's Yup'ik hunters report similar scents before autumn storms (Giles, 2003). This indicates that local sensory cues are used by different cultures to anticipate extreme weather.

Barangays can easily turn these trusted signals into official community alerts. For instance, if a *balkak* roar or strong fishy odour is noticed and a matching PAGASA advisory is issued, fishers can begin their rain or typhoon response protocols right away. Community workshops can also help check if these cues still work as rainfall and typhoon patterns change (Mercer et al., 2010).

Including these warning cues in local disaster risk reduction and management (DRRM) plans ensures that local knowledge is recognized in line with national policies (DepEd, 2021; National Disaster Risk Reduction and Management Council, 2015). Adding them to education modules also fulfills the Paris Agreement's call to blend indigenous and scientific knowledge (Article 7.5). If these vivid cues help fishers recognize approaching hazards, the final step is to see how they guide practical actions to protect boats, gear, and catches.

4) *Sensory Local Ecological Knowledge and Perceived Climate-Driven Disruptions to Fishing Operations*

After establishing that sensory cues shape how fishers recognize climate hazards, we now show these same cues guide practical decisions about fishing activities. A small set of signals—river roar, fishy sea odor, sudden leaf-fall, abnormal waves, and strong winds—directly influence how mangrove fishers manage their catches, vessels, gear, and fishing trips.

For example, the link between abnormal winds and vessel replacement, as well as between sudden leaf-fall and gear modification, was both especially strong (**Table 11**). This finding matches reports from Sa'ban and the Pacific Islands, where fishers used wind speed and leaf drop to decide when to bring boats ashore or adjust fishing nets (Hosen et al., 2019; Nunn et al., 2016; Nunn et al., 2024). The connection between a strong fishy smell and operational changes also aligns with Palawan accounts, where surf odour warns of dangerous swells that could damage fishing gear (Hujibers et al., 2012). Associations between cues and changes in fishing trips or catches were somewhat weaker (around 0.19 - 0.26), suggesting that outside factors such as market demand or regulations also play a role.

Communities can act on these cues using simple rules. For example, if gusts reach 25 knots and premature leaf-fall is observed, this could trigger the hauling of boats and the preparation of gear. "Knowledge walks" that document how river roar relates to water quality changes can also provide valuable real-time data for science classes (Starkey et al., 2024). At the regional level, using affordable sensors together with local knowledge could improve early warnings and response times across coastal areas (ASEAN Committee on Disaster Management, 2024; ASEAN Secretariat, 2024; UNDRR, 2024).

Incorporating these cue-based triggers into local disaster risk reduction and management (DRRM) plans, and comparing them with official data from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) in school lessons, helps combine traditional knowledge with modern science. This approach not only preserves valuable local practices but also reduces risk for fishers facing more frequent and intense climate hazards. Having identified the small set of cues that guide operational decisions, the next step is to understand why these particular signals have endured over time while others have not.

5) ***Physicochemical Foundations of High-Trust LEK Cues***

The reliability of high-trust local ecological knowledge (LEK) cues comes from their grounding in observable physical and biological processes. Masinloc fishers have narrowed their attention to fourteen warning signs because each is linked to a clear and testable mechanism in the environment.

These cues can be grouped according to the senses that detect them. Visual signs like the 22-degree lunar halo (*kubkob*) and dark nimbostratus clouds are early indicators. The lunar halo forms when ice crystals in high clouds bend moonlight, often appearing one to three days before rain arrives. Thickening, dark clouds signal growing rain potential, as more water droplets form and block sunlight. Both signs offer advanced notice of changing weather. Ocean-based cues provide further warning. Swells that travel a long distance and strong, sometimes fishy or sulphur-like odours signal a coming storm days ahead. These match scientific records and local knowledge from other coastal areas where changes in wave height and smell warn fishers to protect their gear. River and sound cues offer short lead times. The roar (*balkak*) at the river mouth, as reflected in broader studies of Ilocano farmers' ecological knowledge, is associated with warnings of possible flooding following heavy rainfall (Galacgac & Balisacan, 2001). Fishers listen for this sound to act quickly and move to safety. Biological reactions confirm the risk. Reef fish often move closer to shore or behave restlessly as air pressure drops, just before a storm. Fishers also notice leaves falling from trees, even without wind, as rising humidity triggers this response. Both cues prompt last-minute preparations and reflect similar practices among other Southeast Asian fishers who adjust their nets or shelter boats when these signs appear (Mulyasari et al., 2023; Pomeroy & Ahmed, 2006).

The continued use of these fourteen cues fits what scientists call "selective retention"—communities remember and use only the cues that have proven most useful over time, especially as weather becomes less predictable. In Masinloc, the cues with the largest statistical associations (Cramer's V ≥ 0.25) are those linked to the greatest risks, such as losing boats, major gear damage, or having to cancel trips. This means that memory and daily practice focus on signals that protect both livelihoods and lives.

Because these cues signal at different time intervals—some days in advance, others just hours—barangays can adopt simple dual-trigger rules. For example, based on the interview of the mangrove fishers in the study areas, if a lunar halo appears and is soon followed by strong gusts, river roar, or sudden leaf fall, the fishers haul boats ashore, secure nets, prepare repair kits and cancel fishing trips. Documenting these signals, like measuring the loudness of the river or the timing of wave swells, provides useful data for local schools and risk planning.

Adding affordable instruments like wind gauges, sound sensors, and air-quality monitors can further refine these local warning systems. Embedding these triggers in local disaster risk management plans aligns with national and international frameworks, such as the Philippine DRRM Act and the Sendai Framework for Disaster Risk Reduction. UNESCO and the Department of Education (DepEd) guidelines in the Philippines also recommend integrating local cues with scientific knowledge in school curricula.

By formally recognizing and recording these cues, Masinloc's coastal communities gain a reliable, low-cost way to protect boats, gear, and catches. This also helps keep valuable local knowledge alive as climate risks increase.

6. Conclusion

This study confirms that local ecological knowledge (LEK) among Masinloc's mangrove fishers is both resilient and broadly shared. Although more than sixty candidate weather cues are recognized, only a focused set of fourteen have persisted in practice. These cues cut across gender, income, and civil status, showing that LEK is fundamentally communal—not the province of a select group.

Demographic factors such as barangay, age, and education do filter which cues are trusted most, particularly for wind, fog, tides, waves, and branch-fall. However, these influences are modest: the core set of cues remains widely accessible and applicable to nearly all fishers, underscoring the unifying potential of LEK.

What truly sets these high-trust cues apart is their strong physical and scientific basis. Each cue is grounded in observable, measurable changes in the environment, providing reliability that goes beyond mere tradition. This mechanistic credibility explains why certain cues endure while others fade.

Importantly, not all traditional cues are equally influential. Only a small number—most notably the river-mouth "*balkak*" roar and a pungent sea odour—significantly shape fishers' perceptions of climate change, such as heavier rainfall and stronger typhoons. Similarly, just six cues strongly predict real operational disruptions like lost boats, damaged gear, or reduced catches. This selective effect highlights the importance of prioritizing evidence-backed indicators in both community practice and official policy.

Integration with formal early warning and adaptation systems is not only possible but urgently needed. The most trusted local cues can directly complement government alerts (e.g., PAGASA), strengthen disaster risk reduction plans (DRRM), and provide practical material for educational modules and community training. Institutionalizing these cues in local and national frameworks will enhance preparedness, build trust in official forecasts, and reinforce culturally relevant knowledge.

A clear and actionable path emerges: by embedding validated LEK cues in DRRM protocols, DepEd curricula, and Local Climate Change Action Plans—and supporting these efforts with accessible technologies and knowledge archives—Masinloc and similar communities can achieve cost-effective, science-based, and socially grounded climate resilience.

Internationally, this model aligns with the UNESCO-LINKS framework, which support the Sendai Framework's focus on people-centered early warning, and offers a scalable template for coastal communities across the Indo-Pacific. Small pilot grants can facilitate broader adoption, ensuring that both ancestral knowledge and scientific tools work together to protect livelihoods and cultural identity.

In summary, the strength of Masinloc's LEK lies in its careful selection of cues that are both empirically reliable and contextually meaningful. By linking these cues to real risks and integrating them with formal systems, communities can secure both their assets and their heritage—proving that village-level knowledge remains essential for effective climate change adaptation and disaster preparedness.

7. Recommendations and Ways Forward

This study validated fourteen high-trust local ecological knowledge (LEK) cues that Masinloc's mangrove fishers use in daily risk decisions, yet it was limited to four barangays and a cross-sectional design. To make these findings actionable, scalable, and relevant beyond the immediate study area, we propose several interrelated recommendations grounded in both our results and established best practices for disaster risk reduction and climate adaptation.

First, local government units and barangay disaster teams should institutionalize the most reliable LEK cues into their disaster preparedness protocols. This involves adopting a dual-trigger early warning approach, wherein cues such as lunar halos or the distinct river roar (*balkak*) are monitored alongside PAGASA advisories. Regular drills and clear, written trigger-action guidelines will help embed these protocols in community practice, while participatory monitoring over at least one full year can provide essential feedback to further refine and validate these early warning systems (Hiwasaki et al., 2014; Mercer et al., 2010).

Second, integrating LEK into both formal and non-formal education is vital for sustainability and intergenerational knowledge transfer. Educational modules and activities—such as "knowledge walks" or hands-on experiments that compare traditional cues with data from affordable sensors—should be incorporated into DepEd science and social studies curricula. Comparing learning outcomes from LEK-enriched lessons versus conventional curricula will help determine the added value of this approach in building climate-risk literacy (Reyes-García et al., 2010).

Third, to ensure the continued transmission of traditional knowledge, communities are encouraged to create digital and physical archives of validated cues. These repositories, ideally co-produced by youth councils, fisher associations, and local schools, can include photographs, audio recordings, and videos in local languages. Tracking usage and engagement with these materials will provide insight into their effectiveness in supporting learning and cultural continuity (Tengö et al., 2017).

Fourth, the empirical validation of LEK cues should be strengthened by deploying low-cost environmental sensors—such as anemometers, hydrophones, and VOC detectors—in critical areas like river mouths and shorelines. By combining sensor data with observational LEK, communities can increase trust in their warning systems and fine-tune response protocols. Advanced data analysis, such as Bayesian data fusion, can further sharpen the reliability and accuracy of these locally adapted systems (Hiwasaki et al., 2014; McNamara & Prasad, 2014).

Fifth, there is a need to develop a national registry of validated LEK indicators, hosted by a relevant agency such as PCAARRD or PAGASA. This registry would allow coastal communities to benchmark, cross-validate, and adapt cues for their local contexts, while annual reporting and meta-analysis would identify emerging patterns and support evidence-based policy making for climate adaptation at the regional and national levels (IPBES, 2019).

Sixth, Masinloc's model for integrating LEK with formal risk management should be aligned with international frameworks, such as the Sendai Framework, UNESCO-LINKS, and ASEAN's Multi-Hazard Early Warning System. By positioning Masinloc as a demonstration site and engaging with these regional and global initiatives, there are opportunities to attract investment, share lessons learned, and pilot the approach in other high-risk coastal communities across ASEAN and beyond (ASEAN Secretariat, 2024; UNDRR, 2024).

Finally, it is essential to sustain ongoing monitoring and continually advance methodological rigor. A collaborative monitoring team—including local government staff, academics, and fishers—should regularly review the effectiveness of LEK cues, update archives and protocols, and inform future educational efforts. Moreover, a study regarding perceptions of mangrove fishers about LEK and climate change in other coastal communities in the Philippines in order to investigate similarities and differences, must be conducted. Employing advanced statistical approaches, such as mixed-effects modeling or structural equation modeling on longitudinal datasets, can help disentangle the complex interactions of gender, education, and location identified in this study (Reyes-García et al., 2016). Further studies must be conducted to include an econometric model using Likert Scale to enhance the paper scientifically and to address the objectivity of the perception study.

In sum, these recommendations provide a comprehensive, evidence-based roadmap for bridging local ecological knowledge with science, policy, and education. By promoting the systematic validation, documentation, and integration of LEK, this approach offers a scalable and pragmatic template for building climate resilience in Masinloc and other vulnerable coastal communities.

Ultimately, while this study does not claim to be wholly novel, it offers an important, evidence-based guide for bridging traditional local knowledge with formal risk management systems. By systematically validating which local ecological knowledge cues remain effective and credible, the research provides a practical foundation for integrating community-based observations into policy and education. This approach is both innovative and actionable, serving as a blueprint for other coastal communities facing similar climate risks. The lessons from Masinloc thus offer a foundation for future research and policy development, ensuring that valuable indigenous insights continue to inform adaptive strategies in an era of climate uncertainty.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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