

Local ecological knowledge and fishers' conservation attitudes toward marine mammals in Brunei Bay, Malaysia

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ABSTRACT

Brunei Bay is part of Southeast Asia's data-scarce areas that offer immense challenges for the conservation of marine mammals due to a lack of systemic biological studies and the overwhelming presence of anthropogenic activities. This study attempts to address these challenges by measuring the Local Ecological Knowledge (LEK) and how it affects the conservation attitude of 288 fishers through a stratified random sampling method. Although traditional surveys have a high degree of logistical challenges, this study illustrates the importance of using LEK as a practical supportive mechanism for transforming local knowledge into actionable management frameworks. This study reveals that the respondents possess moderate LEK (mean = 0.53) and exhibit mostly neutral to positive attitudes (mean = 0.60) towards marine mammal bycatch. Crucially, a strong, positive, and statistically significant correlation was identified between LEK and conservation attitudes ($p = 0.86$, $p < 0.05$), suggesting that experiential knowledge is a primary driver of conservation support. Conversely, the high non-response rates regarding hunting and stranding sites reveal a cultural taboo and social desirability bias. This study is the very first of its kind conducted in the region, making it clear that educational interventions need to be targeted in certain localities, particularly Menumbuk and Labuan, where the most negative attitudes were found. Future policy proposals are suggested to move away from general awareness to a more community-based approach in the stewardship of marine resources through the proposed and custom-fit LEK validation workshops and incentivised live release protocols.

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1 INTRODUCTION

Biodiversity and its preservation have become a pivotal focal point of global ecological studies (IPBES, 2024). However, the condition of the world's oceans is dire, as anthropogenic pressures, including habitat degradation, pollution, over-exploitation, ocean acidification, and climate change, lead to cascading impacts on the world's oceans (Halpern *et al.*, 2019; United Nations, 2024). The alarming trend of decreasing global marine populations further indicates the need for a more proactive approach to global conservation (IPBES, 2024).

In particular, marine mammals, which often serve as proxies for the overall health of marine ecosystems (Parsons *et al.*, 2014), are subject to disproportionate levels of risk. Out of 31 marine mammal species, approximately 25% are considered endangered, and 98% of species within coastal

environments are considered at risk of extinction (Avila *et al.*, 2018). The inherent problem of insufficient data for protection

is largely due to the highly migratory and expansive thermohaline circulation patterns of these mammals (Tiongson *et al.*, 2021). A global inventory, for instance, documented large areas of the world's oceans as unsurveyed for cetaceans, making it difficult to analyse and assess critical population metrics (Tiongson *et al.*, 2021). Consequently, pervasive data gaps remain a dominant constraint for global marine conservation (IUCN, 2024).

Integrating Local Ecological Knowledge (LEK) into modern conservation science is necessary and is recognised globally for alleviating the financial and logistical challenges posed by traditional scientific surveys (Silvano *et al.* 2023; Kembo & Utete, 2025). LEK is defined as the cumulative body of knowledge, practice, and belief, evolving through adaptive processes and handed down through generations, encompassing a deep understanding of the relationship

between living beings, including humans, and their biophysical environment (Silvano *et al.*, 2023). Within the parameters of this study, LEK specifically relates to the ecological knowledge of local fishers, who have gained knowledge through long periods of meaningful and participatory experiences.

Rather than being a mere data collection practice, this study employs a knowledge-attitude framework based on conservation social science. This framework theorises that awareness of ecology positively affects supportive attitudes towards conservation, leading to the formation of behavioural intent and the ultimate effectiveness of management policies (Macale *et al.*, 2024). By emphasising the human components of conservation, it is acknowledged that the persistence of certain marine species is determined not only by biological factors but also by the local community's social tolerance of protective measures (Jones *et al.*, 2025). Additionally, placing this study within the theory of community-based resource management allows local fishers to be considered as key active participants, whose views are critical to the resource governance framework of sustainability and equity (Jones *et al.*, 2025).

The combination of insufficient data and increasing human-induced threats is most pronounced in Southeast Asia, one of the world's regions with the greatest marine biodiversity and the least protected marine mammals, which are severely threatened by bycatch, overfishing, and habitat loss (Tiongson *et al.*, 2021; ASEAN ENMAPS, 2024). A case in point is Brunei Bay, Malaysia, which is designated as an important marine mammal habitat. However, data regarding the fisheries-marine mammal interactions and the threats that fishing activities pose to marine mammals are still greatly lacking (Mahmud *et al.*, 2018).

Filling such a critical gap is essential for informing more relevant and tailored conservation planning. Hence, this study aims to document fishers' local ecological knowledge of marine mammals and evaluate their conservation attitudes in Brunei Bay using a large-scale LEK survey. This research contributes to marine conservation social science in three ways: (1) it develops a standardised LEK index for small-scale fishers in Brunei Bay; (2) it empirically tests the relationship between ecological knowledge and conservation attitudes through rigorous non-parametric and multiple regression analysis; and (3) it identifies spatial variation in conservation support across distinct fishing districts, providing actionable insights for community-based conservation programmes. These findings provide a valuable baseline, based on local communities, to inform the long-term management of marine mammals in Malaysian waters.

2 MATERIALS AND METHODS

The study was conducted on the Malaysian side of Brunei Bay, 4°45'-5°02'N, 114°58'-115°10'E, as it is known as one of the important habitats for marine mammals in Borneo (Mahmud *et al.*, 2018). The study area was stratified into five main districts, which are Lawas, Menumbuk, Sipitang, Weston, and Labuan, based on their provinces and orientation towards the bay (Figure 1).

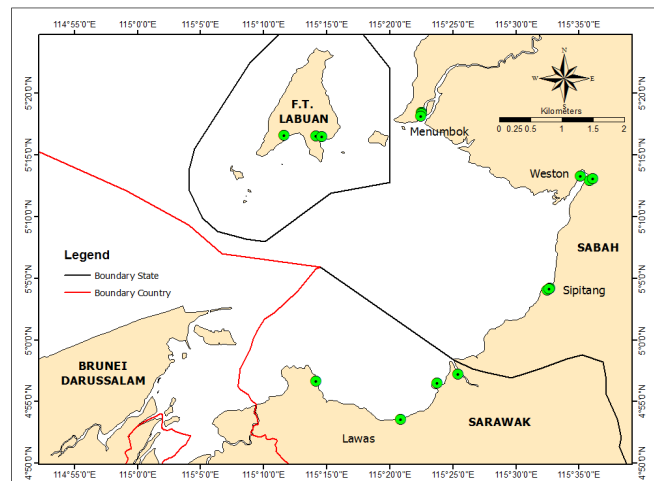


Figure 1: Map showing Brunei Bay, Malaysia, and surrounding area. The green dotted circles indicate their interviewed fishers communities' sites, and the top-left box is the location of Brunei Bay on Borneo map. Reprints with permission from Raman (2013)

A stratified random sampling technique was used to capture adequate representation of the local fishing population. The sampling frame comprised active fishers met at landing jetties, fishing villages, and local markets. The fishing participants included in the criteria were active fishers, encompassing both owners of fishing boats and crew members, to capture different degrees of exposure to interactions with marine mammals. To enhance community cooperation and lower the likelihood of refusals, initial engagement involved informal community visits to establish rapport with the local community and village heads prior to obtaining formal informed consent (Hines *et al.*, 2015).

Regarding Local Ecological Knowledge (LEK) and conservation attitudes, data were collected through interviewer-administered, semi-structured LEK and conservation attitude surveys adapted from the CMS-UNEP Standardised Dugong Catch/Bycatch questionnaire (CMS-UNEP, 2010). Since the survey instrument was adapted from the globally standardised CMS-UNEP Dugong Catch/Bycatch questionnaire, it possesses strong inherent content validity for use in artisanal fishing communities. To ensure local comprehension and cultural resonance in the translation to Bahasa Melayu, data collection was conducted strictly through interviewer administration. Additionally, paper copies of the

Brunei Bay map (British Admiralty Nautical Chart 1844 - Brunei Bay and Approaches) in A4 scale, a graphic poster of marine mammals (published by UMT), and fishing gear illustrations (from the FOA website) were used to help fishers to point out the locations, document the spatial information where marine mammals were observed, and confirm their answers (CMS-UNEP, 2010).

In the interest of maintaining methodological rigour, standard additive techniques were applied in constructing the indices of Local Ecological Knowledge (LEK) and conservation attitudes (Macale *et al.*, 2024). To ensure full transparency and reproducibility, the structure of the indices is detailed in Table 1. The LEK index was derived from eight specific survey items, while the Conservation Attitude index consisted of six distinct items. A three-point ordinal scale (0–2) was used to distinguish a total lack of knowledge or “uncertainty” (0), some knowledge or “neutral” (1), and a significant amount of knowledge or “positive” (2). The index scores were calculated by summing the individual item scores and normalising them against the maximum possible score to ensure valid comparison:

LEK or Attitude Index = (Sum of item scores / Maximum possible score)

Given the anticipated sensitivity of certain fisheries interaction questions, it was necessary to address non-responses systematically. Missing data, where participants declined to answer, were handled by assigning a score of zero for that item, operating under the conservation assumption that a refusal to answer indicated a lack of positive knowledge or attitude. This procedure resulted in range standardisation for the indices from 0.00 to 1.00. Meanwhile, the internal consistency of the survey items was assessed using Cronbach's alpha coefficient to evaluate the reliability of both constructs independently.

Table 1: Description of variables and index construction

Variable	Items	Scale	Scoring Range
Local Ecological Knowledge	8 questions	0-2 ordinal	0.00 – 1.00 (Normalised)
Conservation Attitude	6 questions	0-2 ordinal	0.00 – 1.00 (Normalised)

Statistical analysis was performed using IBM SPSS Statistics, with the alpha level for significance set at 0.05. Prior to hypothesis testing, a Shapiro-Wilk test was utilised to assess the distribution of the data. The resulting non-normal distribution necessitated the use of non-parametric procedures, specifically Spearman's rank correlation (ρ) to test the relationship between continuous variables and chi-square tests to evaluate significant differences among

categorical variables (e.g., sighting frequencies, sighting patterns, attitudes towards bycatch, and others).

To address potential Common Method Bias (CMB) inherent in self-reported surveys, Harman's Single Factor Test was applied as a post-hoc diagnostic to ensure that no single factor accounted for the majority of the variance. Furthermore, to mitigate concerns regarding the high correlation between LEK and attitudes, collinearity diagnostics, including the Variance Inflation Factor (VIF), were integrated into the analytical framework to confirm that the constructs remained statistically distinct.

To visually inspect linearity and potential outliers, scatterplots with fitted regression lines and 95% confidence intervals were generated for all primary bivariate analyses. Finally, to rigorously test the impact of knowledge on conservation attitudes while controlling for potential confounding variables, a multiple linear regression analysis was performed using the following model:

$$\text{Attitude} = \beta_0 + \beta_1(\text{LEK}) + \beta_2(\text{Age}) + \beta_3(\text{Experience}) + \beta_4(\text{Region}) + \epsilon$$

While the raw index scores deviated from normality, the assumptions for multiple linear regression were verified post-hoc. The residuals (errors) of the regression model were visually inspected using normal P-P plots and scatterplots, confirming that they adequately met the assumptions of normality and homoscedasticity, thereby justifying the use of an Ordinary Least Squares (OLS) approach.

2.1 Ethical considerations

The research involving the participants (local fishers) gained a positive review from the ethics committee of Universiti Malaysia Terengganu. For data collection, community and higher approval were obtained from the local authorities, the Department of Fisheries, and the village heads. Initial contact was made through visits to the fishing communities to explain the project, develop a relationship, and get the participants' consent. The fishers were assured that they would not be identified and that their answers would be treated confidentially.

3 RESULT

3.1 Profile of the fishers

A total of 288 fishers were interviewed around the Malaysian waters of Brunei Bay through the semi-structured questionnaire. Within this fishing community, 33.3% (N = 96) of the respondents came from Lawas, 22.2% (N = 64) from Menumbuk, 13.9% (N = 40) from Sipitang, 15.3% (N = 44) from Weston, and 15.3% (N = 44) from Labuan. The

interviewed fisher's age ranged from 27 to 82 years old (mean = 47.07; SD = 15.00), with working experience ranging from 1 to 66 years as a fisher (mean = 27.54; SD = 15.24). In addition, the majority of the respondents (N = 259/288; 89.9%) stated that they came from fishing families.

3.2 Data validation and normality

Prior to the primary analysis, the dataset was subjected to several diagnostic tests. The Shapiro-Wilk test indicated that the distribution of both LEK and Attitude index scores significantly deviated from normality ($W = 0.959$, $p < .001$; $W = 0.948$, $p < .001$), necessitating the use of non-parametric procedures. To assess Common Method Bias (CMB), Harman's Single Factor Test was performed. The first emerging factor accounted for 38.4% of the total variance, which is well below the 50% threshold, suggesting that the results were not significantly distorted by common method variance. Finally, internal reliability was assessed. The Cronbach's alpha coefficient for the 8-item LEK scales was approximately 0.81, and the 6-item conservation attitude scale demonstrated an alpha of 0.78. These high values confirm measurement consistency and mitigate concerns of construct overlap.

3.3 Local ecological knowledge (LEK) levels

The average LEK indicator on marine mammal catch/bycatch, as shown by the interviewed fishers around Brunei Bay, Malaysia, was 0.53 (SD = 0.193, min = 0.12, max = 0.88), which is classified as moderate. Based on the established classes, 18.1% (N = 52/288) of the respondents had low knowledge, 52.1% (N = 150/288) had medium knowledge, and 29.9% (N = 86/288) showed that they had a high level of knowledge on marine mammal catch/bycatch. No fisher reported zero knowledge on marine mammals, as most of them stated that they had seen at least one dugong or dolphin during their lifetime as a fisher.

A total of 59.4% (N = 171/288) of the interviewed fishers stated that they had seen at least one individual marine mammal (dugong or dolphin) in their lifetime. These 171 respondents reported sighting frequency was "ONCE" (59.1%), "FEW TIMES" (36.5%), and "FREQUENT" (4.4%). The chi-square test showed that there was a significant difference between the sighting frequency and the responses according to the categorical index ($\chi^2 = 71.025$, $df = 2$, $p < 0.05$).

14% of these 171 fishers managed to state the marine mammals' characteristics and species correctly with the help of the visual aids that had been prepared. Respondents were also asked about patterns of marine

mammal sightings, and the result showed that 39.1% agreed that the trend has become "LESS". 1% of them answered "SAME", no responses were recorded for the "MORE" index, 22.9% answered "DON'T KNOW", and the remaining 37% did not answer the question. The chi-squared test showed that there was a significant difference in the categorical index of marine mammal sighting patterns around Brunei Bay, Malaysia ($\chi^2 = 106.028$, $df = 3$, $p < 0.05$).

A total of 26.7% stated that they knew where to find marine mammals (dugong or dolphin), while 37.2% of the respondents reported that they knew nothing about the area, and the remaining 36.1% gave no answer to that question. There was no significant difference in the responses according to the categorical index ($\chi^2 = 5.688$, $df = 2$, $p = 0.58$).

Fisher's perspectives on marine mammals' significance were also explored during the interview session. A total of 35.4% stated that marine mammals held important value in their lives, while 14.9% stated that marine mammals gave no value to them, 14.2% stated that they did not know of any importance of marine mammals at all, and the remaining 35.4% chose not to answer the question. The statistical analysis showed that there was a significant difference in the categorical index of the marine mammal's significance in their life ($\chi^2 = 50.028$, $df = 3$, $p < 0.05$).

For the fisheries interaction questions, the interviewed fishers were asked about hunting, incidental catches, and stranding events involving marine mammals. A total of 84% of them appeared to have experienced these fisheries interactions at least once in their lifetime as fishers.

3.4 Conservation attitude levels

Regarding attitudes on fisheries interactions with marine mammals, the average indicator score was 0.60, with a minimum index of 0.00 and a maximum of 1.00. Based on the indicator obtained, the attitudes shown by the respondents around Brunei Bay, Malaysia, were classified as neutral. A total of 14.2% (N = 41/288) of the interviewed fishers scored within the range of negative attitudes, 34.3% (N = 99/288) had a moderate attitude, and the remaining 51.4% (N = 148/288) were shown to have a positive attitude. As for attitudes on stranding events specifically, 39.2% showed positive attitudes, 22.2% chose to not give any harm or goodness, 5.6% reported negative attitudes, and 33% gave no answer.

While the average indicator score for attitudes was 0.60, this finding must be interpreted with caution due to potential non-response bias. This is because a substantial portion of the participants (35.4% for hunting status and 33%

for stranding events) exercised cultural restraint and declined to answer. Therefore, it is plausible that those withholding responses generated more negative or utilitarian views. Consequently, the observed neutral-to-positive mean might be slightly artificially elevated.

3.5 Fisheries interactions

When asked about hunting, incidental catches, and stranding events, 85% of respondents appeared to have experienced these fisheries interactions at least once in their lifetime. As for hunting activities, a total of 10.8% have experienced such activities before. The fishers were then asked whether they still continued their hunting activities or not. Of these, 32.6% stated that they have stopped hunting marine mammals. A further 31.9% stated that they did not know whether the hunters had stopped these illegal activities or not, while the remaining 35.4% provided no answer to the question. The chi-square test showed that there was no significant difference in the categorical index on the current status of marine mammal hunting activities ($\chi^2 = 0.583, df = 2, p = 0.747$).

For incidental catches of marine mammals, a total of 26% of the interviewed fishers had experienced bycatch events. If the fishers stated that they had experienced this, they were then asked what they would do with the animals. A total of 11.2% answered that they might eat the meat or cook it as the main dish for that day. A further 14.1% answered that they sold the catches, as the meat of marine mammals, especially dugong, is expensive. The majority of the respondents (66%) reported that they released the non-targeted fish, whether the animals were still alive or not. A total of 13% chose none of the provided answers and were categorised as others, while the remaining 17.3% did not provide any answer to that question. The chi-square test showed that there was a significant difference in the categorical index of the bycatch attitudes on marine mammals ($\chi^2 = 81.417, df = 3, p < 0.05$).

A total of 42.7% reported that they had engaged with stranded marine mammals at least once in their lifetime as a fisher. As for attitudes on marine mammals stranding events, 39.2% tended to show their positive attitudes. A total of 22.2% chose to not give any harm or goodness to the animals. Meanwhile, 5.6% reported having negative attitudes towards the animals. The remaining 33% choose to not give any answer to that question. There was a significant difference in the categorical index of the attitudes shown towards stranded marine mammals, as reported by the Chi-square test ($\chi^2 = 75.139, df = 3, p < 0.05$).

3.6 Analysis of non-response rate

A noteworthy outcome of this research is the high non-response rate, which may require consideration within the realm of social ecology and behavioural studies of social behaviour. In fact, a considerable number of participants declined to answer questions about sighting trends (37%), knowledge about habitats (36.1%), and the status of illegal hunting (35.4%). In a similar manner, one-third of participants (33%) did not respond regarding “What they would do during marine mammal stranding events.”

3.7 Correlation analysis

Spearman's rank correlation coefficient was calculated to determine the correlation between the normalised indices of LEK and the Attitude, both of which ranged from 0.00 to 1.00. The findings yielded a statistically significant, strong, and positive correlation ($\rho = 0.856, p < 0.05$), suggesting that most fishers with more positive ecological knowledge also had positive attitudes towards the conservation of marine mammals (Figure 2). To address potential multicollinearity, a Variance Inflation Factor (VIF) was calculated, yielding a value of 2.1, confirming that the constructs remained statistically independent.

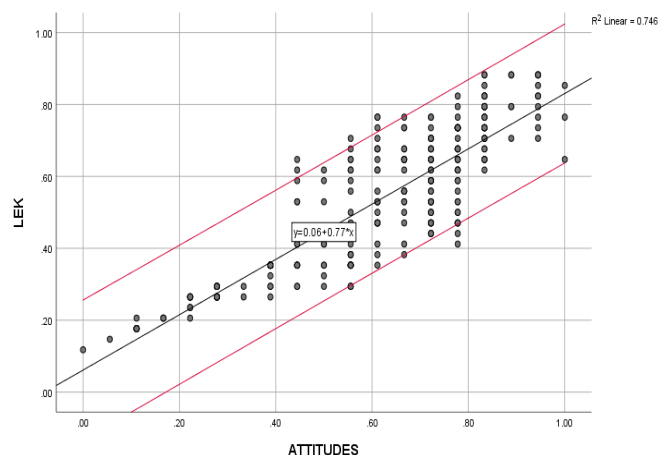


Figure 2 Scatter plot between LEK and attitude of fishers towards marine mammals around Malaysian Brunei Bay

Note: Scatter plot illustrating the strong positive correlation between the normalised Local Ecological Knowledge (LEK) index and the normalised Conservation Attitude Index among interviewed fishers (N=288). The solid black line represents the line regression fit ($y=0.06 + 0.77x$), with an R^2 value of 0.746 and a Spearman's rank correlation coefficient of $\rho = 0.856$ ($p < 0.05$). The parallel red lines indicate the 95% confidence intervals for the regression.

To further investigate the strength of LEK as a predictor of conservation attitudes while controlling for socio-demographic variables, a multiple regression analysis was conducted. The model significantly predicted conservation

attitudes, $F(4, 283) = 114.2$, $p < 0.05$, accounting for 74.6% of the total variance ($R^2 = 0.746$). The LEK Index remained the strongest significant predictor of positive attitudes ($\beta = 0.851$, $p < 0.05$).

3.8 Regional differences

The composite indices of LEK and attitudes did not meaningfully correlate with the majority of the socio-demographic variables (age, fishing experience, and family background). In the multiple regression model, age ($p = 0.510$) and experience ($p = 0.741$) did not yield significant predictive power. However, there was a minor negative correlation between attitudes and the geopolitical region ($\beta = -0.095$, $p < 0.05$). In particular, the conservation attitudes of fishers in Lawas and Weston were more positive compared to the other respondents in Menumbuk, Sipitang, and Labuan, who were more likely to be negative or neutral (Figure 3).

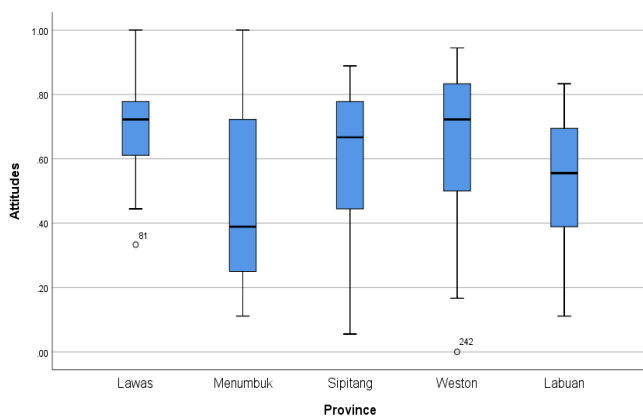


Figure 3. Box-and-whisker plot comparing the index of attitudes across five survey areas in Brunei Bay, Malaysia

Note: The boxes represent the interquartile range, with the internal horizontal lines marking the median values. The whiskers extend to the minimum and maximum values within 1.5 times the interquartile range, while the open circles denote individual outliers that fall outside this range.

4 DISCUSSION

4.1 Synthesis of local ecological knowledge (LEK): Why is LEK moderate?

An average level of ecological knowledge regarding marine mammals can be seen among fishers in Brunei Bay, evidenced by an overall LEK index of 0.53 (SD = 0.19). While this provides a functional baseline for conservation, it serves as a knowledge-practice plateau rather than strong theoretical engagement (Jones *et al.*, 2025). This moderate level of knowledge aligns closely with findings from other coastal communities across Southeast Asia. For example, similar moderate LEK levels have been reported among small-scale fishers in the Philippines and Indonesia, where marine

mammals are not primary fishing targets (Tiongson *et al.*, 2021). Furthermore, regional studies spanning the Gulf of Thailand (Hines *et al.*, 2015) and the coastal waters of Vietnam and Cambodia (Hines *et al.*, 2015) demonstrate a comparable dynamic. Fishers often possess functional, experience-based knowledge of marine mammals, but this knowledge remains constrained by a lack of direct economic motivation.

There are several analytical components that can be used to explain this level of scoring. Primarily, marine mammals are non-target species in this area. There is very little economic incentive for fishers to track the life cycles or the movements of marine mammals, as they do with commercial fish stocks (Silvano *et al.*, 2023). This is compounded by the low sighting rate of marine mammals, with almost 60% of respondents observing a marine mammal only once or a few times. This results in a lack of high-frequency experiential data, as data are more commonly collected through frequent observations.

Additionally, the lack of correlation with socio-demographic factors suggests an erosion of knowledge. Ecological systems of interrelations can empirically be seen to decline with the modernisation of artisanal fishing practices (Liu *et al.*, 2019). The knowledge of intricate interrelations appears to fade with each generation (Liu *et al.*, 2019; Kembo & Utete, 2025). Moreover, passive observation of policy in the past may lead to fishers being discouraged from documenting observations, resulting in a knowledge base that is uniform yet contains gaps. The qualitative data, although rich, remain spatially constrained. This provides a more complex base for participatory spatial data in community planning (Jones *et al.*, 2025; Kembo & Utete, 2025).

4.2 Conservation attitudes and the knowledge-attitude link

There is statistical significance in the correlation between LEK and positive attitude towards conservation ($p = 0.86$, $p < 0.05$). In the context of Brunei Bay, it can be said that knowledge is an important factor influencing these attitudes. The Theory of Planned Behaviour (Ajzen, 1991) explains how knowledge shapes an individual's positive behavioural belief and influences them to act towards conservation.

The positive correlation demonstrates that knowledge fostered through experiential learning is well developed in this context. In practice, as fishers become familiar with marine mammals through their work, they undergo a process of positive value formation, in which these animals are no longer viewed only as competitors but rather as an integral part of the ecosystem (Liu *et al.*, 2019). This positive value formation can

lead to a process of self-regulation, in which conservation of these mammals becomes a community norm and is no longer perceived as an externally imposed requirement (Macale *et al.*, 2024). This observation is consistent with the principle of environmental literacy, where ecological understanding is the first step towards stewardship. This explains the less positive attitude among fishers in Menumbuk, Sipitang, and Labuan compared to their peers in Lawas and Weston, where higher levels of literacy and more positive conservation attitudes are observed. This has been identified as a gap in the recent report by the IPBES (2024).

Finally, while the Variance Inflation Factor (VIF) values confirmed statistical independence between the constructs, the exceptionally high explanatory power of the regression model ($R^2 = 0.746$) and the strong bivariate correlation ($\rho = 0.856$) suggest a conceptual limitation. In the socio-cultural context of Brunei Bay's artisanal fishers, experiential ecological knowledge and conservation attitudes may be so deeply intertwined that they function as partially overlapping constructs in the minds of the respondents. Future studies should consider incorporating qualitative, ethnographic approaches to further untangle how these communities cognitively separate what they know about marine mammals from how they value them.

4.3 Implications for fisheries interactions and bycatch mitigation

Fisheries interactions are one of the most widespread and serious threats to marine mammals, resulting from human activity (Moore *et al.*, 2021; Thavasi *et al.*, 2025). Bycatch, defined as the accidental capture of marine mammals by fishing gear such as trawls, purse seines, and gillnets, remains the greatest mortality threat (Moore *et al.*, 2021; Thavasi *et al.*, 2025). The current research indicated that 26% of respondents reported incidences of marine mammal bycatch, providing that this threat is measurably present within the Brunei Bay region. Furthermore, the varied responses regarding how fishers handle these animals underscore the critical and often blurred line between incidental and intentional capture. Although the majority of fishers claimed to release the animals, the admission by a subset of respondents that they utilise the bycatch, whether for personal consumption or financial gain, is extremely problematic from a conservation standpoint. Since marine mammals, especially dugongs, possess high economic and nutritional value (Mahmud *et al.*, 2018; Tiongson *et al.*, 2021), there is a risk of mitigation failure, where accidental bycatch transitions into intentional retention or targeted hunting.

These findings are crucial for developing conservation strategies in Southeast Asia. Similar to studies focusing on dugongs and small cetaceans, the socio-economic complexities of the Southeast Asia region have been noted, making the distinction between bycatch and intentional take nearly impossible (Tiongson *et al.*, 2021). With the various attitudes towards bycatch, with some fishers opting to release the bycatch while others are willing to sell or consume it, more complicated and culturally sensitive bycatch reduction strategies are needed. These strategies have to go beyond simple gear restrictions and have to include (1) promoting the release of bycatch and (2) in areas with more neutral attitudes, strengthening awareness and legal protection of the species to reinforce conservation behaviours. Active management needs to be done with local communities to foster a sense of ownership and cultural acceptance (ASEAN ENMAPS, 2024).

4.4 Policy implications & management recommendations

To facilitate the practical expansion of the current research findings in Brunei Bay, the following geographically tailored methods are suggested:

- (i) Codesigned LEK Validation Workshops: Utilising a bottom-up approach, these workshops should integrate fisher-mapped hotspots with relevant scientific data.
- (ii) Community-Based Bycatch Reporting Scheme: A localised reporting system should be created to formalise the current 26% of incidental reports into a monitoring system.
- (iii) Incentive-Based Live-Release Protocol: To reduce the 25% of bycatch that is consumed and is therefore problematic, non-cash incentives should be offered for the live release of dugongs and cetaceans.
- (iv) Region Specific Educational Campaigns: Priority should be given to Menumbuk, Sipitang, and Labuan, where conservation awareness was the lowest and attitudes were more neutral.

5 CONCLUSION

This study demonstrates that Local Ecological Knowledge (LEK) plays a crucial role in shaping the conservation attitudes of small-scale fishers in Brunei Bay. While baseline LEK regarding marine mammals is moderate, it serves as the strongest predictor of positive conservation attitudes, functioning independently of a fisher's age, experience, or family background. Spatially, these dynamics vary across the bay, with communities like Weston exhibiting

the highest knowledge levels and most supportive attitudes. Consequently, effective marine mammal conservation cannot rely solely on top-down enforcement, since it requires the active involvement of local stakeholders who are most directly impacted by environmental and industrial shifts. Policy frameworks must prioritise community-based co-management and targeted educational outreach to successfully mitigate bycatch and hunting activities. Moving forward, future research should expand to assess the LEK of artisanal fishers in other data-deficient coastal regions of Malaysia to further integrate community-level socio-ecological insights into national marine conservation planning.

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DECLARATIONS

Ethical approval/statement. This research received formal ethical approval from the Institute of Oceanography and Environment (INOS), Universiti Malaysia Terengganu. All study participants were fully informed about the research purpose, their right to withdraw at any time, and the assurance of their personal data confidentially.

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