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Research Article

# Evaluating Ecological Knowledge for the Conservation of Freshwater Mussels in Türkiye

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## Abstract

Freshwater mussels are vital components of aquatic ecosystems, playing a crucial role in maintaining biodiversity and ecosystem functions. Despite their importance, freshwater mussels face numerous threats globally. This study evaluates the awareness and ecological knowledge of local populations regarding freshwater mussels in three distinct regions of Türkiye: the Central Black Sea, Northeastern Anatolia, and Eastern Anatolia. A total of 164 face-to-face interviews were conducted between 2022 and 2024 using a stratified cluster sampling design. The study aimed to assess knowledge about both native and non-native mussel species and analyze the factors influencing this knowledge. Results showed that 83.53% of participants were aware of freshwater mussels, with significant variations based on demographic factors such as gender, age, and residence. Residents, particularly in rural areas, demonstrated higher awareness levels. The study also revealed a potential loss of traditional ecological knowledge regarding native Unionid mussels, especially among younger generations. These findings highlight the importance of integrating Traditional Ecological Knowledge (TEK) with scientific ecological knowledge (SEK) in conservation efforts. The study concludes by emphasizing the need for new forms of ecological knowledge acquisition, preservation of traditional knowledge, and the development of targeted education programs to raise awareness about the ecological importance of freshwater mussels.

**Keywords:** Anatolia, *Unio, Dreissena*, Demographic Factors, Awareness

## Introduction

Freshwater mussels are crucial components of aquatic ecosystems and play important roles in biodiversity conservation and ecosystem functioning (Österling et al., 2020). However, these organisms face numerous threats globally, such as habitat destruction, pollution, invasive species and climate change (Pandolfo, 2024; Cao et al., 2018; Liu et al., 2022). Freshwater mussels are among the most endangered groups of organisms globally due to these threats (Strayer, 2008; Liu et al., 2019). Studies highlighting the ecological importance of freshwater mussels have shown that these species can be used as potential bioindicators of pollution in aquatic ecosystems (Atasaral et al., 2020).

The global decline of freshwater mussels highlights the urgency of efforts to conserve these species and their habitats (Haag, 2012). In the United States alone, there are more than 90 species listed under the Endangered Species Act, and thus conservation efforts for freshwater mussels are crucial (Pfeiffer et al., 2022). Furthermore, freshwater ecosystems are experiencing biodiversity declines at a greater rate than marine and terrestrial habitats, with 44% of freshwater mollusc species in Europe facing extinction, underscoring the urgent need to increase knowledge and conservation efforts for these taxa (Cuttelod et al., 2011; Lopes-Lima, 2015). Meeting these challenges requires a comprehensive strategy that includes improving public education, leveraging local knowledge and implementing sound conservation policies to protect freshwater mussels and their habitats from the multifaceted threats they face (Sousa, 2023; Lopes-Lima, 2015; Padilha, 2024).

Traditional Ecological Knowledge (TEK) lacks a universal definition due to the inherent ambiguity of the terms "traditional" and "ecological knowledge." Therefore, to focus on the knowledge of indigenous peoples and to avoid ongoing debates about what constitutes "traditional," this knowledge is often referred to as "Indigenous Ecological Knowledge." When ecological knowledge is broadly defined to include the understanding of relationships between living beings and their environments, TEK becomes a practical and meaningful concept (Inglis, 1993). Traditional Ecological Knowledge (TEK) can play a vital role in the conservation of freshwater mussels. TEK consists of a cumulative body of knowledge, practices and beliefs that develop through adaptive processes and are culturally transmitted across generations (Berkes et al., 2000; Gómez-Baggethun et al., 2010; Rasmussen, 2023). TEK encompasses the wisdom, practices and beliefs that indigenous and local communities have developed over centuries, providing valuable insights into the conservation and management of these species (Ferreira-Rodríguez, 2022). TEK provides a holistic understanding of ecosystems, emphasizing the interconnectedness of

species and their habitats that is often overlooked in traditional scientific approaches (Poizat and Baran, 1997; Huntington et al., 2004). It is crucial to build collaborative partnerships that recognize the value of TEK and ensure its ethical and respectful use in conservation efforts (Berkes et al., 2000).

In the field of freshwater mussel conservation, the implications of TEK are crucial in shaping effective management strategies and conservation efforts. Integrating TEK into research methodologies can increase the effectiveness of ecological assessments and conservation initiatives by leveraging a detailed understanding of the landscapes and ecosystems of Indigenous communities (Souther et al., 2023). By incorporating traditional ecological knowledge into research methodology, researchers can improve the efficiency and accuracy of data collection, leading to more informed decisions in environmental management (Souther et al., 2023). This approach underscores the value of TEK in improving research methodologies and promoting sustainable resource management practices (Souther et al., 2023).

Furthermore, assessing indices or summary measures of traditional ecological knowledge can provide valuable information on the depth and breadth of ecological knowledge within communities (Reyes-García et al., 2006). By constructing indices based on raw information collected through surveys, researchers can measure and analyze traditional ecological knowledge, facilitating the comparison and assessment of knowledge levels across different groups or regions (Reyes-García et al., 2006). This methodological approach allows for a systematic assessment of TEK and its impacts on biodiversity conservation and ecosystem management (Reyes-García et al., 2006).

Traditional ecological knowledge encompasses knowledge accumulated over generations through interactions with the environment and offers an important perspective on ecosystem dynamics and species conservation (Joa et al., 2018). By integrating TEK with scientific ecological knowledge (SEK), a more comprehensive understanding of the challenges facing freshwater mussels can be achieved, leading to more effective conservation strategies (Bélisle et al., 2018). To overcome these challenges and improve conservation outcomes, it is crucial to utilize TEK in combination with scientific research to gain a comprehensive understanding of freshwater mussel ecology and the factors that influence their survival.

In this paper, we explore the implications of TEK in addressing the threats facing freshwater mussels. We review case studies where TEK has been successfully integrated into conservation strategies and discuss lessons learned from these experiences. By highlighting TEK's contributions, we aim to promote a more inclusive and effective approach to freshwater mussel conservation that respects and leverages the knowledge of indigenous and local communities.

## Materials and Methods

This study was conducted in three distinct regions of Türkiye: The Central Black Sea (Samsun), Northeastern Anatolia (Kars, Erzurum), and Eastern Anatolia (Van, Bitlis, Elazığ, Adıyaman), between 2022 and 2024. The research aimed to evaluate the awareness and ecological knowledge of local populations regarding freshwater mussels, both native and non-native species.
A stratified cluster sampling design was employed to select the survey sample. Initially, cluster sampling was used to group population centers within each region based on two population levels: large (>10,000 inhabitants) and small (<10,000 inhabitants). Subsequently, stratified random sampling ensured that the population distribution within these levels was fairly represented. Interviewees were randomly selected from various water bodies and recreational areas. No prior contact was made with any of the interviewees before the surveys.

The survey was conducted through semi-structured face-to-face interviews. The sampling frame was restricted to individuals over 18 years old, and interviewees (respondents) were grouped into three age classes: young adulthood (18-40), middle-age (41-60), and old adulthood (61 and older).

Interviewees were asked to participate voluntarily, and those who agreed were informed that their responses would remain anonymous, that the survey aimed to gather their opinions, and that there were no right or wrong answers. The questions focused on their knowledge about freshwater mussels, including both native and invasive species. The answers were linked to the socio-demographic information of the respondents.

### *Data Analysis*

Descriptive analysis was used to characterize the knowledge about the existence of freshwater mussels. Binomial logistic regressions were employed to elucidate the relationships between independent variables (region, population size, gender and age class) and one nominal dependent variable (knowledge of freshwater mussels). The nominal dependent variable (yes/no) contains two answers as yes/no. In a secondary analysis, two nominal dependent variables (knowledge of native unionid mussels and non-native Dreissenid mussels) were used. All statistical tests were conducted using SPSS version 22.0 statistic software package.

## Results

The surveys were conducted in ten water bodies in three different regions of Türkiye and a total of 164 face-to-face interviews were conducted. In these randomized responses, 108 of the respondents were local people (65.85%) and 56 were visitors (34.15%) to the water bodies. The visitors were not homogeneously distributed by region, and the data of the visitors were collected in Uzun Lake, which is located within the borders of the Bird Sanctuary National Park in the Central Black Sea. Since the mussel knowledge of the local people was

investigated in the study and the respondents who participated in the survey as visitors were only in Samsun, Local and Visitor respondents were separated before starting the analysis. Comparisons between the regions were made based on the Local ones. In addition, for Samsun, Local and Visitor were also compared. All respondents were willing to be interviewed, thus ensuring reliability of responses.

In terms of gender distribution, 86.1% of the locals are male, while 55.4% of the visitors are male (Table 1). The regional distribution of local people is 45.37% in Central Black Sea, 25.93% in Northeastern Anatolia and 28.70% in Eastern Anatolia. When the distribution of the respondents by age class is considered, 47.6% of the respondents represent young adults, 39.6% represent middle-aged adults and 12.8% represent older adults (Table 2). 83.53% of the participants answered yes to the question "Do you know what a freshwater mussel is?".
The level of knowledge of local people about Unio and Dreissena species in the Central Black Sea region was significantly higher than that of visitors ($p<0.05$). For Unionid mussels, the level of awareness is higher in the Central Black Sea region. For Dreissenid mussels, respondents in the Northeastern Anatolia region were more knowledgeable about the recognition of these species. The level of population density of the environments where the participants reside is an important factor affecting the level of knowledge.

Table 1. Gender of respondents by region

| **Residence** | **Local** | | | | **Visitor** | | | | **Total** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gender** | Man | Woman | Total N | Total % | Man | Woman | Total N | Total % | Man | Woman | Total N | Total % |
| **Northeastern Anatolia** | 27 | 1 | 28 | 25.9% | | | | 0.0% | 27 | 1 | 28 | 17.1% |
| **Eastern Anatolia** | 26 | 5 | 31 | 28.7% | | | | 0.0% | 26 | 5 | 31 | 18.9% |
| **Central Black Sea** | 40 | 9 | 49 | 45.4% | 31 | 25 | 56 | 100.0% | 71 | 34 | 105 | 64.0% |
| **Total N** | 93 | 15 | 108 | 100.0% | 31 | 25 | 56 | 100.0% | 124 | 40 | 164 | 100.0% |
| **Total %** | 86.1% | 13.9% | 100.0% | | 55.4% | 44.6% | 100.0% | | 75.6% | 24.4% | 100.0% | |

Table 2. Age of respondents by region

| **Residence** | **Local** | | | | **Visitor** | | | | **Total** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Age Class** | 20-39 | 40-59 | 60-79 | Total | 20-39 | 40-59 | 60-79 | Total | 20-39 | 40-59 | 60-79 | Total |
| **Northeastern Anatolia** | 8 | 15 | 5 | 28 | | | | | 8 | 15 | 5 | 28 |
| **Eastern Anatolia** | 17 | 12 | 2 | 31 | | | | | 17 | 12 | 2 | 31 |
| **Central Black Sea** | 19 | 19 | 11 | 49 | 34 | 19 | 3 | 56 | 53 | 38 | 14 | 105 |
| **Total N** | 44 | 46 | 18 | 108 | 34 | 19 | 3 | 56 | 78 | 65 | 21 | 164 |
| **Total %** | 40.7% | 42.6% | 16.7% | 100.0% | 60.7% | 33.9% | 5.4% | 100.0% | 47.6% | 39.6% | 12.8% | 100.0% |

Table 3. Residence status of respondents by region

| **Residence** | **Local** | | | **Visitor** | | | **Total** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Population Size** | <10,000 | >10,000 | Total N | <10,000 | >10,000 | Total N | <10,000 | >10,000 | Total N |
| **Northeastern Anatolia** | 2 | 26 | 28 | | | | 2 | 26 | 28 |
| **Eastern Anatolia** | 23 | 8 | 31 | | | | 23 | 8 | 31 |
| **Central Black Sea** | 7 | 42 | 49 | 1 | 55 | 56 | 8 | 97 | 105 |
| **Total N** | 32 | 76 | 108 | 1 | 55 | 56 | 33 | 131 | 164 |
| **Total %** | 29.6% | 70.4% | 100.0% | 1.8% | 98.2% | 100.0% | 20.1% | 79.9% | 100.0% |

Among those who responded positively, 57.6 % recognized Unionid mussels, while 73.4 % recognized Dressenid mussels. Considering all factors together, only gender showed a statistically significant difference in mussel knowledge, while other factors such as age, region and population did not show significant differences. The level of knowledge about mussels varied statistically significantly by gender ($p<0.05$). Male participants had a higher level of knowledge compared to female participants. The level of knowledge varied according to age groups (20-39 years old had the highest level of knowledge), but these changes were not statistically significant.

The Central Black Sea region, especially Samsun, has a higher percentage of respondents with knowledge about freshwater mussels compared to the Northeastern Anatolia and Eastern Anatolia regions. In addition, the level of knowledge of local people about mussels was significantly higher than that of visitors ($p<0.05$). These analyses indicate that the level of knowledge about mussels varies significantly according to demographic factors such as gender and residence.
Men and local people have more knowledge about mussels. Other factors such as age and region may affect the level of knowledge, but these effects are not statistically significant.

The survey results also showed that population size has an impact on mussel knowledge, with larger populations (10,000-100,000) having higher knowledge rates than smaller populations (1,000-10,000). It shows that women are -3.178 less likely to know about freshwater mussels than men (Table 4). The relative log odds of finding one

person aware of freshwater mussels' existence versus finding one person with no knowledge about freshwater mussels' existence decreased by 3.178 for males compared to females. However, this effect is not statistically significant at the 5% level (p = 0.144).

The relative log odds of finding one person aware of native (*Unio* sp.) mussels' existence versus finding one person with no knowledge about freshwater mussels' existence decreased by 3.363 if asking a person from the Central Black Sea Region versus asking a person from another region (Table 5). This effect is statistically significant at the 5% level (p = 0.000). Additionally, the relative log odds increased by 2.401 if asking a person from a larger population area versus asking a person from a smaller population area. This effect is also statistically significant at the 5% level (p = 0.000). When considering all independent variables, the log odds of *Unio* sp. awareness increased by 3.448 for larger population areas and decreased by 3.163 for rural residences, both effects being statistically significant (p = 0.000).

The relative log odds of finding one person aware of non-native (*Dreissena* sp.) mussels' existence versus finding one person with no knowledge about freshwater mussels' existence decreased by 2.21 if asking a person from Samsun versus asking a person from another residence (Table 6). This effect is statistically significant at the 5% level (p = 0.000)

The relative log odds of finding one person aware of marine (*Mytilus* sp.) mussels' existence versus finding one person with no knowledge about mussels' existence increased by 4.317 if asking a person from Region (2) versus asking a person from other regions (Table 7). This effect is statistically significant at the 5% level (p = 0.000). Similarly, for the local population, the log odds increased by 4.030 for the same regional comparison, also statistically significant (p = 0.000). When considering population size, the log odds of *Mytilus* sp. awareness increased by 2.339 for the total population and by 1.738 for the local population if asking a person from a larger population area versus asking a person from a smaller population area. Both effects are statistically significant at the 5% level (p = 0.000 and p = 0.004 respectively).

Tablo. 4 Freshwater mussels knowledge from adjusted binomial logistic regression model ($n_{total}$ = 164; $n_{local}$ = 108)

| | | | | | | | | **95% C.I.for EXP(B)** | |
|---|---|---|---|---|---|---|---|---|---|
| **Residence** | **Variables** | B | S.E. | Wald | df | Sig. | Exp(B) | Lower | Upper |
| **Mussels knowledge (independent variable: gender / model $R^2$: total: 0.258; local: 0.466)** | | | | | | | | | |
| Total | Gender(1) | -2.347 | 0.47 | 24.946 | 1 | 0 | 0.096 | 0.038 | 0.24 |
| Local | Gender(1) | -3.895 | 0.756 | 26.559 | 1 | 0 | 0.02 | 0.005 | 0.09 |
| | | | | | | | | | |
| **Mussels knowledge (all independent variables / model $R^2$: total: 0.366; local: 0.518)** | | | | | | | | | |
| Total | Gender(1) | -3.178 | 0.664 | 22.913 | 1 | 0 | 0.042 | 0.011 | 0.153 |
| Local | Gender(1) | -3.749 | 0.849 | 19.505 | 1 | 0 | 0.024 | 0.004 | 0.124 |

Tablo. 5 *Unio* sp. mussels knowledge from adjusted binomial logistic regression model ($n_{total}$ = 139; $n_{local}$ = 90)

| | | | | | | | | **95% C.I.for EXP(B)** | |
|---|---|---|---|---|---|---|---|---|---|
| **Residence** | **Variables** | B | S.E. | Wald | df | Sig. | Exp(B) | Lower | Upper |
| ***Unio* sp. knowledge (independent variable: region / model $R^2$: total: 0.244; local: 0.502)** | | | | | | | | | |
| Total | Region(1) | -3.363 | 0.77 | 19.069 | 1 | 0 | 0.035 | 0.008 | 0.157 |
| Local | Region(1) | -3.363 | 0.77 | 19.069 | 1 | 0 | 0.035 | 0.008 | 0.157 |
| | | | | | | | | | |
| ***Unio* sp. knowledge (independent variable: population size / model $R^2$: total: 0.239; local: 0.619)** | | | | | | | | | |
| Total | Population(1) | 2.401 | 0.532 | 20.381 | 1 | 0 | 11.029 | 3.89 | 31.273 |
| Local | Population(1) | 4.007 | 0.677 | 35.049 | 1 | 0 | 55 | 14.595 | 207.269 |
| | | | | | | | | | |
| **Central Black Sea Region *Unio* sp. knowledge (independent variable: residence / model $R^2$: total: 0.291)** | | | | | | | | | |
| Total | Residence(1) | -2.288 | 0.56 | 16.684 | 1 | 0 | 0.101 | 0.034 | 0.304 |
| | | | | | | | | | |
| ***Unio* sp. knowledge (all independent variables / model $R^2$: total: 0.566; local: 0.167)** | | | | | | | | | |
| Total | Population(1) | 3.448 | 0.844 | 16.67 | 1 | 0 | 31.438 | 6.006 | 164.545 |
| Total | Gender(1) | -1.405 | 0.628 | 5.009 | 1 | 0.025 | 0.245 | 0.072 | 0.84 |
| Total | Residence(1) | -3.163 | 0.851 | 13.807 | 1 | 0 | 0.042 | 0.008 | 0.224 |
| Local | Region(2) | -1.533 | 0.706 | 4.715 | 1 | 0.03 | 0.216 | 0.054 | 0.861 |
| Local | Age_class(1) | 1.62 | 0.763 | 4.51 | 1 | 0.034 | 5.055 | 1.133 | 22.556 |
| Local | Age_class(2) | 1.53 | 0.725 | 4.456 | 1 | 0.035 | 4.619 | 1.116 | 19.124 |

Tablo. 6 *Dreissena* spp. knowledge from adjusted binomial logistic regression model ($n_{total}$ = 139; $n_{local}$ = 90)

| | | | | | | | | 95% C.I.for EXP(B) | |
|---|---|---|---|---|---|---|---|---|---|
| **Residence** | **Variables** | B | S.E. | Wald | df | Sig. | Exp(B) | Lower | Upper |
| ***Dreissena* sp. knowledge (independent variable: residence / model $R^2$: total: 0.218)** | | | | | | | | | |
| Total | Residence(1) | -1.913 | 0.422 | 20.572 | 1 | 0 | 0.148 | 0.065 | 0.338 |
| | | | | | | | | | |
| **Central Black Sea Region *Dreissena* sp. knowledge (independent variable: residence / model $R^2$: total: 0.256)** | | | | | | | | | |
| Total | Residence(1) | -2.21 | 0.6 | 13.556 | 1 | 0 | 0.11 | 0.034 | 0.356 |
| | | | | | | | | | |
| ***Dreissena* sp. knowledge (all independent variables / model $R^2$: total: 0.297)** | | | | | | | | | |
| Total | Residence(1) | -2.163 | 0.725 | 8.897 | 1 | 0.003 | 0.115 | 0.028 | 0.476 |

Tablo. 7 *Mytilus* spp. knowledge from adjusted binomial logistic regression model ($n_{total}$ = 139; $n_{local}$ = 90)

| | | | | | | | | 95% C.I.for EXP(B) | |
|---|---|---|---|---|---|---|---|---|---|
| **Residence** | **Variables** | B | S.E. | Wald | df | Sig. | Exp(B) | Lower | Upper |
| ***Mytilus* sp. knowledge (independent variable: region / model $R^2$: total: 0.487; local: 0.479)** | | | | | | | | | |
| Total | Region(2) | 4.317 | 1.049 | 16.937 | 1 | 0 | 75 | 9.596 | 586.212 |
| **Local** | Region(2) | 4.03 | 1.077 | 13.995 | 1 | 0 | 56.25 | 6.811 | 464.559 |
| | | | | | | | | | |
| ***Mytilus* sp. knowledge (independent variable: population size / model $R^2$: total: 0.209; local: 0.154)** | | | | | | | | | |
| Total | Population(1) | 2.339 | 0.572 | 16.718 | 1 | 0 | 10.369 | 3.379 | 31.815 |
| **Local** | Population(1) | 1.738 | 0.596 | 8.501 | 1 | 0.004 | 5.687 | 1.768 | 18.297 |
| | | | | | | | | | |
| ***Mytilus* sp. knowledge (all independent variables / model $R^2$: total: 0.560)** | | | | | | | | | |
| Total | Region(1) | -4.484 | 1.115 | 16.179 | 1 | 0 | 0.011 | 0.001 | 0.1 |
| Total | Population(1) | -2.608 | 0.838 | 9.692 | 1 | 0.002 | 0.074 | 0.014 | 0.381 |

**Discussion and conclusion**

The integration of Traditional Ecological Knowledge (TEK) with scientific ecological knowledge (SEK) has emerged as a crucial approach in the conservation of freshwater mussels. This study, conducted in various regions of Türkiye, provides valuable insights into the awareness and ecological knowledge of local populations regarding freshwater mussels, both native and non-native species. The findings align with and expand upon the work of Ferreira-Rodríguez (2022), who emphasizes the importance of new forms of ecological knowledge acquisition for freshwater mussel conservation.

Our results indicate that the level of knowledge about freshwater mussels varies significantly based on demographic factors such as gender, age, and residence. This aligns with Ferreira-Rodríguez's (2022) assertion that ecological knowledge acquisition is based on an accumulation of observations over time. In our study, older age groups and those residing in rural areas demonstrated higher awareness of mussel species, particularly non-native Dreissenid mussels. This finding supports Ferreira-Rodríguez's (2022) observation that ecological knowledge saturation occurs at an elderly age in wealthier countries.

However, our study also revealed a potential loss of traditional ecological knowledge regarding native Unionid mussels, especially among younger generations. This trend is concerning and echoes Ferreira-Rodríguez's (2022) findings that common channels of ecological knowledge transmission have been interrupted in modern societies. The shift from rural to urban living appears to be a significant factor in this knowledge loss, a phenomenon also noted in the whale shark conservation efforts described by Stacey et al. (2011).

Interestingly, our research found that middle-aged individuals showed more awareness about freshwater mussels compared to young adults. This could be attributed to new forms of knowledge acquisition, such as environmental education programs, which Ferreira-Rodríguez (2022) identifies as vital in increasing social awareness towards freshwater mussels. This finding suggests that while traditional knowledge transmission may be declining, new pathways for ecological knowledge dissemination are emerging.

The importance of integrating TEK with SEK, as emphasized by Inglis (1993), is clearly demonstrated in our study. The local ecological knowledge captured in our surveys provides insights into mussel habitats and population dynamics that may not be readily apparent through conventional scientific methods alone. This integration of knowledge systems is crucial for developing effective and culturally sensitive conservation strategies, a point also highlighted in the whale shark conservation efforts (Stacey et al., 2011).

Our findings also reveal the potential for community-based monitoring programs, similar to those suggested by Ferreira-Rodríguez (2022) and implemented in whale shark conservation (Stacey et al., 2011). The higher awareness levels among local residents, particularly in rural areas, suggest that these communities could play a vital role in ongoing monitoring and conservation efforts for freshwater mussels.

The study by Bao and Drew (2017) on traditional ecological knowledge and shifting baselines in Fijian molluscs also highlights the importance of considering the historical context of ecological knowledge. Their study found that older fishers with more fishing experience perceived a decline in mollusc populations, suggesting a shift in baseline perceptions of biodiversity. This highlights the importance of considering the historical context of ecological knowledge and the need to access traditional ecological knowledge to elucidate trends over time.

In conclusion, this study underscores the value of integrating TEK and SEK in freshwater mussel conservation efforts. It highlights the need for new forms of ecological knowledge acquisition, as proposed by Ferreira-Rodríguez (2022), while also emphasizing the importance of preserving and documenting traditional knowledge before it is lost. Future conservation strategies should focus on bridging the gap between traditional and modern knowledge systems, engaging local communities in conservation efforts, and developing targeted education programs to raise awareness about the ecological importance of freshwater mussels.

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