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Astronomical Knowledge and Cardinal Directions among the Coastal Communities of Medan amid Climate Change

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ABSTRACT

This study examines the knowledge of constellations and cardinal directions among the Malay coastal community in Medan as part of a traditional knowledge system (Ilmu Falak) used in maritime activities and sea-based livelihoods, particularly in the context of climate change. Drawing upon the cultural framework proposed by Koentjaraningrat, Ilmu Falak is understood as an element of a knowledge system transmitted across generations and serving both practical and symbolic functions. The Malay astronomical tradition is historically connected to the development of Islamic astronomy, which flourished during the era of scholars such as Al-Khwarizmi, Al-Farghani, and Nasir al-Din al-Tusi, and was documented in classical manuscripts such as Sulalatus Salatin.

This research employs a qualitative method with historical and ethnographic approaches through literature studies, interviews with coastal fishermen in Medan, and comparison with contemporary meteorological data. The findings show that Malay coastal communities utilize the positions of constellations, seasonal wind directions, lunar phases, and natural signs as guides for navigation and weather prediction. However, shifts in seasonal patterns caused by global climate change have affected the accuracy of several traditional indicators. Nevertheless, Malay astronomical knowledge still possesses adaptive value, particularly when integrated with modern scientific data.

This study emphasizes that Malay Ilmu Falak is not merely a cultural heritage but also a form of ecological wisdom that remains relevant in contemporary contexts. The integration of local knowledge and modern science is essential to strengthen the resilience of coastal communities facing increasingly unpredictable climate dynamics.

INTRODUCTION

Indonesia is a country endowed with diverse natural resources, cultures, cuisines, and natural wealth that attract both domestic and international tourists. One of its most distinctive aspects is its multicultural heritage, including the Malay ethnic group in North Sumatra. The term *Malay* is generally used to identify people belonging to the Austronesian cultural and linguistic family that spans the Malay Peninsula, the Indonesian archipelago, the Philippine islands, and several islands in the South Pacific Ocean. In a broader sense, Malays are people categorized within the Malay racial group, which historically consists of a mixture of various ethnic groups across the archipelago.

The Malay race that embraced Islam in the 13th century developed a cultural identity that was often distinguished from inland Proto-Malay communities such as the Batak Toba, Karo, Simalungun, and Pakpak-Dairi, who maintained their own traditional belief systems. Nevertheless, assimilation processes also occurred, particularly when Batak communities converted to Islam and adopted elements of Malay culture.

The uniqueness of Malay culture is closely linked to its environmental context. According to Koentjaraningrat, culture is a comprehensive system of ideas, actions, and human creations within social life that are learned and shared by members of society (1990:180). Koentjaraningrat also identifies universal elements of culture, including religious systems and ceremonies, social organization, knowledge systems, language, arts, livelihood systems, and technological systems with their associated tools.

One distinctive element within this cultural system is the knowledge of *Ilmu Falak* (astronomical science). This body of knowledge forms part of the knowledge system used by coastal Malay communities to assist maritime navigation, as their economic activities and livelihoods are closely connected to the sea.

Malay *Ilmu Falak* represents an ancient scientific tradition and one of the most significant intellectual heritages of the Malay world, although today it is increasingly rare to find in its original form. Historically, this knowledge contributed to scientific understanding, particularly in astronomy. Through this tradition, Malay communities developed knowledge about natural phenomena, weather patterns, celestial bodies, and environmental cycles.

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In the wider Malay world, Islamic astronomy also developed significantly and influenced local traditions of celestial observation and navigation.

LITERATURE REVIEW

Traditional Ecological Knowledge (TEK) refers to a cumulative body of knowledge, practices, and beliefs developed by local communities through long-term interactions with their natural environment. This knowledge is transmitted across generations through cultural traditions, oral narratives, and daily practices. In coastal communities, traditional ecological knowledge plays an important role in helping fishermen interpret environmental signals such as wind direction, ocean currents, seasonal changes, and celestial phenomena used for navigation and fishing activities. TEK is not only a cultural heritage but also a practical knowledge system that supports sustainable resource management and community resilience (Morales-Bojórquez et al., 2021; Shaffril et al., 2025).

Recent studies emphasize that indigenous and local knowledge systems remain highly relevant in addressing environmental challenges. Small-scale fishers in many coastal regions rely heavily on traditional weather prediction methods, including observations of clouds, wind patterns, star positions, and sea conditions to determine safe fishing periods (Shaffril et al., 2025).

Traditional ecological knowledge also contributes to sustainable fisheries management by providing long-term observations of marine ecosystems. Communities that depend directly on marine resources often possess detailed knowledge about fish migration patterns, seasonal cycles, and environmental indicators. This knowledge enables local communities to adjust their fishing activities to environmental changes and helps prevent overexploitation of marine resources (Morales-Bojórquez et al., 2021).

Moreover, TEK provides a localized understanding of environmental dynamics that may not always be captured through short-term scientific monitoring. In many developing regions, local ecological knowledge has proven valuable for identifying environmental changes earlier than formal scientific observations because it is based on long-term empirical experience (Santos et al., 2023).

Climate change is widely recognized as one of the most significant global environmental challenges affecting coastal ecosystems and fisheries. Rising sea surface temperatures, changing ocean circulation patterns, sea-level rise, and increasing frequency of extreme weather events have disrupted marine ecosystems worldwide. These environmental changes significantly affect fish stocks, fishing productivity, and the economic stability of coastal communities (Rekarti et al., 2025).

Research indicates that climate change creates significant uncertainties in the marine environment, making traditional fishing practices more difficult to maintain. Changes in wind patterns, ocean currents, and seasonal cycles directly influence fishing activities and the availability of marine resources (Santos et al., 2023).

Small-scale fishing communities are particularly vulnerable to climate change because their livelihoods depend heavily on natural environmental conditions. When weather patterns become unpredictable, fishermen face greater risks during fishing operations, including stronger waves, unexpected storms, and declining fish catches (Kouadio et al., 2024).

In addition to environmental impacts, climate change also affects the social and economic conditions of fishing communities. Reduced fishing productivity can threaten food security and increase poverty levels among coastal populations. Consequently, fishing communities must develop adaptive strategies to maintain their livelihoods and reduce vulnerability to environmental changes (Rekarti et al., 2025).

In response to climate change, many coastal communities have developed adaptation strategies to maintain their livelihoods. Climate adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climate-related stimuli. These adaptations aim to reduce vulnerability and increase resilience in the face of environmental change (Shaffril et al., 2025).

Several studies identify key adaptation strategies commonly adopted by fishing communities. These include diversification of fishing techniques, modification of fishing gear, livelihood diversification, and the adoption of new technologies such as satellite weather forecasts and GPS navigation systems (Shaffril et al., 2025; Santos et al., 2023).

Adaptive capacity is influenced by several factors, including access to information, education, social networks, and institutional support. Communities with strong social cohesion and knowledge-sharing systems tend to demonstrate greater resilience when facing environmental challenges (Woods, 2022).

In many cases, successful adaptation strategies involve integrating traditional knowledge with modern scientific approaches. This integration allows communities to combine long-term ecological observations with contemporary technological tools, resulting in more effective decision-making processes (Morales-Bojórquez et al., 2021).

Local knowledge systems have gained increasing attention in climate change research due to their potential to complement scientific knowledge. Local knowledge provides valuable insights into environmental changes that may not be immediately visible through conventional scientific monitoring methods. For example, fishermen often detect shifts in wind direction, ocean currents, and fish migration patterns long before these changes are documented in official climate records (Santos et al., 2023).

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Studies conducted in Southeast Asia show that traditional knowledge significantly contributes to community resilience in coastal regions. Fishermen who maintain traditional environmental observation practices often demonstrate greater capacity to anticipate environmental risks and adjust their fishing strategies accordingly (Shaffril et al., 2025).

Traditional knowledge systems also play an important role in strengthening social cohesion within communities. Knowledge transmission occurs through intergenerational learning processes, where experienced fishermen teach younger generations how to interpret natural signs and environmental indicators (Woods, 2022).

In addition, local knowledge contributes to community-based natural resource management. Many coastal communities have developed informal rules regulating fishing seasons, fishing zones, and gear usage based on traditional ecological observations (Morales-Bojórquez et al., 2021).

Astronomical knowledge has historically played a significant role in maritime navigation across many coastal societies. Before the introduction of modern navigation technologies, sailors and fishermen relied heavily on celestial bodies such as stars, the moon, and the sun to determine direction, time, and seasonal changes. This practice, commonly referred to as celestial navigation, enabled seafarers to travel long distances across oceans without modern instruments.

Celestial navigation is based on observing the positions of stars and constellations relative to the horizon. These observations allow navigators to determine geographic direction and approximate location. In traditional maritime cultures, constellations serve as navigational references that guide fishermen during nighttime voyages (Santos et al., 2023).

In the Malay maritime tradition, astronomical knowledge is closely related to the concept of *Ilmu Falak*, which integrates scientific observation with practical navigation techniques. Historically, Malay seafarers used star constellations, wind patterns, and ocean currents to navigate across the Malacca Strait and other regional maritime routes. This knowledge system played a crucial role in supporting trade networks and maritime activities throughout Southeast Asia.

Furthermore, astronomical knowledge in maritime societies often contains cultural and spiritual dimensions. Observations of celestial bodies are not only used for navigation but also for determining religious calendars, ritual timing, and seasonal cycles that influence fishing activities.

METHOD

This study employed a mixed-method research design, combining qualitative ethnographic approaches with quantitative statistical analysis. The qualitative approach aimed to explore the cultural meaning and transmission of traditional astronomical knowledge (*Ilmu Falak*) among Malay coastal communities. Meanwhile, the quantitative component was used to statistically analyze patterns in fishermen's environmental observations, navigation practices, and perceived climate changes.

The integration of qualitative and quantitative methods allows for a more comprehensive understanding of how traditional astronomical knowledge functions within coastal societies and how it adapts to environmental changes.

The study was conducted in several coastal areas of Deli Serdang Regency, North Sumatra, particularly in fishing communities located near the eastern coast of Sumatra, including Paluh Sibaji Village.

The population of the study consisted of local fishermen who actively engage in marine fishing activities and possess traditional knowledge related to navigation, wind direction, and celestial observations.

A purposive sampling technique was used to select participants based on specific criteria:

1. Fishermen with at least 10 years of fishing experience
2. Fishermen who frequently conduct night fishing activities
3. Fishermen who possess knowledge related to traditional navigation or star observation

A total of 60 respondents were selected for quantitative data collection, while 15 key informants (senior fishermen and community elders) participated in in-depth qualitative interviews.

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Table 1. Data Collection Techniques

No	Method	Description	Data Source	Purpose
1	Literature Study	Review of scientific articles, books, and reports related to traditional ecological knowledge, maritime astronomy, coastal communities, and climate change published between 2021–2025.	Academic journals, books, climate reports, and previous research	To build theoretical foundations and identify research gaps related to traditional astronomical knowledge and coastal adaptation strategies
2	Field Observation	Direct observation of fishermen's activities in interpreting natural signs such as wind direction, wave patterns, lunar phases, and star constellations during fishing activities.	Coastal fishermen in Deli Serdang and Paluh Sibaji Village	To document real practices of traditional navigation and environmental interpretation used by fishermen
3	In-depth Interview	Semi-structured interviews with experienced fishermen and community leaders regarding knowledge transmission, navigation practices, and climate change experiences.	15 key informants (senior fishermen and community elders)	To explore cultural meanings, traditional knowledge transmission, and adaptation strategies
4	Questionnaire Survey	Distribution of structured questionnaires using a Likert scale (1–5) to measure fishermen's knowledge, perception of climate change, and use of navigation technology.	60fishermen respondents	To obtain quantitative data that can be statistically analyzed regarding traditional knowledge and climate adaptation

Statistical Data Analysis

Quantitative data were analyzed using descriptive and inferential statistical techniques with statistical software such as SPSS.

Descriptive Statistics

Descriptive statistics were used to summarize respondent characteristics and survey responses. The analysis included:

- Frequency distribution
- Percentage
- Mean score
- Standard deviation

The mean score formula used in the analysis is:

$$\bar{X} = \frac{\sum X}{N}$$

Where:
X = total score
N = number of respondents

This analysis helps identify the dominant knowledge patterns among fishermen regarding traditional navigation practices.

Reliability Test

To ensure the reliability of the questionnaire instrument, **Cronbach's Alpha reliability testing** was conducted. The formula used:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum S_i^2}{S_t^2}\right)$$

Where:
α = Cronbach's Alpha coefficient
k = number of questionnaire items
Si^2 = variance of each item
St^2 = total variance

A reliability coefficient greater than **0.70** indicates acceptable reliability for research instruments.

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Correlation Analysis

Pearson correlation analysis was conducted to examine the relationship between:

- Traditional astronomical knowledge
- Climate change perception
- Adaptation strategies among fishermen

The correlation formula used:

$$r = \frac{\sum(X - \bar{X})(Y - \bar{Y})}{\sqrt{\sum(X - \bar{X})^2 \sum(Y - \bar{Y})^2}}$$

Where:
r = correlation coefficient
X = independent variable
Y = dependent variable

The correlation results were interpreted as follows:

Table 2. Correlation Interpretation

r value	Interpretation
0.00–0.19	Very weak
0.20–0.39	Weak
0.40–0.59	Moderate
0.60–0.79	Strong
0.80–1.00	Very strong

Simple linear regression analysis was used to examine the influence of traditional astronomical knowledge on fishermen's adaptation strategies to climate change.

The regression model used:

$$Y = a + bX + e$$

Where:
Y = adaptation strategy
X = traditional astronomical knowledge
a = constant
b = regression coefficient
e = error term

This analysis helps determine whether traditional knowledge significantly influences fishermen's ability to adapt to climate variability.

RESULT

This section presents the empirical findings obtained from the statistical analysis conducted in this study. The results include descriptive statistics, correlation analysis, and regression analysis to examine the relationships between traditional astronomical knowledge, wind direction knowledge, climate change perception, and fishermen's adaptation strategies.

The descriptive statistics show that fishermen in the study area still possess relatively strong traditional knowledge related to natural navigation and environmental observation. Traditional astronomical knowledge has a relatively high average score, indicating that fishermen continue to rely on the observation of stars to determine direction and timing when fishing. Similarly, knowledge of wind direction shows the highest mean value among the variables, suggesting that understanding seasonal wind patterns remains a crucial factor in planning fishing activities.

In terms of climate change perception, the results indicate that fishermen are moderately aware of environmental changes affecting their fishing patterns. Many respondents reported experiencing shifts in seasonal wind patterns, wave intensity, and weather conditions that influence their daily fishing decisions. Adaptation strategies also show relatively high mean values, indicating that fishermen have developed various ways to respond to environmental uncertainty, such as adjusting fishing schedules, changing fishing locations, and combining traditional knowledge with modern navigation technologies.

Meanwhile, the use of modern navigation technology shows a slightly lower mean value compared to traditional knowledge variables. This suggests that although technologies such as GPS and mobile navigation applications are increasingly available, traditional navigation methods based on stars and wind directions remain highly relevant among

fishermen.

Table 4. Descriptive Statistics of Research Variables

Variable		Mean	Std. Deviation	Minimum	Maximum
Traditional Astronomical Knowledge	0	4.12	0.58	3.00	5.00
Wind Direction Knowledge	60	4.25	0.51	3.20	5.00
Climate Change Perception	60	3.96	0.63	2.80	5.00
Adaptation Strategies	60	4.08	0.55	3.00	5.00
Use of Modern Navigation Technology	60	3.54	0.71	2.10	5.00

The correlation analysis was conducted to examine the relationships between the key variables in this study. The results indicate a strong positive relationship between traditional astronomical knowledge and fishermen's adaptation strategies. This finding suggests that fishermen who possess stronger traditional knowledge are better able to adapt to environmental and climate-related changes.

Wind direction knowledge also shows a significant positive relationship with adaptation strategies, highlighting the importance of understanding seasonal wind patterns in making fishing decisions. In addition, climate change perception is moderately correlated with both traditional knowledge and adaptation strategies, indicating that fishermen who are more aware of environmental changes tend to develop stronger adaptive responses.

The results of the Pearson correlation analysis are presented in Table 5.

Table 5. Pearson Correlation Matrix

Variables	1	2	3	4	5
1. Traditional Astronomical Knowledge	1				
2. Wind Direction Knowledge	.62**	1			
3. Climate Change Perception	.45**	.48**	1		
4. Adaptation Strategies	.67**	.59**	.53**	1	
5. Modern Navigation Technology	.32*	.28*	.41**	.46**	1

Notes:
* $p < 0.05$
** $p < 0.01$

Interpretation:

The correlation analysis reveals a strong relationship between traditional astronomical knowledge and fishermen's adaptation strategies ($r = 0.67$, $p < 0.01$). This indicates that fishermen who possess higher levels of traditional knowledge are more capable of adapting to environmental changes. Additionally, wind direction knowledge also shows a strong correlation with adaptation strategies ($r = 0.59$, $p < 0.01$).

To further examine the influence of traditional knowledge variables on fishermen's adaptation strategies, a multiple regression analysis was conducted. The results indicate that traditional astronomical knowledge has the strongest effect on adaptation strategies. This suggests that knowledge of star positions and celestial patterns plays a significant role in guiding fishermen's responses to changing environmental conditions. Wind direction knowledge also significantly contributes to adaptation strategies, although the effect is smaller compared to astronomical knowledge. Climate change perception shows a positive and statistically significant effect, indicating that awareness of environmental changes can encourage fishermen to adopt adaptive behaviors. Overall, the regression model explains approximately half of the variance in fishermen's adaptation strategies, suggesting that traditional ecological knowledge remains a major factor influencing adaptive decision-making. The regression results are presented in Table 6.

Table 6. Regression Analysis Results

Variable	B	Std. Error	Beta	t	Sig.
Constant	1.124	0.421	—	2.67	0.010
Traditional Astronomical Knowledge	0.48	0.09	0.52	5.21	0.000
Wind Direction Knowledge	**0.31**	**0.11**	**0.29**	**2.81**	**0.007**
Climate Change Perception	0.22	0.10	0.21	2.20	0.032

The regression analysis indicates that traditional astronomical knowledge significantly influences fishermen's adaptation strategies ($\beta = 0.52$, $p < 0.001$). The model explains approximately **50% of the variance** in adaptation strategies ($R^2 = 0.50$), suggesting that traditional knowledge plays an important role in helping fishermen respond to environmental changes.

DISCUSSION

The findings of this study highlight the continuing importance of traditional ecological knowledge among fishermen in navigating environmental uncertainties and adapting to changing climate conditions. The results indicate that traditional astronomical knowledge remains a significant factor influencing fishermen's adaptation strategies. This

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finding suggests that knowledge of celestial bodies, including the observation of stars and their positions, continues to play an important role in guiding fishing activities and determining navigation routes.

The strong relationship between traditional astronomical knowledge and adaptation strategies reflects the persistence of indigenous navigation systems that have been passed down through generations. These systems allow fishermen to interpret natural signs such as star patterns, moon phases, and seasonal indicators to predict weather conditions and determine the most appropriate time to go fishing. This finding is consistent with previous studies on traditional ecological knowledge, which emphasize the role of accumulated local knowledge in supporting sustainable resource management and environmental adaptation.

In addition, knowledge of wind direction also shows a significant contribution to fishermen's adaptive behavior. Seasonal wind patterns are essential indicators used by fishermen to determine fishing routes, identify safe sailing conditions, and estimate the potential availability of fish. The ability to interpret wind patterns enables fishermen to respond more effectively to environmental variability, particularly in coastal areas where weather conditions can change rapidly.

The results also indicate that fishermen demonstrate moderate levels of climate change perception. Many respondents reported experiencing changes in seasonal patterns, including shifts in wind directions, increasing wave intensity, and unpredictable weather conditions. These observations align with broader scientific findings that highlight the growing impact of climate variability on coastal and marine environments. Fishermen's experiential knowledge therefore provides valuable insights into localized environmental changes that may not always be captured through formal scientific monitoring.

Furthermore, although modern navigation technologies such as GPS devices and mobile navigation applications are increasingly accessible, the findings suggest that fishermen still rely heavily on traditional knowledge systems. Rather than replacing traditional practices, modern technologies tend to complement them. This integration of traditional and modern knowledge reflects a hybrid adaptation strategy that allows fishermen to maintain cultural practices while benefiting from technological advancements.

Overall, the findings of this study demonstrate that traditional astronomical knowledge and wind direction knowledge remain crucial components of fishermen's adaptive capacity. These forms of knowledge not only support navigation and fishing efficiency but also strengthen fishermen's resilience in facing environmental and climate-related changes. Recognizing and preserving such traditional knowledge is therefore essential for developing sustainable coastal management policies and climate adaptation strategies.

CONCLUSION

This study examines the role of traditional astronomical knowledge and wind direction knowledge in shaping fishermen's adaptation strategies to environmental and climate-related changes. The findings indicate that traditional knowledge remains a crucial component in supporting fishermen's navigation practices and decision-making processes. Fishermen continue to rely on observations of celestial bodies and seasonal wind patterns to determine fishing routes, predict weather conditions, and plan fishing activities.

The results also demonstrate that traditional astronomical knowledge has a significant influence on fishermen's adaptation strategies. This suggests that inherited knowledge systems, which have been developed and transmitted across generations, play an important role in helping fishing communities respond to environmental uncertainties. In addition, knowledge of wind direction contributes significantly to adaptive behavior, highlighting the importance of environmental awareness in traditional fishing practices.

Although modern navigation technologies are increasingly available, the study finds that fishermen tend to integrate these tools with traditional knowledge rather than replacing it entirely. This combination of traditional and modern knowledge forms a hybrid adaptation strategy that strengthens fishermen's resilience in dealing with climate variability and environmental changes.

Overall, this study emphasizes the importance of recognizing and preserving traditional ecological knowledge as part of sustainable coastal management and climate adaptation efforts. Incorporating local knowledge into policy frameworks and fisheries management programs can enhance community-based adaptation strategies and support the long-term sustainability of coastal livelihoods.

Future research may further explore the integration of traditional knowledge with modern technological systems in fisheries management and investigate how such knowledge can contribute to broader climate resilience strategies in coastal communities.

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