READING A DYNAMIC SEA: MARITIME PRACTICES IN RESPONSE TO WIND-WAVE CONDITIONS IN KARIMUNJAWA, JAVA SEA

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ABSTRACT

The sea is a constantly changing physical environment, as wind conditions can influence the formation and development of waves. These conditions are part of coastal communities' everyday lives because fishers directly encounter changes in the sea through their daily maritime activities. Repeated experiences subsequently shape local knowledge, which is used to understand environmental conditions and determine appropriate actions. This study aims to explain the wind and wave conditions encountered by the coastal community of Karimunjawa, how fishers perceive and interpret changes in these conditions, and how such changes influence the community's maritime practices. This study employs a qualitative method with an interdisciplinary approach and an ethnographic case study design. Data were collected through observations of maritime activities, everyday interactions, naturalistic and informal conversations, field notes, documentation, as well as physical data obtained from scientific sources and credible datasets. The findings indicate that (1) wind and wave conditions in Karimunjawa are dynamic and vary across time and location, making them an integral part of the physical environment encountered by the coastal community; (2) fishers understand changes in sea conditions through observation, experience, memory, and knowledge exchange, which shape fishers' knowledge as part of local ecological knowledge; and (3) changes in wind and wave conditions can influence maritime practices through adjustments in timing, location, fishing gear, fishing strategies, and economic activities. Therefore, wind and wave conditions should not be understood solely as physical phenomena, but also as part of the relationship between the environment, local knowledge, and the everyday practices of the Karimunjawa coastal community.

Keywords : *Wind And Wave Conditions, Karimunjawa, Local Ecological Knowledge, Maritime Practices, Coastal Community.*

INTRODUCTION

The sea is a constantly changing physical environment because wind conditions can cause changes on the sea surface. Surface waves are formed through the transfer of energy from the wind to the water surface, allowing wave conditions to develop in response to wind conditions (Csanady, 2001). Previous research has shown that waves can begin to form when wind speed reaches approximately 1.8 m/s, indicating that even small changes in wind conditions may be associated with changes in sea-surface conditions (Cavaleri et al., 2024). These conditions can be observed through wave height, period, and direction. Karimunjawa has wave conditions that can vary considerably, as indicated by hydro-oceanographic research. Gunawan et al. (2017) found a significant wave height of 0.64 meters with a significant wave period of 5.66 seconds, as well as a maximum wave height of 1.22 meters with a maximum period of 7.30 seconds. Another study showed that waves in the waters of Karimunjawa predominantly move from east to west, with wave heights reaching 0.9 meters and a peak period of approximately 7 seconds (Yulius et al., 2021). These data clearly indicate that wind and wave conditions are important components of Karimunjawa's physical environment, which continuously undergoes change.

Changes in sea conditions are not merely physical issues because coastal communities directly interact with this environment through various maritime activities. Fishers need to recognize sea conditions when traveling and carrying out fishing activities. Repeated experiences can shape knowledge of environmental signs and changes in conditions over time. Such knowledge can emerge through observations and skills developed through direct interactions with the sea (Simon, 2023). Fishers' experiences can also shape broader knowledge of the environment and fishing activities, meaning that such knowledge is not limited to knowledge of fish species but also involves ways of understanding sea conditions (Stephenson et al., 2016). Studies of coastal communities have shown that human-environment relationships can shape particular ways of identifying risks and determining appropriate actions when environmental conditions change (Kamstra, 2019). This relationship makes Local Ecological Knowledge, or local ecological knowledge, important because such knowledge emerges from communities' experiences with the environments they encounter. Therefore, fishers' knowledge can be understood as part of local ecological knowledge that is developed and applied through experience, observation, and everyday maritime practices.

Studies of the physical conditions of the sea and local knowledge have developed through different approaches. Oceanographic studies generally explain sea conditions through measurements, data, and modeling, producing an understanding of environmental changes from a physical perspective. Studies of coastal communities, on the other hand, tend to focus more on the experiences and knowledge that fishers use to understand environmental changes. Research in the Galápagos Islands has shown that fishers can identify environmental changes and relate them to changes in fishing activities through their local ecological knowledge (Cavole et al., 2020). Other studies have also shown that local ecological knowledge can provide more detailed information about the spatial and temporal dimensions of human activities in marine environments (Baker & Constant, 2020). These findings indicate that fishers' experiences can serve as an important source of knowledge when changes in the marine environment are understood alongside scientific data. However, the relationship between wind and wave conditions and the ways in which communities experience and understand these conditions require further examination in Karimunjawa. Therefore, this study connects wind and wave conditions with the experiences and maritime

knowledge of the Karimunjawa coastal community. Accordingly, this study aims to examine how wind and wave conditions are experienced by the coastal community, how fishers perceive and interpret changes in these conditions, and how changes in wind and wave conditions influence the community's maritime practices.

Based on the background described above, this study addresses three research questions:

1) How are wind and wave conditions experienced by the coastal community in Karimunjawa?
2) How do fishers perceive and interpret changes in wind and wave conditions?
3) How do changes in wind and wave conditions influence maritime practices in Karimunjawa?

Conceptual Framework

1) Wind-Wave Conditions

Wind-wave conditions refer to the physical conditions of the sea that result from interactions between wind and surface waves. Wind acts as the primary source of energy in wave formation, while the characteristics of the resulting waves are influenced by wind speed and direction, wind duration, and fetch, or the distance of open water over which the wind blows (Carter, 1982; Le Roux, 2007). The greater the amount of wind energy transferred to the sea surface, the greater the potential for wave development, although these conditions are also influenced by characteristics of the waters, such as water depth and coastal configuration. In wave studies, wind conditions can be represented by wind speed and direction and their changes over time, while wave conditions can be described using significant wave height (H_s), peak wave period (T_p), and wave direction. H_s describes wave height characteristics based on the energy contained in the wave spectrum, while T_p indicates the period at the frequency with the highest spectral energy. The relationship between wind conditions and wave development can be analyzed through spectral approaches and parameters that consider wind speed and fetch (Young, 1999). Therefore, wind and wave parameters are not only used to describe the physical conditions of the sea but also serve as important indicators for understanding changes in marine conditions that may affect activities at sea.

The characteristics of wind-wave conditions in Karimunjawa need to be understood by considering its geographical setting as an archipelagic region. Yulius et al. (2021) showed that the hydro-oceanographic conditions of the Karimunjawa waters can be described through significant wave height, peak wave period, and current parameters, which vary spatially. The study showed that waves in the waters of Karimunjawa generally move from east to west, with wave heights reaching approximately 0.9 m and peak periods of around 7 seconds, while several areas around Karimunjawa and Kemujan have relatively calmer conditions. These variations indicate that sea conditions in an archipelagic region cannot be represented by a single value because their characteristics are influenced by geographical position and water configuration (Yulius et al., 2021). On a broader scale, Nugroho et al. (2022) also showed that wave height and direction in the Java Sea are associated with seasonal variations in wind conditions, meaning that changes in wind patterns can produce changes in wave characteristics. The influence of wave conditions on maritime activities is also evident in the study by Putra et al. (2024), which showed that wave height and direction are important factors in evaluating ship seakeeping in the waters of Karimunjawa. Based on these considerations, this study uses wind and wave conditions as a basis for understanding the physical dynamics of the sea before examining how the people of Karimunjawa recognize changes in these conditions and adjust their maritime practices.

2) Local Ecological Knowledge

Local Ecological Knowledge (LEK) is a concept that describes knowledge developed through direct and repeated interactions between communities and their environment. Such knowledge can be formed through everyday experiences, observation, memory, conversations, and practices carried out continuously. García-Quijano (2007) explains that the LEK of communities that depend directly on ecosystems can serve as a source of information about environmental changes. This knowledge emerges because communities have long-term experience with the environments in which they carry out their activities. Berkström et al. (2019) showed that fishers' knowledge can be acquired through direct experience, shared knowledge, as well as formal education or activities. This pattern indicates that LEK does not come from a single source. Knowledge can also change when individuals gain new experiences or when environmental conditions change. Hind (2015) explains that fishers' knowledge has a long history in fisheries research but still faces challenges when considered alongside scientific knowledge. Silvano et al. (2023) further showed that fishers' knowledge has broad contributions to fisheries and aquatic ecosystem sciences. Such knowledge can help researchers understand environmental changes that may be difficult to capture through limited scientific observations. Therefore, LEK is used in this study as a concept for understanding the Karimunjawa community's knowledge of changes in the marine environment based on their experiences.

Fishers' knowledge is positioned as a more specific form of LEK because it develops through fishers' experiences in direct interaction with the marine environment. Fishers' knowledge may include information about water conditions, weather changes, fishing locations, seasons, currents, waves, and other environmental indicators. Lauer and Aswani (2009) showed that fishers' ecological knowledge is not necessarily separate from everyday activities such as navigation and fishing. This means that knowledge can emerge together with practice. Fishers can recognize sea conditions through their experiences while traveling by boat or carrying out fishing activities. García-Quijano (2007) also showed that fishers' experiences can help explain relationships between habitats and changes in the marine environment. Such knowledge is not always expressed through numerical measurements such as wave height or wind speed. Instead, it may appear through local terms that describe sea conditions based on experience. Berkström et al. (2019) found that direct experience was one of the main sources of fishers' ecological knowledge in their study. The study also showed that the level of experience and the spatial extent of fishers' activities can influence variations in the knowledge they possess. Therefore, this study understands fishers' knowledge through the experiences, observations, memories, and practices that people use when reading sea conditions. This concept helps the study understand how communities give meaning to wind and wave conditions without equating local knowledge with physical measurements.

3) Human-Environment Interaction

Human-environment interaction is a concept used to understand the relationship between people and the environmental conditions they encounter. This concept views the environment not merely as a physical space external to human life. The environment is also part of people's everyday experiences and activities. Orlove (2005) explains that human-environment relationships can be examined through changes in the ways people understand and interact with their environment. Moran (2010) also explains that human-environment relationships involve interconnected ecological, social, economic, and cultural processes. This concept is

particularly relevant to coastal communities because their lives are directly connected to changing sea conditions. Wind and waves can influence people's experiences when carrying out maritime activities. These experiences can then shape knowledge of signs indicating changes in sea conditions. Such knowledge can be used when communities assess the conditions they are facing. These assessments can influence decisions concerning timing, routes, locations, and the continuation of maritime activities. Turner et al. (2003) explain that human-environment interactions can be understood through the relationship between environmental processes and human decisions and actions. Therefore, this concept serves as a bridge between the physical conditions of the sea and the experiences of the Karimunjawa community. It allows the study to view wind and wave conditions as part of a social process that is experienced and interpreted by the community.

Human-environment relationships in this study are viewed as a process that takes place gradually. Environmental conditions become experiences when people directly encounter sea conditions. These experiences are then understood through the knowledge already possessed by the community. Local knowledge helps people identify whether a change they observe represents a familiar condition or differs from their previous experiences. Such interpretations can then influence decisions related to maritime activities. Lauer and Aswani (2009) showed that fishers' ecological knowledge cannot be simply separated from navigation practices and fishing activities. Adger et al. (2009) also explained that communities' ability to respond to environmental change is related to their social and institutional capacities. Berkes and Jolly (2002) showed that communities can develop adaptation strategies through their experiences with changing environmental conditions. Cinner et al. (2012) likewise demonstrated that knowledge, experience, and social conditions can influence the ability of coastal communities to respond to changes in the marine environment. Based on these perspectives, this study examines human-environment relationships through community experiences, interpretations, decisions, and practices. Wind and wave conditions are not considered the sole causes of changes in people's behavior. Instead, physical conditions are part of the environment that is understood through local knowledge and translated into action. Therefore, human-environment interaction serves as an integrative concept connecting the study of marine physics with the anthropological study of coastal communities.

METHOD

This study employs an interdisciplinary qualitative approach with an ethnographic case study design to connect the study of the physical conditions of the sea with the experiences of the Karimunjawa coastal community. A qualitative approach was used because the study focuses on the experiences, meanings, knowledge, and practices of people in their interactions with the marine environment. Creswell and Poth (2018) explain that qualitative research can be used to understand the meanings that individuals or groups assign to a social issue. An ethnographic design was employed because the study considers people's everyday lives and the relationship between knowledge and practice. Hammersley and Atkinson (2019) explain that ethnography places the observation of social life as an important part of the research process. The study was conducted in Karimunjawa, Jepara, Central Java, with the coastal community and fishers as the primary focus of observation because their activities are directly connected to sea conditions. Ethnographic data were collected through observations of maritime activities, everyday interactions, naturalistic and

informal conversations, field notes, and relevant documentation. These conversations were not treated as formal interviews because the study sought to understand local knowledge through naturally occurring interactions. Physical data were obtained from scientific sources and credible datasets and included wind speed, wind direction, significant wave height, wave period, and wave direction. These data were used to describe environmental conditions and were not considered direct measurements made by the community. The ethnographic data were analyzed thematically by grouping information according to people's experiences of wind and waves, ways of interpreting changes in sea conditions, forms of local knowledge, and changes in maritime practices. Braun and Clarke (2006) explain that thematic analysis can be used to identify important patterns and themes emerging from qualitative data. The physical data were analyzed descriptively by considering the characteristics of the available parameters. The two types of data were then compared through an integrative interpretation to identify similarities or differences between recorded physical conditions and community experiences. This process was not intended to treat community knowledge as a substitute for scientific measurements. Research ethics were maintained by respecting the community's social spaces, protecting identities when necessary, using documentation proportionally, and respecting local knowledge. Therefore, the research process was designed to preserve the social context of community knowledge while maintaining a clear distinction between scientific data and local experiences.

RESULTS AND DISCUSSION

1) Wind and Wave Conditions Experienced by Coastal Communities in Karimunjawa

Wind and wave conditions in Karimunjawa indicate that coastal communities carry out their activities within a dynamic marine environment. Based on BMKG data from August 30, 2026, the area around Karimunjawa Port experienced easterly winds at speeds of approximately 16-18 knots (8.2-9.3 m/s), with gusts reaching up to 23 knots (11.8 m/s), and wave heights of approximately 0.8-1.5 m (BMKG, 2026).

$$H_s = 4\sqrt{m_0}$$

Where H_s is the significant wave height (m) and m_0 is the zeroth-order spectral moment. The significant wave height (H_s) is an important parameter for describing sea-state conditions. It can be estimated from the zeroth-order spectral moment using:

$$H_s = 4\sqrt{m_0}$$

(Mankle, H., DuPont, B., & Robertson, B. (2025)).

These variations indicate that changes in wind strength can occur alongside changes in sea-surface conditions. At the Java Sea scale, Nugroho et al. (2022) found that wave height and direction are associated with seasonal wind variability. This condition is relevant to the characteristics of Karimunjawa as an archipelagic region. Yulius et al. (2021) showed that waves in the waters of Karimunjawa vary spatially, with waves predominantly moving from east to west and reaching approximately 0.9 m in height with a peak period of around 7 seconds,

$$T_p = \frac{1}{f_p}$$

where:

T_p = peak wave period (s)

f_p = peak frequency (Hz)
Thus, $T_p \approx 7T_p \approx 7s$:

$$f_p \approx \frac{1}{7} \approx 0.143\,\text{Hz}$$

(Mankle, H., DuPont, B., & Robertson, B. (2025)).
While several areas on the eastern side of Karimunjawa, Kemujan, and the western part have relatively calmer conditions.

Table 1. Wind and Wave Conditions in the Waters of Karimunjawa

Source	Wind Conditions	Wave Conditions	Characteristics
BMKG (2026)	Easterly, 16-18 knots; gusts up to 23 knots	Approximately 0.8-1.5 m	Conditions recorded on August 30, 2026
Yulius et al. (2021)	Associated with hydro-oceanographic conditions	Up to approximately 0.9 m; T_p approximately 7 seconds	Waves predominantly move from east to west and exhibit spatial variations
Nugroho et al. (2022)	Varies according to seasonal wind patterns	Wave height and direction vary	Indicates the relationship between wind and waves in the Java Sea

Source: Compiled by the authors based on BMKG (2026), Yulius et al. (2021), and Nugroho et al. (2022).

These data indicate that the sea conditions in Karimunjawa cannot be understood through a single fixed value because wind and wave characteristics can change over time and across locations. These changes can be observed through several oceanographic parameters used to describe sea conditions. Wind speed and direction, significant wave height (H_s), peak wave period (T_p), and wave direction are important parameters for understanding wind-wave characteristics. Yulius et al. (2021) used significant wave height and peak wave period as part of the hydro-oceanographic characterization of Karimunjawa, while Putra et al. (2024) showed that wave height and direction are important parameters in the analysis of ship seakeeping in the waters of Karimunjawa. These parameters provide a basis for understanding the physical conditions of the sea encountered by communities during maritime activities.

Table 2. Wind-Wave Parameters for Describing Sea Conditions

Parameter	Symbol	Function
Wind speed	*U*	Describes wind strength above the sea surface

Wind direction	Dir.	Indicates the direction from which the wind originates
Significant wave height	H_s	Describes wave-height characteristics based on wave energy
Peak wave period	T_p	Indicates the period at the frequency with the highest wave energy
Wave direction	Dir. wave	Indicates the direction of wave propagation

Source: Compiled by the authors based on Carter (1982), Young (1999), Yulius et al. (2021), and Putra et al. (2024).

The use of these parameters helps distinguish between sea conditions as physical phenomena and sea conditions as experienced by the community. Scientific data provide an overview of wind and wave characteristics through measurable parameters, while communities directly encounter these conditions through their everyday maritime activities. Changes in wind and waves consequently become part of the environment that can be observed, experienced, and compared with previous experiences. The relationship between physical conditions and community experiences can be illustrated as follows.

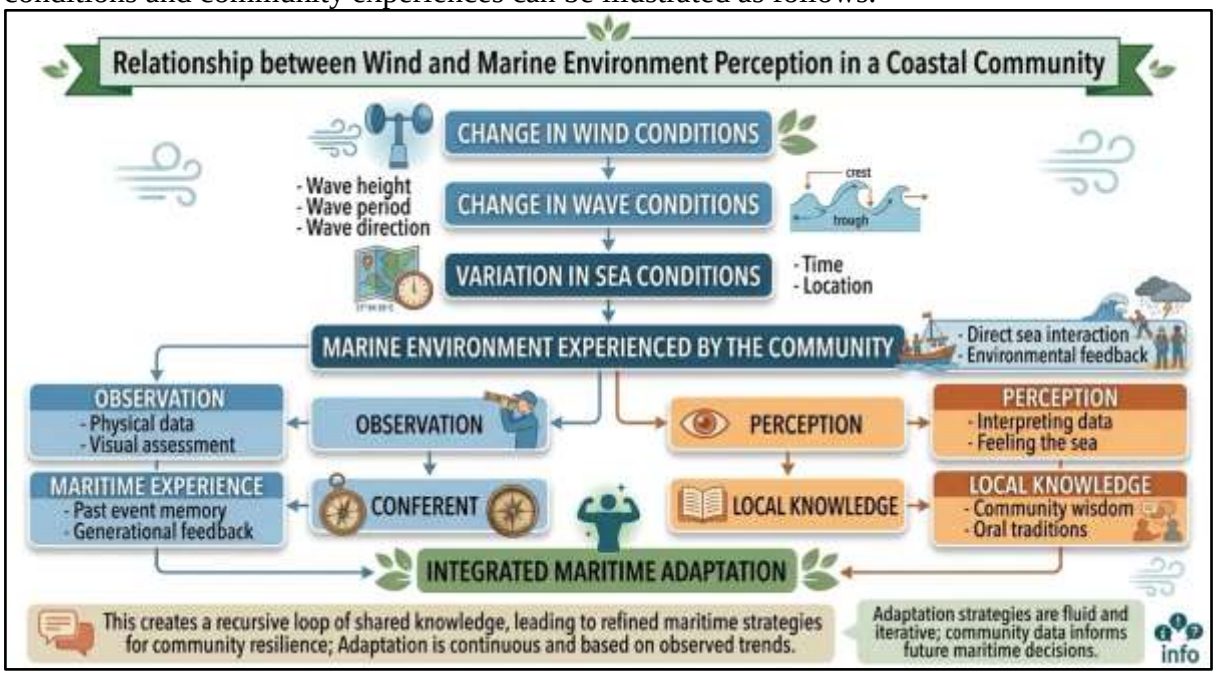


Figure 1. Relationship between Wind-Wave Conditions and the Maritime Experiences of the Karimunjawa Community

Compiled by the authors based on the concept of wind-wave conditions and studies of the maritime experiences of coastal communities.

Based on this framework, wind and wave conditions can be viewed as part of the physical environment that directly provides the context for the activities of the Karimunjawa coastal community. The physical data in this study are not intended to replace community knowledge about the sea but are used as a basis for understanding the environment in which such knowledge and experiences are formed. Sea conditions recorded through scientific data can then be compared with the ways in which communities observe and understand sea conditions through their everyday experiences. Therefore, this comparison provides a basis for understanding how wind and wave conditions are perceived and interpreted by fishers.

2) Fishers' Perception and Interpretation of Changes in Wind and Wave Conditions

Changes in wind and wave conditions provide an important basis for Karimunjawa fishers when assessing sea conditions before carrying out maritime activities. Fishers do not view the sea merely as a space for catching fish, but as an environment that must be understood through everyday experience. Repeated experiences enable fishers to recognize changes in wind direction, wind strength, wave patterns, and surface-water movements through direct observation. Such local knowledge is consistent with the concept of local ecological knowledge, which views community experience as an important part of the relationship between people and their environment (Leithäuser & Holzhacker, 2020). Fishers' experiences can also preserve information about environmental changes that may not always be captured through short-term scientific observations (Pita et al., 2020). Studies of coastal fishers show that decisions to go to sea can be influenced by weather, currents, familiarity with fishing locations, information from other fishers, and social and economic conditions (Sudarmo et al., 2016). Environmental conditions are therefore not understood through a single indicator but through a combination of different signs that appear simultaneously. Therefore, fishers' perception of wind and waves can be understood as a process of reading the environment based on experience, observation, and knowledge developed through everyday maritime activities.

Table 3. Indicators Used by Fishers to Observe Wind and Wave Conditions

Environmental Condition	Observed Indicators	Form of Fishers' Knowledge	Meaning for Activities
Wind	Wind direction and strength	Experience in reading wind direction and changes in gusts	Assessing the feasibility of departure
Waves	Height, distance between waves, and surface movements	Visual observation and experience on board	Assessing the level of sailing difficulty
Weather changes	Changes in wind and sea-surface conditions	Observation of environmental signs	Determining departure or return times

Sea conditions	Vessel movement and fishing gear response	Bodily experience and practice	Adjusting the way activities are carried out

Source: Compiled by the authors based on Leithäuser and Holzhacker (2020), Pita et al. (2020), Sudarmo et al. (2016), and Pfeiffer (2020).

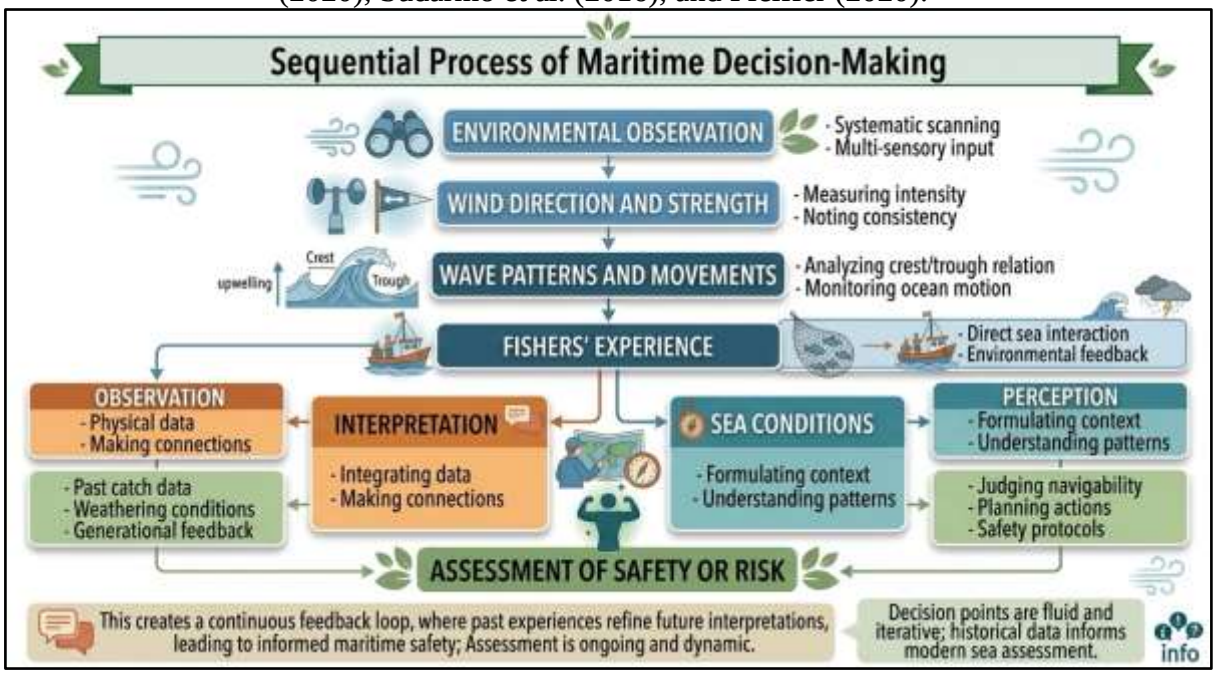


Figure 2. Process of Fishers' Perception of Wind and Wave Conditions

Source: Compiled by the authors based on the concept of local ecological knowledge and studies of fishers' decision-making.

Interpreting sea conditions through experience allows fishers to develop particular ways of distinguishing between conditions considered safe and those considered risky. Assessments of safety or risk do not always rely on wave-height or wind-speed measurements such as those used by meteorologists and oceanographers. Instead, fishers more often rely on signs that can be seen, felt, and compared with previous experiences. This way of reading the environment through experience indicates that fishers' knowledge can be understood as a specific form of local ecological knowledge directly related to fishing activities. Research on fishers' ecological knowledge shows that fishers' experiences can provide insights into changes in ecosystems and water conditions over long periods (Pita et al., 2020). Other studies have also found that fishers' knowledge can help explain the relationship between environmental changes and fishing activities, even though such knowledge cannot always be easily translated into numerical measurements (Davis et al., 2020). The ability to read sea conditions is also related to safety because strong winds and high waves can increase risks for fishers and the vessels they use (Pfeiffer, 2020). Therefore, the ways in which fishers understand wind and waves demonstrate that maritime knowledge emerges from an ongoing relationship between human experience and changes in the marine environment.

The ongoing relationship between human experience and the marine environment subsequently forms environmental memory, which helps fishers compare current sea conditions with those they have encountered in the past. Environmental memory allows past experiences to remain useful when fishers face changes in wind and wave conditions. Fishers can recognize conditions because previous experiences provide references for identifying conditions considered normal or unusual. Such knowledge does not come only from personal experience but can also develop through information exchange among fishers. Studies of fishers' decision-making indicate that information and the sharing of experiences are among the factors that can influence decisions about fishing locations (Sudarmo et al., 2016). Leithäuser and Holzhacker (2020) also explain that local experience can provide a basis for community adaptation when environmental conditions change. The exchange of experiences allows knowledge about the sea to move beyond individual experience and develop into shared knowledge. In addition, the use of shared knowledge enables fishers to assess changes in sea conditions through language and signs that are closely connected to their everyday lives. Therefore, fishers' perception of wind and waves is shaped not only by what they observe at a particular moment but also by memories, experiences, and knowledge exchange developed through shared maritime life.

The shared knowledge formed through maritime life also shows that fishers' interpretations cannot be separated from the social and environmental contexts in which they live. Each environmental sign acquires meaning through community experiences and the needs arising from fishing activities. Fishers can relate changes in wind and waves to travel conditions, fishing activities, and the level of risk they may face. The relationship between physical conditions and human decisions reflects the concept of human-environment interaction because people do not simply respond passively to environmental changes but adjust their actions based on the changes they experience. A study of coastal communities in Vietnam shows that local experience and environmental knowledge can serve as a link between resource users and their social-ecological systems (Leithäuser & Holzhacker, 2020). Research on fishers also shows that decisions to go to sea are influenced not only by weather but also by economic factors, vessel conditions, fishing gear, and individual experience (Shepperson et al., 2022). Another study indicates that fishers consider both physical risks and economic benefits when deciding whether to go to sea (Calil et al., 2021). Therefore, fishers' interpretations of wind and waves can be understood as the result of interactions among physical sea conditions, human experience, local knowledge, and everyday livelihood needs.

The relationship among physical sea conditions, human experience, local knowledge, and everyday needs ultimately gives fishers' perceptions a practical function. Perception does not remain merely as knowledge about sea conditions but becomes a basis for determining actions. Wind and wave conditions considered unsafe may lead fishers to delay departure, choose another location, or return earlier. Pfeiffer (2020) shows that fishers tend to avoid storm conditions and may postpone trips when the level of danger increases. Other research indicates that wave height can also influence the decisions of small vessels when leaving port (Shepperson et al., 2022). Weather conditions do not operate independently because fishers also consider vessel conditions, fishing gear, previous catches, and economic needs (Calil et al., 2021). This condition demonstrates that fishers' knowledge functions as part of a decision-making process that connects environmental perceptions with concrete actions. At the same time, the use of local experience does not mean that fishers' knowledge replaces scientific

measurements, as the two represent different forms and functions of knowledge. Therefore, fishers' perceptions of changes in wind and wave conditions can be understood as a form of fishers' knowledge that helps communities read the environment before determining their maritime practices.

3) The Influence of Changes in Wind and Wave Conditions on Maritime Practices

Changes in wind and wave conditions can influence how fishers organize their fishing activities. Changing sea conditions mean that departure times cannot always be determined in advance, as fishers need to assess weather conditions before setting out. Mulyasari et al. (2023) found that adjusting fishing times is one of the most used forms of adaptation among small-scale fishers in coastal Bengkulu. The study also showed that fishers' perceptions of climate change are related to historical climate data, indicating that community experience can help identify changes in environmental conditions. Rahman et al. (2021) found that access to climate information is also associated with adaptation strategies among small-scale fishers in East Java. Weather information can help fishers reduce risks when sea conditions change. Similar conditions are important for the Karimunjawa community because fishers' livelihoods are closely connected to seasonal changes and sea conditions. Ramadhan and Apriliani (2014) found that fishing seasons in Karimunjawa follow patterns, with a peak period around September to October and a low-fishing period from late December to February. These seasonal patterns indicate that environmental changes can directly influence the organization of fishing activities. Therefore, changes in wind and wave conditions may encourage fishers to adjust the timing of their maritime activities based on their experience and the environmental information available to them.

Table 4. Forms of Maritime Practice Adjustment in Response to Changes in Environmental Conditions

Environmental Change	Maritime Practice Response	Form of Adaptation	Purpose
Increasingly strong winds	Postponing departure	Time adjustment	Reducing travel risks
Increasingly high waves	Reducing fishing activities	Reducing trip frequency	Maintaining safety
Changing sea conditions	Changing fishing locations	Adjustment of activity space	Seeking more suitable conditions
Changes in fishing season	Changing fishing times and strategies	Operational adjustment	Maintaining catch yields
Declining catches	Changing fishing gear or strategies	Technological and economic adaptation	Maintaining income

Source: Compiled by the authors based on Mulyasari et al. (2023), Rahman et al. (2021), Ramadhan and Apriliani (2014), and Wiyono and Kartawijaya (2016).

Adjustments in fishing times identified in studies of fishers show that environmental changes can be translated into changes in everyday activity patterns. Changes in daily activity patterns can also be observed through shifts in fishing locations when environmental conditions or resource availability no longer correspond to previous practices. Wiyono and Kartawijaya (2016) showed that Karimunjawa fishers experienced changes in fishing operation strategies between the 2003-2005 and 2009-2011 periods. These changes included shifts in the fishing gear used and the composition of fishing activities. Hafsaridewi et al. (2025) also identified Karimunjawa fishers as a group with adaptive capacity in responding to environmental changes through changes in fishing techniques, livelihood diversification, and strengthened social networks. Changes in fishing locations can also serve as a strategy when resource conditions or environmental conditions at previous locations no longer support fishing activities. Suadi (2022) found that fishers in the Spermonde Islands changed fishing locations and added fishing gear when facing environmental changes and uncertain catches. These choices show that adaptation does not always involve stopping fishing but can instead take the form of changes in how maritime activities are carried out. In addition, changes in fishing gear and locations demonstrate that environmental knowledge can be applied through practical decision-making. Therefore, changes in sea conditions can affect not only when fishers go to sea but also where and how they carry out their fishing activities.

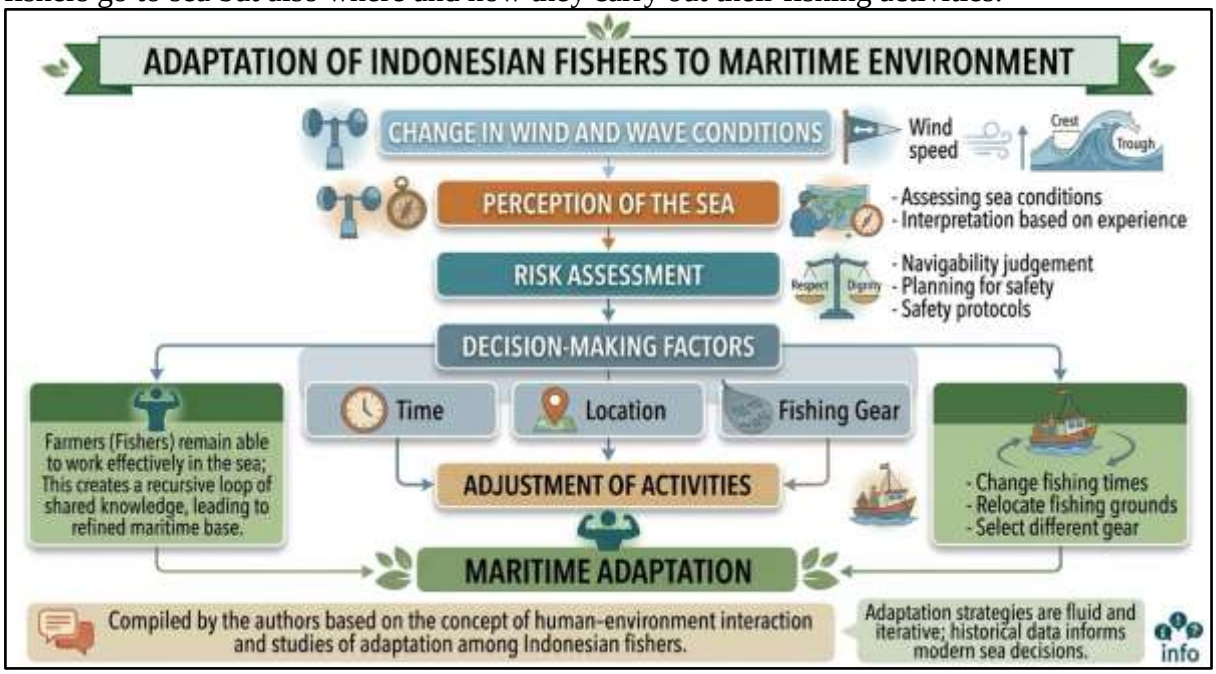


Figure 3. Relationship between Environmental Conditions and Adjustments in Maritime Practices

Source: Compiled by the authors based on the concept of human-environment interaction and studies of adaptation among Indonesian fishers.

Adjustments in fishing locations and methods further indicate that maritime adaptation is not only related to safety but also to the sustainability of fishing households' livelihoods. Economic livelihood security is particularly important because many coastal communities

remain highly dependent on fisheries. Saksono et al. (2023) reported that approximately 2.67 million Indonesian fishers depend on small-scale fisheries and face environmental pressures as well as limited employment alternatives. These pressures mean that changes in weather and seasons are not merely environmental problems but also household economic concerns. Rahman et al. (2021) showed that adaptation strategies have positive effects on income and household food security among small-scale fishing households in East Java. Idrus (2024) also found that small-scale fishers can use livelihood diversification as a strategy for dealing with economic pressures associated with climate change. Diversification allows households to avoid complete dependence on fishing income when sea conditions do not support fishing activities. Adaptation choices may also involve technology, fisher groups, climate information, and social support. These conditions indicate that responses to changes in wind and waves can develop from simple actions at sea into broader livelihood strategies. Therefore, maritime adaptation needs to be understood as a process connecting environmental changes with safety, fishing activities, and the economic sustainability of fishing households.

The economic sustainability of fishing households further means that adaptation cannot be separated from the community's ability to choose actions that are most appropriate to the conditions they face. This ability to choose is reflected in decisions to postpone trips, change fishing locations, adjust fishing gear, or seek alternative economic activities when sea conditions are unfavorable. Rahim et al. (2024) showed that small-scale fishers face difficult choices during periods of bad weather because their income remains dependent on catches. This condition makes decisions about going to sea a process that considers both environmental risks and economic needs. Studies of fisher safety also show that weather is an important factor in decisions to go to sea, but it is not the only factor determining fishers' actions (Bradley et al., 2022). Access to fishing grounds, competition among fishers, vessel capacity, and economic needs can also influence decision-making. These conditions demonstrate that maritime practices emerge from the intersection of physical sea conditions and human needs. Local knowledge helps communities understand environmental conditions, while economic experience helps them determine which actions are considered feasible. This relationship is consistent with the concept of human-environment interaction because environmental changes generate human responses, while human responses in turn shape patterns of life in coastal environments. Therefore, changes in wind and wave conditions can be understood as one of the factors driving changes in maritime practices while also shaping the adaptive capacity of the Karimunjawa coastal community.

CONCLUSION

1) Wind and wave conditions in Karimunjawa show that the coastal community encounters a marine environment that continuously changes over time and across locations. This can be seen from variations in wind speed and direction, as well as wave height, period, and direction recorded in BMKG data and previous hydro-oceanographic studies. These differences also indicate that sea conditions in Karimunjawa cannot be explained through a single value because the characteristics of the waters may vary across times and areas. These physical conditions are part of the environment directly encountered by the community during maritime activities. Therefore, the concept of Wind-Wave Conditions can be used to describe the

physical conditions of the Karimunjawa sea as a basis for understanding the maritime experiences of the coastal community.

2) Fishers' perceptions and interpretations of changes in wind and wave conditions in Karimunjawa are formed through experience, observation, environmental memory, and knowledge exchange that take place in everyday maritime life. Fishers understand sea conditions not only through signs that can be seen and felt, but also by comparing them with previous experiences and information obtained from other fishers. This process forms fishers' knowledge as part of local ecological knowledge, which is used to identify sea conditions, distinguish between conditions considered safe or risky, and understand environmental changes in the context of fishing activities. Interpretations of wind and waves also do not exist independently, as they are related to vessel conditions, fishing gear, individual experience, economic needs, and the social situation of the community. The knowledge that is formed subsequently serves a practical function in decision-making, such as determining departure times, selecting fishing locations, adjusting activities, or postponing trips when sea conditions are considered unsafe. Therefore, the concept of Local Ecological Knowledge can be used to explain how local experience and knowledge shape the ways in which Karimunjawa fishers perceive and interpret changes in wind and wave conditions before determining actions in maritime activities.
3) The influence of wind and wave conditions on fishers' experiences can subsequently be seen in changes in the maritime practices of the Karimunjawa community. Changes in sea conditions may encourage fishers to adjust their departure and return times when carrying out fishing activities. Less favorable sea conditions may also lead fishers to reduce their activities or choose fishing locations considered more suitable. Such adjustments may develop through changes in fishing gear, fishing strategies, and the allocation of time for different activities. Community experiences may also encourage livelihood diversification when sea conditions do not support fishing activities. These various forms of adjustment indicate that maritime adaptation is related not only to safety but also to the economic sustainability of fishing households. This relationship demonstrates that physical sea conditions are part of a process that influences community perceptions, decisions, and actions. Therefore, changes in wind and wave conditions can be understood as one of the factors that encourage the Karimunjawa community to adjust the timing, spatial use, methods, and strategies of their maritime activities according to their experiences and the environmental conditions they face. Thus, the maritime practices of the Karimunjawa community represent forms of adaptation that emerge from the relationship between changes in the marine environment, local knowledge, fishers' experiences, and everyday livelihood needs.

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