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Analysis of Zonal Winds in Determining the Onset of the Season to Support Fishing Activities on the Western Coast of Makassar City

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Abstract: This study examines the determination of the fishing season to support fishermen's activities on the western coast of Makassar City through the analysis of zonal winds. Wind is a crucial meteorological element, influenced by its direction and speed. Coastal wind patterns differ from those in open seas due to the interaction between land and sea breezes. As Makassar City is located in a coastal area, many of its residents work as fishermen whose activities are significantly influenced by weather conditions. Weather information plays a critical role in ensuring optimal fishing outcomes and improving safety for fishermen before they venture to sea. This research was conducted on the western coast of Makassar City using both quantitative and qualitative methods. Quantitative analysis involved windrose diagrams to identify wind trends and bar charts to analyze rainfall patterns, while qualitative analysis employed questionnaires with 46 respondents. The findings indicate that zonal wind data from the study area cannot reliably determine the fishing season due to the local influence of land-sea wind interactions, which disrupt the monsoonal wind patterns. However, weather conditions were found to have a significant impact on fishing activities, with a Likert scale score of 89.86%, indicating a strong influence. Seasonal weather information enhances fishermen's safety, guides the selection of fishing gear, and increases catch yields. Therefore, providing reliable seasonal weather information is essential for supporting fishing activities on the western coast of Makassar City.
Keywords: zonal wind, coastal fishing, weather information, land-sea breeze, fishermen safety, Makassar City

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INTRODUCTION

Wind is a crucial meteorological element, characterized by its direction and speed. Coastal wind patterns differ significantly from those in open seas due to the influence of land-sea breeze systems. In the Maritime Continent of Indonesia, global monsoons—namely the Asian and Australian monsoons—play a vital role in shaping seasonal weather patterns. During the Asian summer, low-pressure systems form over Asia, while high-pressure systems dominate over Australia, resulting in easterly winds crossing the Indonesian Maritime Continent, bringing dry conditions during June, July, and August. Conversely, during the Asian winter, high-pressure systems develop over Asia, while low-pressure systems emerge over Australia, inducing westerly winds that usher in the rainy season from December to February (Haryanto et al., 2020).

The horizontal movement of wind is categorized into zonal (east-west) and meridional (north-south) components, with the zonal wind, or Walker circulation, significantly affecting rainfall variability in Indonesia (Simanjuntak, 2022). These interactions influence weather formation, season onset, and duration across the region. Accurate seasonal predictions are critical for various sectors, including fisheries, as they aid fishermen in planning optimal fishing times and ensuring safety at sea. The Indonesian Meteorological, Climatological, and Geophysical Agency determines the onset of seasons by analyzing 10-day rainfall periods (dasarian). A dry

season begins when rainfall remains below 50 mm for 3–6 consecutive dasarians, while a wet season starts when rainfall consistently exceeds 50 mm for at least three dasarians (BMKG, 2010; 2013).

Makassar City, located on the southwestern coast of Sulawesi, spans a coastal area with a shoreline of approximately 52.8 km, including mainland and small islands (BPS, 2022). Its coastal communities, heavily reliant on fishing activities, face significant challenges from weather variability. Weather conditions such as wind speed and direction, wave height, tidal patterns, and rainfall critically impact fishing productivity and safety. Adverse weather conditions often force fishermen to cease operations, directly affecting their livelihoods (Harahap et al., 2017; Sari et al., 2021). Additionally, fluctuations in oceanographic conditions, influenced by atmospheric interactions and ecological dynamics, alter fish abundance and migration patterns (Asbar & Ihsan, 2022; Putra, 2014).

In Indonesia, zonal winds generally blow eastward during the rainy season and westward during the dry season, with speeds ranging from 0 to 10 m/s (Sartika et al., 2016). In Makassar waters, zonal winds driven by the West and East Monsoons are more influential in seasonal transitions than meridional winds. However, the relationship between zonal wind patterns and seasonal onset, particularly for supporting fishermen's activities, remains underexplored.

This study aims to analyze the role of zonal wind patterns in determining the onset of seasons along the western coast of Makassar. It further evaluates the impact of weather conditions on fishermen’s activities and explores how seasonal prediction data can support coastal fishing operations. This research is expected to provide valuable insights for academics, meteorological institutions, and local stakeholders, particularly in enhancing the safety and efficiency of fishing activities. Using updated data from the past five years, this study addresses a knowledge gap by investigating the relationship between zonal winds and seasonal onset in Makassar, contributing to the broader understanding of weather dynamics in supporting fisheries.

METHOD

Study Design

This study used a descriptive analysis with a quantitative approach. The quantitative descriptive analysis was conducted to evaluate wind and rainfall data from the Maritime Meteorology Station of BMKG in Makassar, located on the western coast of Makassar City, to assess the impact of zonal winds on the start of the season. Additionally, a survey was conducted using questionnaires to evaluate the utility of early season information for supporting the activities of fishermen along the western coast of Makassar City.

Study Location and Period

This study was conducted in the western coastal area of Makassar City (Figure 2). Observational data on wind and rainfall were obtained from BMKG’s Maritime Meteorology Station in Paotere, Makassar. Interviews and questionnaires were distributed to fishermen operating in the same area. Observational data covering the most recent five years up to December 2023 were used. Interviews and questionnaire surveys were carried out in July 2024.

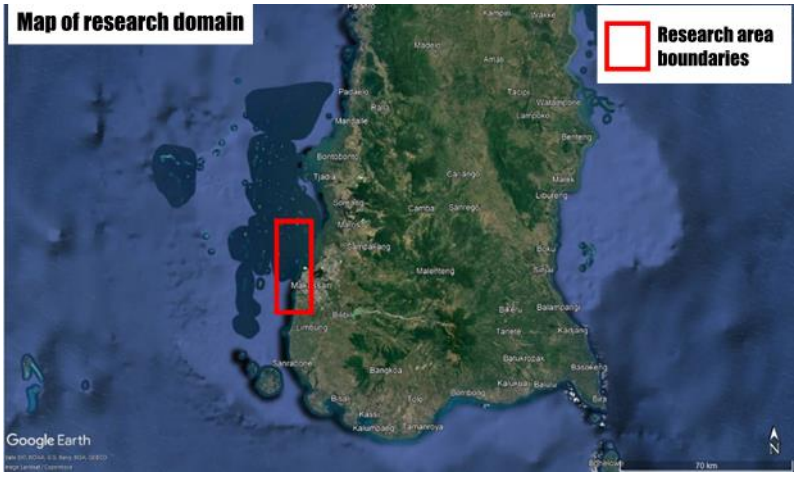


Figure 1. Map of research domain

Data Types and Sources

This study used quantitative and qualitative data, such as:

a) **Quantitative Data**: Wind direction and speed, as well as rainfall data.
b) **Qualitative Data:** Information obtained from interviews and questionnaires with fishermen.

The data for wind direction, wind speed, and rainfall were obtained from observations conducted by BMKG's Maritime Meteorology Station in Paotere, Makassar. The qualitative data were derived from interviews with fishermen operating along the western coast of Makassar City.

Population and Sampling

The study population included all fishermen active along the western coast of Makassar City. A total of 46 fishermen were selected as respondents, comprising:

a) 7 fishermen from Buloa
b) 7 fishermen from Kaluku Bodoa
c) 8 fishermen from Tallo
d) 8 fishermen from Ujung Tanah
e) 8 fishermen from Untia
f) 8 fishermen from Bira

The respondents were chosen to represent various boat sizes and fishing gear used in the area.

Data Collection Techniques

a) **Meteorological Data:** Wind direction, wind speed, and rainfall data were collected from BMKG's Maritime Meteorology Station in Paotere, Makassar.
b) **Questionnaires:** Surveys were conducted to evaluate the impact of seasonal variations on fishermen's activities.

Data Analysis

a) **Wind Pattern Analysis:** Monthly average wind patterns from 2019 to 2023 were analyzed using WRPLOT View software for Windows. This software generated wind rose diagrams illustrating the frequency of wind occurrences based on direction and speed categories for specific locations and timeframes.
b) **Rainfall Pattern Analysis:** Quantitative analysis of rainfall patterns was performed using graphical methods.

c) **Questionnaire Analysis:** The impact of seasonal variations on fishermen's activities was evaluated using a Likert scale, as per Fitriani et al. (2021). The formula used for score calculations was:

$$Total\ Score = T\ x\ P_n \quad (1)$$

Where T is the total number of respondents selecting a specific option, and P_n is the Likert score for that option. The interpretation of the percentage results was categorized into five levels ranging from "very low impact" to "very high impact."

RESULTS AND DISCUSSION

General Conditions of Coastal and Marine Waters of Makassar City Design

Makassar City, the capital of South Sulawesi Province, is located in the southern part of Sulawesi Island, between 119º24'17"38" E and 5º8'6"19" S, covering an area of 175.77 km². Administratively, the city is bordered by Maros Regency to the north and east, Gowa Regency to the south, and the Makassar Strait to the west. Of its 15 districts and 153 sub-districts, 24 sub-districts are situated in coastal areas, with a total coastline of 52.8 km, comprising 36.1 km of mainland coastlines and 16.7 km of island and sandbank coasts. These regions are particularly vulnerable to climate change impacts, such as rising sea levels and extreme weather events. The city is known as a "Waterfront City," featuring major rivers like the Tallo, Jeneberang, and Pampang, all of which flow through the city and contribute to flooding during the rainy season, especially when heavy rainfall coincides with high tides.

Topographically, Makassar City can be divided into two main regions. The western and northern parts are low-lying coastal areas, while the eastern region is hilly, particularly in areas such as Antang Village, Panakkukang District. These geographical features exacerbate flooding risks in low-lying areas during the wet season.

Climatologically, Makassar experiences a tropical climate with distinct wet and dry seasons. According to BMKG (2024), the onset of the wet season occurs when a ten-day cumulative rainfall equals or exceeds 50 mm, sustained for the next two periods, or when a single ten-day period reaches at least 50 mm and the cumulative rainfall over the following two periods exceeds 150 mm. Conversely, the dry season begins when rainfall over a ten-day period is less than 50 mm, with a total of less than 150 mm over the next two periods. Based on 2021 data, January recorded the highest rainfall, with 1,995 mm and 30 rainy days.

This study's findings align with those of Maulidani et al. (2015), who reported that Makassar's rainy season typically begins in November, marked by a significant increase in rainfall. The dry season generally follows the rainy season, starting around May or June. These climatic patterns are essential for understanding the atmospheric dynamics affecting Makassar's coastal and urban areas. This research further supports the need for ongoing monitoring of rainfall patterns and their implications for flood mitigation and urban planning, particularly in low-lying and flood-prone regions.

Zonal Wind Analysis on the West Coast of Makassar City

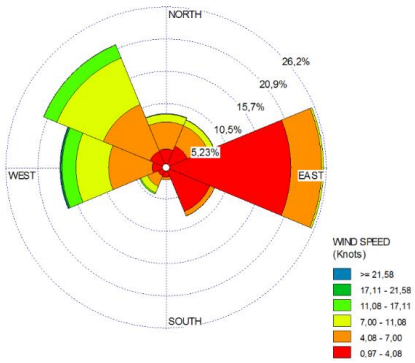
The analysis of zonal winds along the western coast of Makassar from 2019 to 2023 (Figure 2) revealed monthly variations in dominant wind direction and speed. Utilizing WRPlot software, windrose diagrams were generated to illustrate the average wind patterns. In January, winds predominantly blew from the east at speeds of 7–11 knots, accounting for 26.2% of occurrences. Similar patterns were observed in February and March, with easterly winds dominating at comparable speeds and frequencies. The trend shifted slightly in May and June, as southeasterly winds appeared, and wind speeds decreased to 4–7 knots in May. During July and August,

westerly winds began to dominate, particularly in August and September, with speeds ranging from 7–12 knots and increasing to 12–17 knots in September. By November and December, the winds reverted to easterly directions, consistent with the transition back to the rainy season.

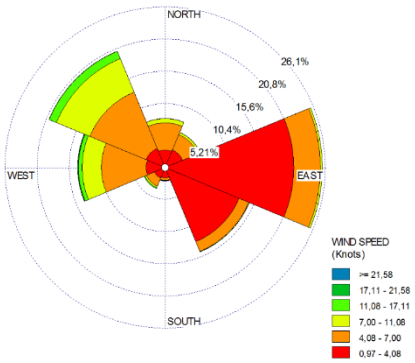
Analysis of the zonal wind components, defined as wind movements parallel to the latitudinal lines (east to west and vice versa), demonstrated that easterly winds dominate the western coastal area of Makassar throughout the year. Table 1 highlights the monthly wind directions, emphasizing deviations from the expected monsoonal patterns. In theory, Indonesia's monsoonal circulation predicts westerly winds during October to April (the West Monsoon) and easterly winds from May to September (the East Monsoon). However, the observed wind patterns along the western coast of Makassar do not fully align with these expectations.

The discrepancies in wind patterns are influenced by local factors, such as land-sea breeze interactions and coastal topography. Pertiwi et al. (2024) noted similar findings, emphasizing that local phenomena, such as the interaction between land and sea breezes, often disrupt monsoonal wind patterns in coastal areas like Makassar. The strong influence of these local dynamics highlights the need to incorporate regional analyses when applying monsoonal models to predict wind behaviors.

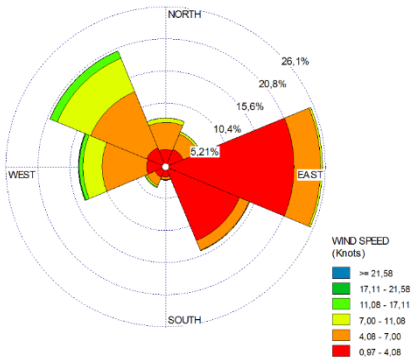
These findings are essential for understanding atmospheric dynamics in coastal Makassar, where deviations from monsoonal norms affect activities such as fishing. The variability in wind direction and speed underscores the importance of localized weather analysis in supporting maritime operations and improving safety and productivity for coastal communities. Further studies could explore the role of global phenomena, such as the Madden-Julian Oscillation (MJO), in amplifying or mitigating these local effects.



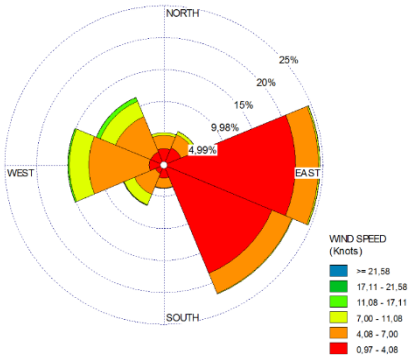
January



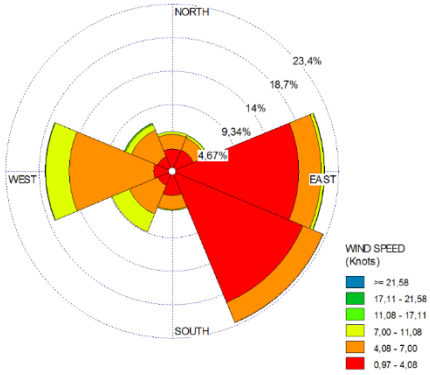
February



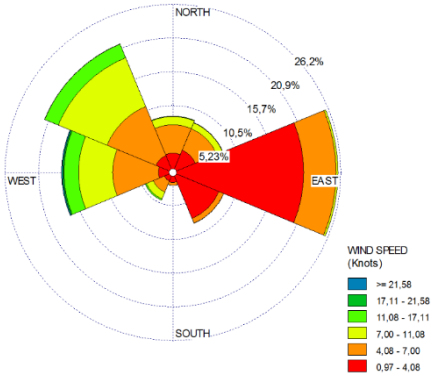
March



April



May



June

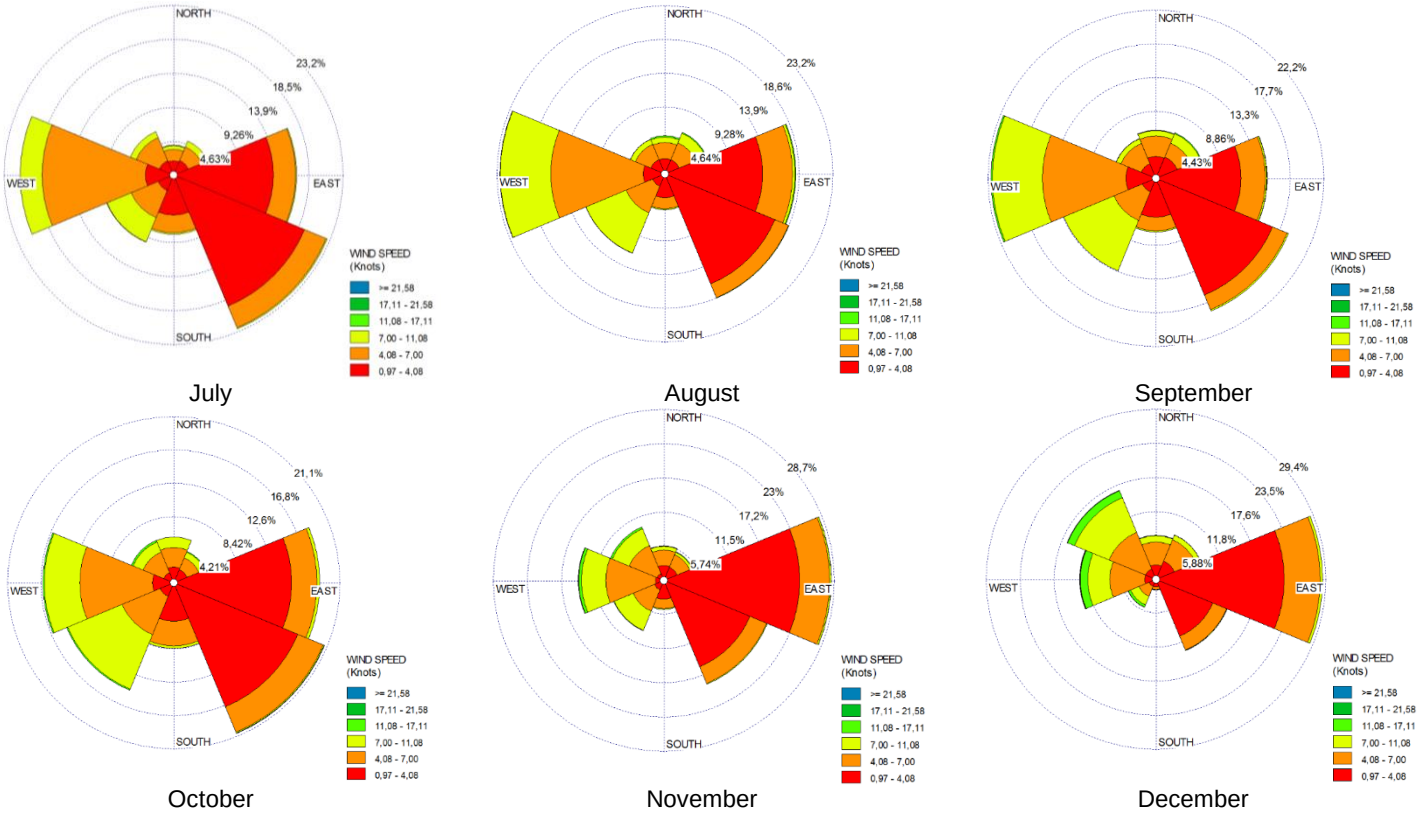


Figure 2. Windrose of monthly wind distribution period 2019-2023

Table 1. Zonal wind components on the west coast of Makassar City

Month	Dominan wind direction
January	East
February	East
March	East
April	East
May	East
June	East – South East
July	East – South East
August	West
September	West
October	East – South East
November	East
December	East

Analysis of Seasonal Onset in the Western Coast of Makassar

The onset of the dry and wet seasons along the western coast of Makassar was determined by analyzing decadal rainfall data from 2019 to 2023. According to BMKG (2024), the dry season begins when rainfall in a single 10-day period is less than 50 mm, with a cumulative rainfall over the subsequent two periods also below 150 mm. Conversely, the wet season commences when a single decadal rainfall exceeds 50 mm, sustained for two additional periods or when the cumulative rainfall of three consecutive periods exceeds 150 mm.

The analysis indicated that the dry season in the study area typically starts in the second decadal period of May. The average rainfall during this period over the five

years analyzed was 28.32 mm. The cumulative rainfall for the second and third decadal periods of May, combined with the first decadal period of June, was 137.08 mm, meeting the criteria for the dry season. This finding aligns with the study by Maulidani et al. (2015), which identified May or June as the typical start of the dry season in Makassar following the rainy season.

Similarly, the wet season begins in the first decadal period of November, with an average rainfall of 58.08 mm. The subsequent two decadal periods recorded rainfall of 62.92 mm and 108 mm, respectively, satisfying the criteria established by BMKG for the onset of the wet season. These results are consistent with the study by Maulidani et al. (2015), which reported November as the typical transition from the dry to the wet season in Makassar.

This seasonal pattern reflects the influence of monsoonal climate dynamics, with the Indian Ocean Dipole (IOD) and El Niño-Southern Oscillation (ENSO) further contributing to variability in rainfall onset timing, as noted by Narulita (2020). The alignment of these results with previous studies highlights the reliability of the criteria used for defining seasonal transitions and underscores the need for continuous monitoring of regional rainfall patterns to support adaptive planning in coastal areas like Makassar.

Analysis of the Impact of Early Season Information to Support Fishing Activities on the Western Coast of Makassar City

This study aimed to analyze the impact of seasonal information on the fishing activities of fishermen in the western coastal areas of Makassar City. A total of 46 fishermen from several villages were surveyed, including Buloa, Kaluku Bodoa, Tallo, Ujung Tanah, Untia, and Bira. The survey data were divided into two sections: the first focusing on the general identity of the fishermen and the second on how seasonal information influences their activities.

In terms of the identity of the fishermen, the distance traveled for fishing was a significant variable. The majority, 22 out of 46 respondents (48%), reported traveling less than 5 km from the shore. This suggests that local weather conditions in the coastal waters of Makassar still significantly affect the fishermen's daily activities. Regarding the location of their fishing activities, 44 respondents (96%) primarily fished in the waters of Makassar, indicating that weather conditions in these areas are directly relevant to their operations.

The study also analyzed the size of the fishing vessels used by the respondents. All respondents used boats with a gross tonnage (GT) of 10 or less, which are categorized as small fishing vessels under the Ministry of Marine Affairs and Fisheries Regulation No. 58/PERMEN-KP/2020. According to BMKG's maritime risk matrix, these boats face moderate risks when winds exceed 15 knots or waves exceed 1.25 meters, meaning weather conditions have a direct impact on the operational safety of these vessels.

Furthermore, the types of fishing gear used were varied, including nets, fishing rods, purse seines, trawl nets, and others. The choice of fishing gear is crucial because certain types, such as purse seines, are significantly influenced by sea currents and wind conditions, affecting their operational efficiency. Junaidi & Bukhari (2016) and Wijopriono & Mahiswara (2017) emphasized that using the appropriate fishing gear in relation to weather conditions can enhance safety and efficiency, particularly in extreme weather situations.

When analyzing the impact of adverse weather conditions, such as strong winds and high waves, 89% of the respondents (41 out of 46) indicated that they would refrain

from going out to sea during such weather, demonstrating a strong link between weather conditions and the fishermen's decision-making processes, particularly for safety reasons.

Regarding the second part of the survey, which focused on the influence of early-season information on the fishermen's activities, the results were calculated using a Likert scale. The data showed a remarkably high impact, with an index of 89.86%. This places the impact of early-season information in the "very influential" category according to the defined criteria. This finding suggests that seasonal forecasts play a crucial role in supporting the fishermen's operations, as they rely on accurate weather information to plan their activities effectively.

In comparison to other studies, the findings align with research indicating that weather forecasts significantly influence maritime activities, especially for small-scale fishermen who face higher risks from adverse weather conditions. The ability to anticipate changes in the season allows fishermen to optimize their fishing schedules and ensure safety, which is consistent with previous studies on the importance of weather information in fisheries management.

Overall, the results indicate that seasonal information is vital for the fishermen in the western coastal areas of Makassar City, as it helps them adapt their activities to changing weather conditions. This study underscores the importance of improving weather information services to support local fishing communities, which is consistent with global trends in the integration of meteorological services in fisheries management.

CONCLUSION

Based on the research findings and discussion, it can be concluded that the zonal wind data on the western coast of Makassar City cannot be used to determine the onset of the season. This is due to the difference in wind patterns in the area, which does not align with the monsoonal wind patterns, largely influenced by local factors such as land-sea wind interactions. The weather conditions significantly impact the fishing activities, as evidenced by the high score of 89.86% (strongly influential) obtained from the Likert scale calculation of early season information's effect on the fishermen's activities. Furthermore, early season information plays a crucial role in improving safety, determining the appropriate fishing gear, and enhancing the catch volume for fishermen on the western coast of Makassar City. The findings of this research underscore the importance of integrating weather information into fishing practices to support safety and productivity in this coastal area.

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