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WAVE HEIGHT CHARACTERISTICS DUE TO THE INFLUENCE OF LAND AND SEA BREEZES ON FISHERMEN'S ACTIVITIES IN THE COASTAL AREA OF MAKASSAR CITY USING DOPPLER WEATHER RADAR

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ABSTRACT: Makassar City, located on the southwest coast of Sulawesi Island, exhibits dominant land and sea breeze circulation, with sea breezes being stronger during the day and land breezes at night. The use of weather radar is effective in identifying these wind characteristics, which are crucial for fishing activities and renewable energy. This study investigates the characteristics of land and sea breezes and their relation to wave heights in the Spermonde Waters of Makassar during the east and west seasons, providing important information for maritime activities in Makassar City. The research area is located between 4°59’20”S 119°27’46”E and 5°11’26”S 119°22’54”E. This study uses weather observation data, including weather radar data, weather observations, and wave heights from January 2020 to December 2020, divided into three seasonal periods (rainy season, transition period, and dry season). The weather observation data were obtained from Hasanuddin Makassar Meteorological Station and Paotere Makassar Maritime Meteorological Station. Additionally, questionnaires were distributed to fishermen at three locations: PPI Paotere Makassar, PPI Untia Makassar, and Kuri Caddi-Maros Beach Fishermen Village, with 15 respondents at each location. The study shows that land breezes in Makassar are dominant from 18:05 to 19:00 LT with a duration of 9.1 to 11 hours, while sea breezes dominate from 08:00 to 09:00 LT with a duration of 5.1 to 7 hours. This phenomenon is most frequently detected during the dry season (JJA). Land and sea breezes can intrude up to 20.1 to 30 km from the coastline. There is a highly significant positive correlation between wind and wave height in January and August, indicating a strong influence of winds on waves in the Spermonde Waters of Makassar. About 80% of fishermen utilize these wind conditions for fishing activities. Overall, the land and sea breeze patterns significantly impact wave heights and the activities of fishermen in the coastal areas of Makassar.
Keywords: land-sea breeze, wave height, Makassar city, weather radar

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INTRODUCTION

Indonesia, as an archipelagic nation, comprises approximately 62% of its territory as sea, while land covers only 38%. This condition leads to high weather variability and significant atmospheric interaction between land and sea. According to Tjasyono (2006) and Aldrian (2008), Indonesia’s climate is heavily influenced by its surrounding seas. Meteorological conditions along Indonesia's coastal regions differ significantly from inland areas due to air flow patterns influenced by

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temperature variations between land and sea, topography, coastline shape, and land use heterogeneity (Pielke, 2013).

One Indonesian city exemplifying distinct land-sea interactions is Makassar. Located on the southwest coast of Sulawesi Island and bordered by the Makassar Strait to the west, Makassar serves as the capital of South Sulawesi Province. Astronomically, Makassar is situated at coordinates 119°24’17.38” E and 5°8’6.19” S, with varying elevations from 1 to 25 meters above sea level. The city's relatively flat topography slopes 0 - 5° westward and is flanked by two river estuaries, namely the Tallo River to the north and the Jeneberang River to the south. These geographical conditions contribute to the dominance of local wind circulation, particularly land and sea breezes (Meilusiani, 2018).

Theoretical perspectives indicate that land and sea breezes result from temperature differences between land and sea (Simpson, 1994). Diurnal temperature variations, particularly between day and night, primarily drive these small-scale and localized daily wind systems (Tjasyono & Harijono, 2006). Daily variations and local circulations are crucial for weather prediction, observation, and research (Tjasyono & Harijono, 2013). Research by Hadi et al. (2002), using Boundary Layer Radar data, shows that sea breezes are more dominant during the day, while land breezes prevail at night. These atmospheric circulations are mesoscale phenomena driven by significant temperature gradients between land and sea (Paski et al., 2019).

Weather radar is widely used as a remote sensing tool to identify local wind characteristics (Kristianto et al, 2018). Studies by Noersomadi et al. (2014), Meilusiani (2018), and Purba et al. (2021) demonstrate the effectiveness of weather radar in detecting sea breeze fronts, especially under cloud-free conditions. Weather radar provides data with good temporal and spatial resolutions for observing short-term phenomena such as land and sea breezes and convective activities.

The coastal regions of Indonesia hold significant potential in the fisheries sector. The abundant marine resources can boost the economy, particularly benefiting fishermen as they engage in fishing activities (Pahlawan et al., 2020). Along coastal areas, winds play a crucial role in daily activities (Saragih et al., 2017). Fishermen often utilize wind to navigate their boats while fishing at sea. They consider factors such as star positions, wind direction, and tidal currents. Indonesia’s fisheries sector holds significant potential, generating over USD 8 billion annually (Supandi et al., 2021). Land and sea breezes provide significant advantages for fishermen in their daily activities.

In addition to fisheries, wind energy is harnessed as a renewable energy source, particularly in coastal areas with high wind potential (Laili & Sudarti, 2021). Patterns of land and sea breezes also influence wave conditions, crucial for marine activities undertaken by communities and government agencies. Thus, research is needed to investigate the characteristics of land and sea breezes and their relation to wave height in the Spermonde Waters of Makassar during the east and west monsoon seasons. The findings are expected to serve as valuable reference and provide useful information for maritime activities, especially for fishermen and the tourism sector in Makassar City.

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METHOD

Study Area and Period

The study area extends from coordinates 4°59’20”S 119°27’46”E to 5°11’26”S 119°22’54”E, bordering Maros Regency to Makassar City, approximately 36.49 km apart. The primary focus of this study is the west coast region from Maros Regency to Makassar City. The study area falls within the coverage of the BMKG Makassar weather radar (Figure 1).

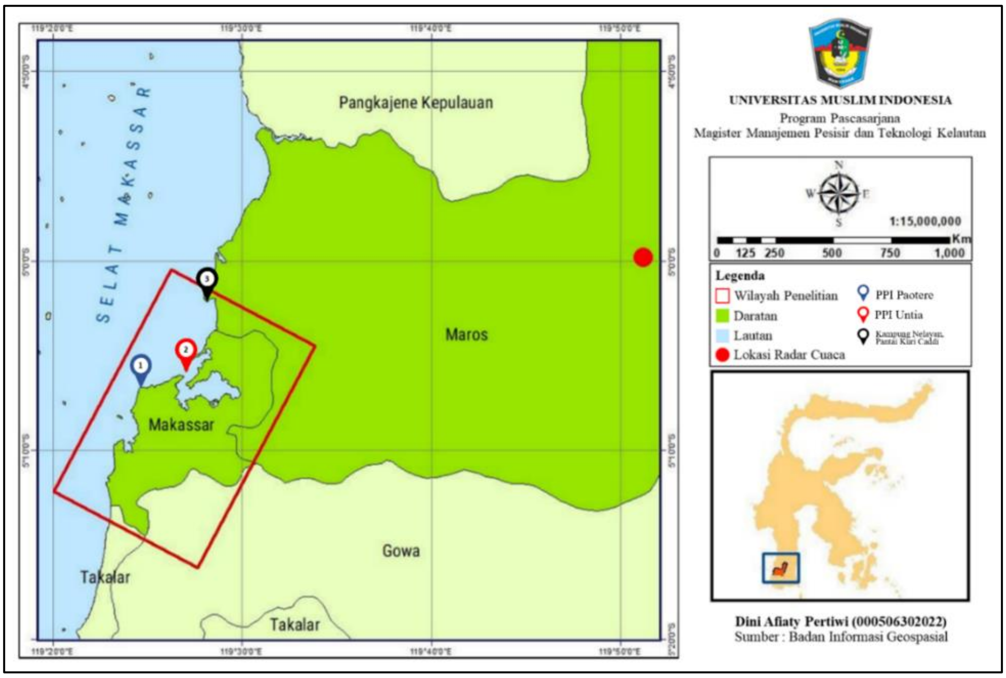

Figure 1: Map of The Study Area

Here are several points that are research locations in the distribution of questionnaires, because these locations are where fishermen gather and serve as points for unloading and selling their catches: (1) Paotere Fishery Port, Makassar, as a central hub for fishermen's activities and the main access point to the sea. Paotere Fishery Port can serve as an ideal location to observe fishermen's activities. (2) Untia Fishery Port, Makassar. (3) Fishing village, Kuri Caddi Beach, Maros Regency. The distance between Paotere Fishery Port, Makassar, and Untia Fishery Port is 7.69 km. Meanwhile, the distance between Untia Fishery Port and the fishing village, Kuri Caddi Beach, Maros Regency, is 3.16 km.

This study utilized radar data, weather observations, and wave heights from January 2020 to December 2020, divided into three seasonal periods (rainy season, transition period, and dry season). The rainy season covers January, February, and December. The transition period includes March, April, and May. The dry season spans June, July, and August. The data used in this study are from the 2020 period, adjusted based on available data. For recent years like 2021-2023, the required data products were not available. The specifications of the BMKG weather radar in Makassar are presented in Table 1.

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Table 1. Specifications of BMKG Weather Radar in Makassar

Specifications	Details
Brand	Gematronik
Latitude position	4.997733 °S
Longitude position	119.572017 °E
Band type	C-band
Polarization	Single polarization (horizontal)
Antenna height	19 meters above ground level
Antenna speed	15°/second

Research Data

The data used in this study includes raw weather radar data from Gematronik Makassar located at the South Sulawesi Climatology Station (operated by the Hasanuddin Meteorological Station). The Makassar weather radar is a Doppler radar type. The raw data utilized consists of reflectivity (Z) and radial velocity (V) data from the 2020 period, specifically selected for case studies showing occurrences of land and sea breezes on the weather radar.

The study also incorporates comparative data, such as wind direction and speed observations sourced from the Paotere Maritime Meteorology Station in 2020. Wave data is used to explore correlations with the presence of these local winds, also obtained from the Paotere Maritime Meteorology Station in 2020. Additionally, interviews were conducted with fishermen at PPI Paotere Makassar, PPI Untia Makassar, and the fishing village of Pantai Kuri Caddi (Maros Regency) to gather information. Interviews were conducted using questionnaires/guided interviews to delve into details. The types and sources of data used in this research are detailed in Table 2.

Table 2. Types and Sources of Research Data

Data	Data Nature		Data Source
	Primary	Secondary	
Radar		V	BMKG
Wind		V	BMKG
Waves		V	BMKG
Questionnaire	V		Fishermen

Data Collection Techniques

The data collection technique involved retrieving Makassar weather radar data by making copies from the database of the Hasanuddin Meteorological Station using external storage devices. Similarly, wind observation data and wave height data were obtained from the Paotere Maritime Meteorology Station. In addition, questionnaires were distributed to fishermen willing to participate as respondents at 3 locations: PPI Paotere Makassar, PPI Untia Makassar, and the fishing village of Pantai Kuri Caddi (Maros Regency), all within the coverage area of the Makassar weather radar. Fifteen respondents were targeted at each location for this study. The data collected were processed at the Paotere Maritime Meteorology Station.

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Data Analysis Techniques

The data processing and analysis technique employed in this study continued with descriptive analysis, a method used to analyze data by describing it in its true form such as through tables, graphs, and pie charts (Sugiyono, 2015). The descriptive analysis conducted in this research is as follows:

1) Analyzing the frequency of onset time, duration, and intrusion of land and sea breezes. This was presented using bar charts and graphs to identify variations and frequencies. Subsequently, descriptive analysis was performed to depict the characteristics of each parameter. For comparative data, observation data processing was conducted, analyzing each parameter. Data processing involved separating land breeze and sea breeze occurrences based on estimated sunrise and sunset times, around 06:00 and 18:00, respectively, and extracting data from two hours after sunrise/sunset to two hours before sunrise/sunset (Anzhar and Yarianto, 2000). Further data processing was performed using WR-Plot software to generate wind rose diagrams, subsequently analyzing wind direction and speed percentages.
2) Analyzing land and sea breeze parameters to determine their correlation with wave height using IBM-SPSS software, thereby determining the correlation coefficient values for each parameter. Sugiyono (2008) provides guidelines for interpreting correlation coefficients as follows:

Table 3. Guidelines for Interpreting Correlation Coefficients

Interval of Coefficient	Level of Relationship
0,00 – 0,199	Very weak correlation
0,20 – 0,399	Weak correlation
0,40 – 0,599	Moderate correlation
0,60 – 0,799	Strong correlation
0,80 – 1,000	Very strong correlation

3) Analysis of the utilization of land breeze and sea breeze activities by fishermen around the west coast area of Makassar City for fishing activities obtained from fishermen respondents using questionnaires.

Data Processing Techniques

Data processing techniques were conducted following the workflow outlined below:

1) Processing Z radar data using Rainbow 5.49 application to generate PPI(Z) products at 0.5-degree elevation angle to detect land breeze and sea breeze, and CMAX (Z) products to detect convective activities. Sea breeze fronts (SBF) were identified by low reflectivity values in thin line patterns similar to the coastline.
2) Creating cross-lines for land breeze and sea breeze using the distance measurement feature to calculate intrusion lengths upon reaching the land.
3) Calculating occurrence frequency, onset times, and durations detected using PPI(Z) products at 0.5-degree elevation angle, presented in tabular form.

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4) Identifying the furthest intrusion distance inland based on time-series data from PPI(Z) products. The furthest intrusion distance was measured from the coastline to the location where land breeze and sea breeze activities began to diminish using the distance measurement feature, presented in tabular form.
5) Further processing observational data including wind direction, wind speed, air temperature, and humidity using WR-Plot (wind rose diagram) and graphs. This served as comparative data alongside radar weather data.
6) Analyzing land breeze and sea breeze correlations with wave heights using IBM-SPSS software to determine correlation coefficients for each parameter.
7) Analyzing based on fisherman questionnaire results at 3 locations (PPI Paotere Makassar, PPI Untia Makassar, and Pantai Kuri Caddi fishing village, Maros Regency) on the utilization of land breeze and sea breeze for fishing activities.

RESULT AND DISCUSSION

Characteristics of Land Breeze and Sea Breeze in Spermonde Waters of Makassar

The determination of land breeze and sea breeze occurrences is based on the characteristics of echo phenomena, where land breeze and sea breeze appear as thin lines with low reflectivity. These phenomena are clearly detected as they begin to move inland and seaward. These conditions were identified using PPI(Z) radar products at a 0.5-degree elevation angle (low elevation), chosen to observe land breeze and sea breeze events effectively. The table below details the occurrences of land breeze and sea breeze in Makassar observed from January to December 2020.

During the research period from January to December 2020, radar weather data was available for analysis over 327 days. The number of radar data processed does not correspond exactly to the number of days in each month due to limited availability of radar weather data. Additionally, radar limitations such as clutter significantly influenced the detection of land breeze and sea breeze events, resulting in fewer identified occurrences compared to the amount of data processed. According to Table 4, land breeze and sea breeze events in Makassar were predominantly observed by radar during the June-July-August period (dry season), with 50 sea breeze events and 39 land breeze events recorded.

Table 4. Identification Results of Land Breeze and Sea Breeze Events in Makassar During 2020 Period Using Doppler Weather Radar

Time Periode (2020)	Number of Days	Number of Days Processed	Number of Sea Breeze Events Observed	Number of Land Breeze Events Observed
January	31	31	8	6
February	29	28	8	5
March	31	31	10	7
April	30	30	10	8
May	31	19	3	3
June	30	30	15	10
July	31	31	20	17
August	31	31	15	12
September	30	29	13	11
October	31	31	6	12

Time Periode (2020)	Number of Days	Number of Days Processed	Number of Sea Breeze Events Observed	Number of Land Breeze Events Observed
November	30	5	0	0
December	31	31	2	4
Total Events	**366**	**327**	**110**	**95**

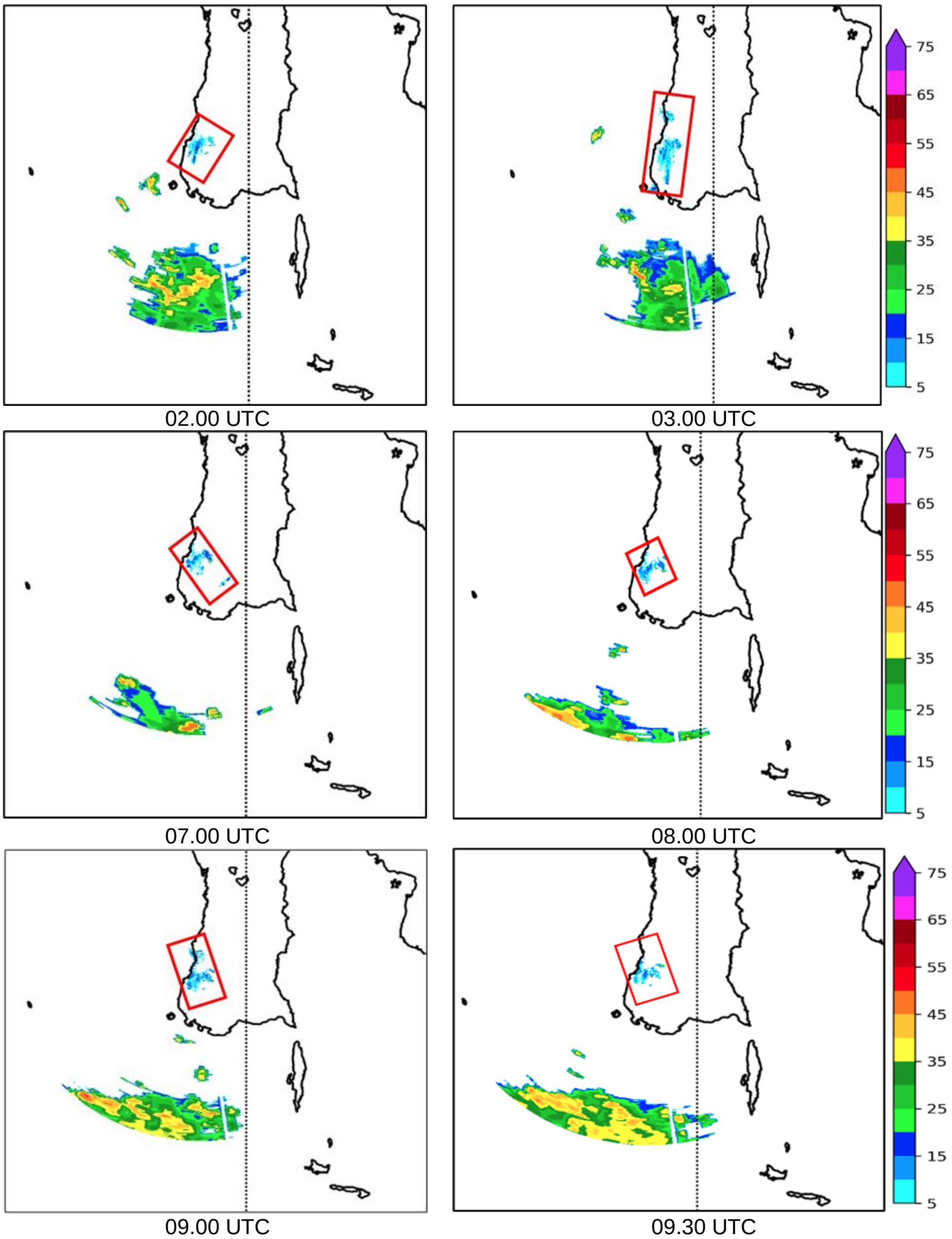

Figure 2: Example of sea breeze event detection on the coast of Makassar; sea breeze event on December 31, 2020 detected by weather radar from 02:00 UTC to 09:30 UTC

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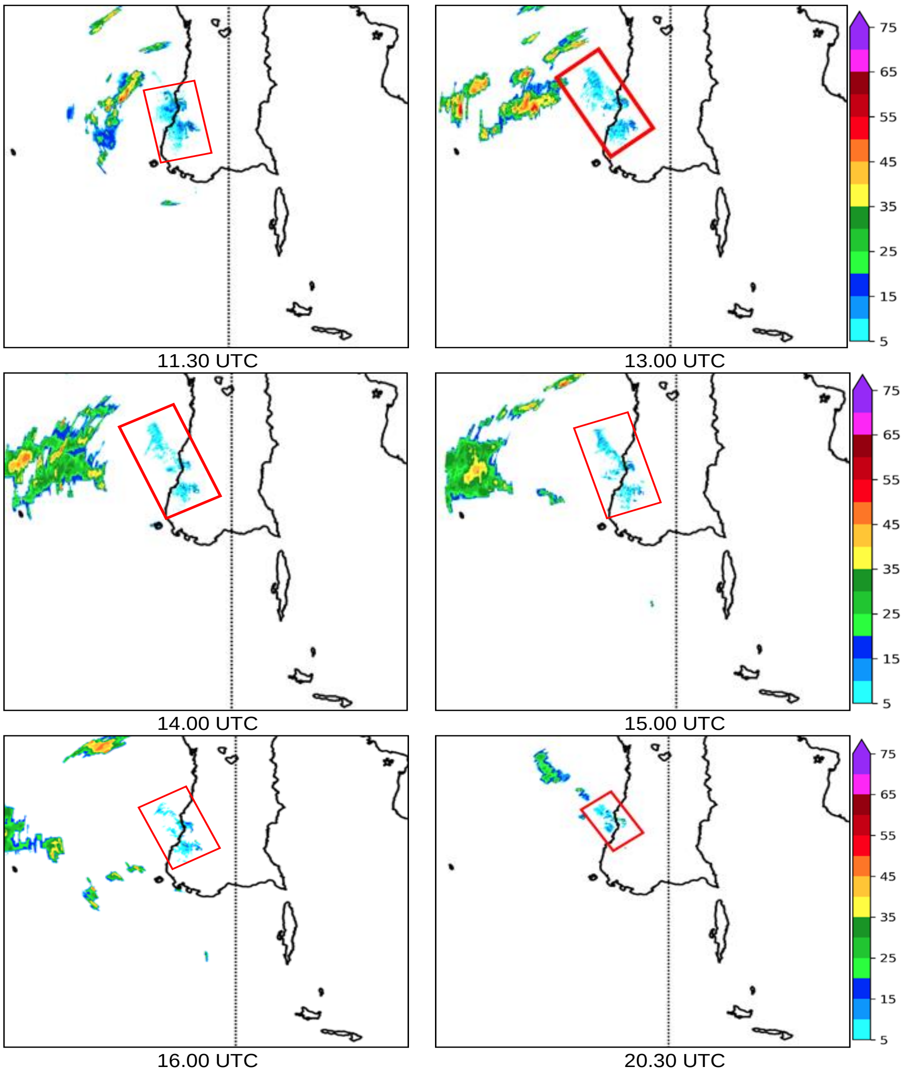

Figure 3: Example of Land Breeze Event Detection on The Coast of Makassar; Land Breeze Event on December 3, 2020 Detected by Weather Radar From 11:30 UTC to 20:30 UTC

Rainy Season (December-January-February or DJF)

During the rainy season, land breeze typically starts between 10:00 UTC - 11:00 UTC with an average duration of 7.9 hours and reaches up to 40.61 km into the sea. The longest duration occurs in February, lasting 11.3 hours, with the furthest intrusion into the sea observed in January at 60.46 km from the coastline of Makassar. For sea breeze events along the Makassar coastal area during the DJF period of 2020, they typically begin between 01:10 UTC - 02:00 UTC with an average duration of 6.8 hours and an average intrusion of 37.69 km inland. The longest duration for sea breeze events was in February 2020, lasting 10 hours, while the furthest intrusion inland occurred in January 2020, reaching 49.30 km from the coastline of Makassar.

The average wind speed and direction during December predominantly blew from the west between 03:00 - 11:00 UTC (11:00 - 19:00 LT) at speeds ranging

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from 4 - 7 knots, and from the east between 12:00 - 02:00 UTC (20:00 - 10:00 LT) at speeds ranging from 3 - 5 knots. In January and February, the wind direction pattern was more consistent compared to December. The wind direction showed an increase from the east around (50° - 150°) at 00:00 UTC (08:00 LT). Subsequently, the wind blew from the west (230° - 350°) between 02:00 and 11:00 UTC (10:00 - 19:00 LT) with average wind speeds ranging from 4 - 6 knots. Later, between 12:00 - 23:00 UTC (20:00 - 07:00 LT), the wind direction returned to blowing from the east with average wind speeds ranging from 2 - 4 knots. This pattern indicates the presence of consistent diurnal circulation during December-January-February, where winds blow from land to sea during the night to morning (20:00 - 10:00 LT), gradually shifting to sea breeze (wind from sea to land) during the afternoon to evening (11:00 - 19:00 LT) due to temperature differences between land and sea, which typically occur during the daytime to evening hours.

Transition Period I (March-April-May or MAM)

During transition period I, land breeze is observed during the night, indicating intrusion into the sea with distances varying between 24 to 57 km. The onset time of land breeze ranges from 10:20 - 12:40 UTC (18:20 - 20:40 LT), with an average duration of about 9 hours. This pattern indicates rapid cooling on land during the night, causing air movement from land towards the sea. On the other hand, sea breeze occurs during the daytime with onset times between 00:00 - 07:30 UTC (08:00 - 15:30 LT). The average duration of sea breeze is around 7 hours, with a longer intrusion distance reaching up to 39.86 km inland. This illustrates faster heating on land during the day, drawing air from the sea to the land.

During transition period I, winds tend to blow from the west and northwest directions, especially during the morning to afternoon hours, with fairly consistent wind speeds but showing peaks at specific times (around 13:00 - 15:00 LT). The wind direction pattern in March and April 2020 is almost identical. In the morning at 00:00 UTC (08:00 LT), the average wind direction is around 100° - 120° (east-southeast) with an average wind speed of 3 knots. Afterward, the wind direction shifts significantly towards west-northwest (around 280° - 340°) at 01:00 UTC (09:00 LT) and remains fairly constant around 240° - 310° (west-west northwest) until 12:00 UTC (20:00 LT) with average wind speeds ranging from 3 - 6 knots. The wind direction undergoes another change at 13:00 UTC (20:00 LT), where the wind blows from the east with average wind speeds of 2 - 3 knots.

In May 2020, at 00:00 UTC (08:00 LT), the average wind direction is around 60° (east) with wind speeds of 3 knots. Essentially, the pattern is almost similar to the previous months, but what distinguishes May 2020 is that sea breeze (westward direction) diminishes or changes to land breeze (eastward direction) one hour earlier. Similar to the preceding months, this pattern indicates the presence of consistent diurnal circulation, where winds blow from land to sea during the night to morning (20:00 - 10:00 LT), gradually shifting to sea breeze (wind from sea to land) during the afternoon to evening (11:00 - 19:00 LT) due to temperature differences between land and sea, typically occurring during the daytime to evening hours.

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Dry Season (June-July-August or JJA)

During the dry season period, land breeze generally occurs during the night to early morning, indicating intrusion into the sea with distances varying between 18 to 69 km. The onset time of land breeze ranges from 10:05 - 13:25 UTC (18:05 - 21:25 LT), with an average duration of about 8.1 hours. This pattern shows rapid cooling on land during the night, causing air movement from land towards the sea. On the other hand, sea breeze occurs during the daytime with onset times between 00:00 - 05:35 UTC (08:00 - 13:35 LT). The duration of sea breeze events also varies but generally shorter compared to land breeze. The average duration of sea breeze during the JJA 2020 period ranges around 7.8 hours, with intrusion distances varying between 12 to 33 km inland. This illustrates faster heating on land during the day, drawing air from the sea to the land.

During the dry season, a pattern is observed where winds blow from land to sea during the night to morning (20:00 - 09:00 LT), gradually shifting to sea breeze during the afternoon to evening (10:00 - 19:00 LT). In June 2020, wind direction from 00:00 - 01:00 UTC (08:00 - 09:00 LT) blows from the east (around 90° - 100°) with average wind speeds of 2 - 3 knots. Subsequently, the wind direction shifts significantly towards southwest - west (around 230° - 290°) at 02:00 UTC (10:00 LT) until 12:00 UTC (20:00 LT) with average wind speeds of 3 - 5 knots. The wind direction undergoes another change at 13:00 UTC (21:00 LT), where the wind blows from east-southeast with average wind speeds of 1 - 3 knots.

Meanwhile, in July 2020, at 00:00 UTC (08:00 LT), the wind predominantly blows from southeast (130°) at 2 knots. Unlike June 2020, in this month, the wind direction from southwest - northwest (230° - 330°) appears one hour earlier than the previous month. This condition persists until 11:00 UTC (19:00 LT) with average wind speeds of 3 - 5 knots. The wind direction undergoes another change at 12:00 UTC (20:00 LT), one hour earlier than June 2020, where the wind blows from east-southeast with average wind speeds of 2 - 3 knots. In August 2020, from 00:00 - 01:00 UTC (08:00 - 09:00 LT), the average wind direction blows from east-southeast (100° - 130°) at 3 knots. Essentially, the pattern is similar to June 2020. However, what distinguishes August 2020 from the previous month is the higher average wind speeds ranging around 4 - 7 knots blowing from southwest - west (210° - 300°). The wind direction undergoes another change at 12:00 UTC (20:00 LT), where the wind blows from northeast - southeast (20° - 190°) with average wind speeds of 2 - 4 knots.

Transition Period II (September-October-November or SON)

During the transition period II period, land breeze generally occurs during the night to early morning, characterized by temperature differences between land and sea that cause air flow from land towards the sea. The onset time of land breeze varies between 09:25 to 15:45 UTC (17:25 – 23:45 LT), with an average event duration of about 8.3 hours. Land breeze intrusions range from 18.38 to 61.68 km. For instance, on October 10, 2020, land breeze started at 10:41 UTC (18:41 LT) with a duration of 10.1 hours and an intrusion distance of 21.08 km. Meanwhile, on September 7, 2020, the event had a shorter duration of 3.1 hours but a significant intrusion distance of 57.78 km.

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Sea breeze occurs during the day to afternoon, caused by the warmer temperature of the sea compared to the land, resulting in air movement from the sea towards the land. The onset time of sea breeze varies between 00:05 to 05:45 UTC (08:05 – 13:45 LT), with an average event duration of about 7.4 hours. Sea breeze intrusions range from 18.77 to 51.45 km. For example, on October 5, 2020, sea breeze started at 05:45 UTC (13:45 LT) with a duration of 4.2 hours and an intrusion distance of 22.22 km. On October 7, 2020, the event lasted for 8.2 hours with a very significant intrusion distance of 51.45 km.

During the transition period II period (September-October-November) 2020, observational data indicates that from September to November 2020, wind direction at 00:00 UTC (08:00 LT) blew from northeast - southeast (around 30° - 120°) with average wind speeds of 2 - 3 knots. Subsequently, the wind direction shifted significantly towards southwest - northwest (around 210° - 310°) at 01:00 UTC (10:00 LT) until 12:00 UTC (20:00 LT) for September, while in November, westward winds persisted until 11:00 UTC (19:00 LT), and in October, westward winds persisted until 10:00 UTC (18:00 LT). The average wind speeds were 3 - 8 knots. The maximum wind speed occurred in October 2020 (8 knots). Later, the wind direction returned to blowing from east - southeast at each period in September (13:00 UTC), October (12:00 UTC), and November (11:00 UTC) with average wind speeds of 2 - 4 knots.

The Relationship Between Land and Sea Breeze Patterns and Wave Height Characteristics in the Spermonde Waters of Makassar

The Spermonde Waters of Makassar are known for their significant atmospheric dynamics influenced by local winds. These wind patterns not only affect local meteorological conditions but also impact wave height characteristics in the region. Land breeze, blowing from land to sea during late night and early morning, and sea breeze, moving from sea to land during daytime, create variations in wind speed and direction that can trigger changes in wave height. This subsection focuses on analyzing the relationship between land and sea breeze patterns and wave height characteristics in the Spermonde Waters of Makassar, aiming to provide deeper insights into their implications for fishing activities and coastal environmental conditions.

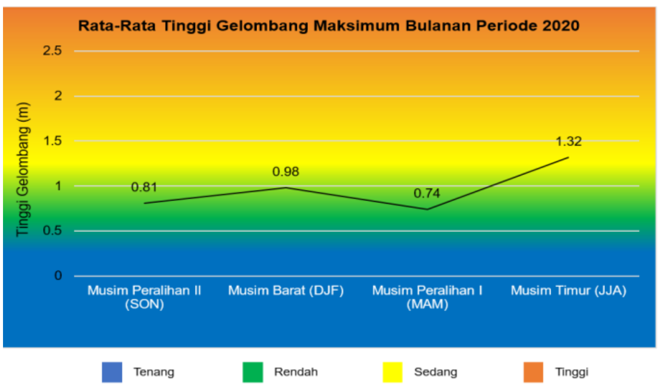

Figure 4: Fluctuations and High Wave Safety Risk Levels in The Spermonde Waters of Makassar During The 2020 Period

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Given the above description, discussions on wind and wave heights in a maritime region are deemed crucial. Information related to wind and wave conditions is essential for both community needs and governmental purposes in marine activities. Wave height data used in this study are based on BMKG Ocean Forecast System (OFS) model data. Subsequently, these data are correlated with local wind data using IBM-SPSS software to determine correlation coefficients for each parameter. Wave height data in Figure 4 are analyzed using a safety risk level matrix to ascertain wave safety levels for navigation. Seasonal fluctuations in wave height during the 2020 period exhibit varying patterns from one season to another, with higher waves typically observed during the west and east monsoon seasons compared to transition period.

This condition aligns with the findings of the research (Putra, 2015), which state that wave height variations in Indonesian waters are influenced by the prevailing seasons. In the Spermonde Waters of Makassar, during the second transition period, wave heights were 0.81 meters. Subsequently, during the west monsoon season, wave heights increased to 0.98 meters, while during the first transition period, wave heights decreased to 0.74 meters, and then increased again during the east monsoon season to 1.32 meters. From December to March, the sun is positioned south of the equator, creating a temperature gradient between Asia and Australia, which triggers the active west monsoon season. Winds during the west monsoon season consistently blow from Asia towards Australia, passing through Indonesia. This condition influences wave height variations in Indonesian waters, where higher wind speeds and directions lead to higher waves. Conversely, from June to September, during the active east monsoon season, winds blow significantly from Australia towards Asia through Indonesia, also resulting in high waves. During the transition periods, wind speeds and directions tend to be lower, thus resulting in lower wave heights.

Correlation of Land and Sea Winds with Wave Heights in Spermonde Waters of Makassar

Based on the correlation values of land and sea winds with wave heights, statistically significant correlations (p-value <0.05) are observed in January, March, May, June, July, August, and December. It is evident that during the first transition period (March-April-May), there exists a weak to moderate positive correlation between sea winds and wave heights, whereas during the dry season (June-July-August), a moderate to strong positive correlation is observed. During the rainy season (December-January-February), a strong positive correlation is observed in January with a correlation value of 0.712. Thus, strong correlations occur in January, July, and August.

Furthermore, statistically significant correlations (p-value <0.05) between land winds and wave heights are observed in January, February, March, July, August, September, and October. It is noted that from mid-rainy season to early first transition period (January to March) and from mid-dry season to mid-second transition period (July to October), there is a moderate to very strong positive correlation between land winds and wave heights. The strongest correlation occurs in January and August, with correlation values of 0.815 and 0.887, respectively.

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The highest correlation value is recorded in August at 0.887 (very strong correlation). In January and August, there is a notably significant positive correlation and the highest correlation values among the months for both land and sea wind variables with respect to wave heights. This indicates that in January and August, land and sea winds strongly influence wave heights to a strong to very strong degree.

Table 5. Correlation of Land and Sea Winds with Wave Heights in Spermonde Waters of Makassar during the 2020 period

Time Period	Correlation	
	Sea Breeze and Wave Height	Land Breeze and Wave Height
January Sig (2-tailed)	0.712 < 0.001	0.815 < 0.001
February Sig (2-tailed)	0.240 0.211	0.646 < 0.001
March Sig (2-tailed)	0.398 0.026	0.457 0.010
April Sig (2-tailed)	-0.121 0.523	0.208 0.269
May Sig (2-tailed)	0.521 0.003	0.353 0.051
June Sig (2-tailed)	0.519 0.003	0.332 0.073
July Sig (2-tailed)	0.665 < 0.001	0.440 0.013
August Sig (2-tailed)	0.687 < 0.001	0.887 < 0.001
September Sig (2-tailed)	0.428 0.060	0.606 0.005
October Sig (2-tailed)	0.315 0.084	0.436 0.016
November Sig (2-tailed)	0.314 0.091	0.142 0.454
December Sig (2-tailed)	0.516 0.003	0.348 0.055

Color Note:
Very strong
Strong
Moderate
Weak
Very weak

Influence of Land and Sea Wind Utilization on Fishermen Activities around the Coastal Areas of Makassar

1) General Conditions

Part A of the questionnaire was used to gather information about the fishermen's identities. This section provided insights into the demographic profile of the fishermen. Figure 5 illustrates the age distribution among the respondents. It was observed that out of 45 fishermen/respondents, the maximum age observed was 65 years, while the minimum age was 25 years. The age range of the respondents indicates that the majority are within their productive years. The most represented age group falls within the range of 30 – 50 years, reflecting the predominant age profile among fishermen. This suggests that fishing activities are primarily carried

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out by individuals in their peak working years. There is a relatively small proportion of fishermen under 30 years old, indicating limited participation of younger individuals in this industry. Meanwhile, the age group over 50 years old represents a significant segment of senior fishermen, suggesting accumulated knowledge and skills over time in the profession. Most fishermen have several years of experience in this field, indicating a high level of expertise and commitment to the fishing profession. Conversely, those under 30 years old typically have less than 5 years of experience. Overall, respondents often choose to become fishermen due to family traditions in the occupation.

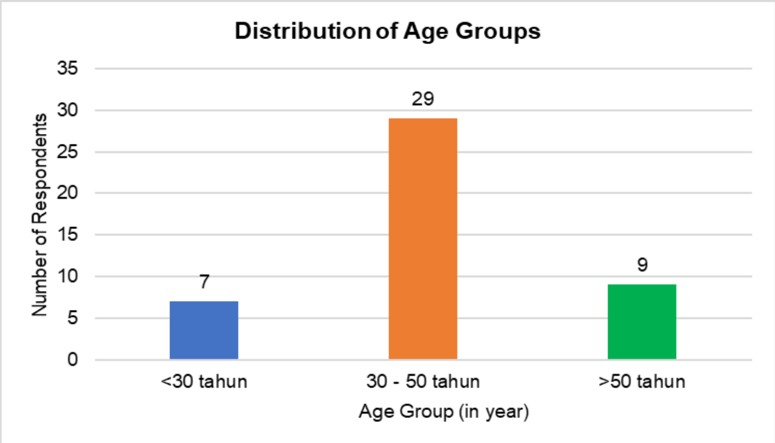

Figure 5: Distribution of Age Groups Among Fishermen

Figure 6 illustrates the distribution of fishermen’s highest educational attainment. It is observed that out of 45 fishermen, 28 have completed primary education, while 11 and 6 fishermen have completed senior high school and junior high school level, respectively. The predominance of fishermen with elementary education backgrounds indicates that the fishing sector is accessible to various segments of society, including those with limited formal education. The presence of fishermen with secondary education reflects that the industry also attracts individuals with higher educational achievements.

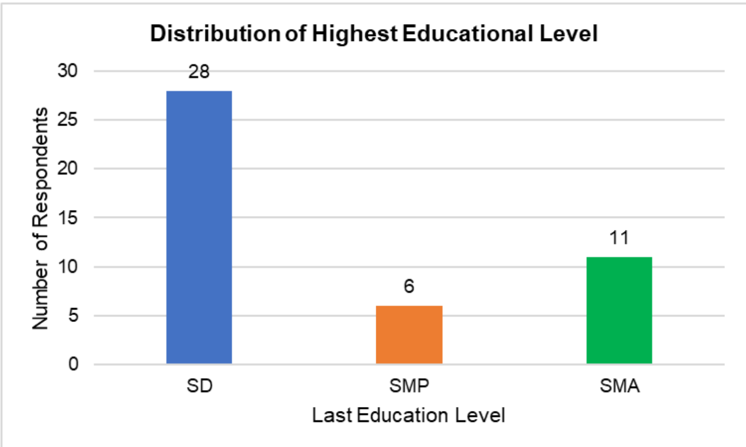

Figure 6: Distribution of Highest Educational Level Groups Among Fishermen

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2) Fishermen Activities in Utilizing Land and Sea Breezes

The majority of fishermen (approximately 62.22%) choose to depart for fishing between 20:00 – 00:00 LT (LT), followed by 28.89% departing between 16:00 – 20:00 LT, and 8.89% departing between 12:00 – 16:00 LT. Very few fishermen depart in the morning to midday, indicating that this timeframe has been their traditional practice for fishing activities besides the fact that they choose this time because of bait availability. Most of the fishermen who depart between 12:00 – 16:00 LT are crab hunters who need to spread nets in the morning and return in the afternoon to be picked up. In contrast, the time of departure from 20:00 – 00:00 LT (62.22%) is correlated with the land breeze period, typically occurring from night to early morning, when the wind blows from land to sea, providing more stable and safer conditions for fishermen to fish at sea.

Meanwhile, the majority of fishermen return between 08:00 – 12:00 LT (68.89%), followed by 04:00 – 08:00 LT (22.22%), and 8.89% return between 16:00 – 20:00 LT. This indicates that most fishermen spend their night to early morning at sea and return to land as morning approaches. Typically, they head directly to the nearest fishing port to unload their catch. Indirectly, they have utilized the phenomenon of sea breeze. The sea breeze, which usually occurs from morning to afternoon, provides a tailwind that helps fishermen return to land more easily. Overall, this research shows that the patterns of land and sea breezes significantly influence the departure and return times of fishermen. Understanding these wind patterns is crucial for fishermen to plan their activities safely at sea, maximize their catch, and return safely to shore.

CONCLUSION

Based on the research results, it can be concluded that land and sea breeze patterns significantly influence fishermen's activities around the coastal areas of Makassar. This is supported by research results, namely: (1) Land breeze in Makassar predominantly occurs between 18:05 – 19:00 LT with a duration of 9.1 – 11 hours. Meanwhile, sea breeze predominantly occurs between 08:00 – 09:00 LT with a duration of 5.1 – 7 hours. When associated with the seasonal patterns in Makassar, this phenomenon is predominantly detected during the dry season (JJA) in 89 cases. Most land and sea breezes can intrude into the sea and land up to a distance of 20.1 – 30 km. Generally, land breeze blows from the east at speeds of 1 – 5 knots, while sea breeze blows from the west at speeds of 3 – 9 knots. (2) In January and August, there is a very significant positive correlation between land breeze and sea breeze with wave height, with the highest values among other months. The correlation in January is 0.712 for sea breeze and 0.815 for land breeze, while in August it is 0.687 and 0.887 respectively. This indicates that in these months, representing the rainy and dry seasons, land and sea breezes strongly influence wave height with a strong to very strong impact. This correlation demonstrates that wind patterns directly affect wave height in the Spermonde Waters of Makassar. (3) Approximately 80% of fishermen utilize these land and sea breeze conditions in their fishing activities.

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