Oceanographic factors and water quality parameters as the indicators for shipyard industry development in Kutaraja Fishing Port, Indonesia

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Abstract. Oceanographic factors and water quality parameters have not yet been considered essential indicators for shipyard industry development. This research was conducted from December 2020 to December 2021 and aimed to identify the impact of oceanographic factors and water quality parameters on shipyard industry development in Kutaraja fishing port. The oceanographic data used included tide, wind, currents, wave, bathymetry, and sediment composition, which were collected from Meteorology, Climatology, and Geophysical Agency over the last three years. Meanwhile, the water quality data recorded were pH, temperature, dissolved oxygen, and salinity. The currents moved from the northeast and northwest towards the coastal areas around the eastern part of Kutaraja fishing port, close to the breakwater. The currents in the eastern part moved faster than those in the western, which comprised mostly shallow waters. The highest and lowest tides occurred at noon and evening, with water heights of -0.3855 and -1.0485 meters, respectively. Fine sand dominated the sediment in the sampling area, with the pH value in the good category, ranging from 7.13 to 8.3. The highest pH value was measured in the waters adjacent to the land. The sea surface salinity in the research area was 32-34 PPT, which gradually increased towards the coastal area at temperatures and Dissolved oxygen of 27.5 to 30°C and 7.02 to 9 mg L^{-1} respectively. The result showed that oceanographic factors and water quality parameters are essential factors that need to be incorporated during shipyard development.

Key Words: bathymetry, currents, sediment, shipyard, wind.

Introduction. A modern shipyard is an entity involved in shipbuilding, ship repair, ship modification, and other marine-related works (Rizwan et al 2023). Managing these activities requires specific skills and knowledge. Ideally, a modern shipyard is equipped with facilities that support the shipyard performance, such as slipway, graving docks, and floating dock. The shipyard industry also uses airbags as a ship launching method by utilizing rubber filled with air for the launching and ship docking process. The modern shipyard industries currently implement the modular construction approach in shipbuilding. Ships were designed and built based on the modular approach. This approach means that the module was built in a particular location and transported to the building location for the final line up then combined. Thus, the shipyard will only focus on the core area for shipbuilding instead of the whole process starting from designing to launching (Abdullah & Razak 2018).

Kutaraja Fishing Port is the biggest port in Aceh Province (Rizwan et al 2021), which accommodated 18,550,924 kg of fish from 244 fishing vessels in 2020. As a large-scale fishing port, it is expected to provide optimal services to support operational activities, such as fishing and the provision of the shipyard. A shipyard is one of the essential elements in the shipping industry, where ships are built and repaired. Around 40% of the operating cost in shipping organizations is allocated for maintenance and repairs, which is the second most important aspect (Zaman et al 2019). Furthermore, the shipyard industry is acknowledged as the main driver of shipping development and increasing income (Soh et al 2019). Unfortunately, shipyards around fishing ports are still traditionally managed on a small scale.

Oceanographic factors, such as currents, water depth, wind, waves, tides, and sedimentations, influence the location suitability for shipyard development in a port. Of those factors, current speed, wind, and wave height play a crucial role because they can disrupt the ships from entering and leaving the docking pool. Moreover, these three major factors also significantly influence the sedimentation level, leading to ponding silting in the future. Researches of the influence of oceanographic factors on shipyard development are still limited because the majority are still oriented to shipyard productivities (Kyaw et al 2016), facilitation layout (Choi et al 2017), production capacity (Lai et al 2020), as well as management and planning (Sukisno & Singgih 2019). Therefore, this research aims to investigate the influence of oceanographic factors and water quality parameters on shipyard industry development in Kutaraja Fishing Port.

Material and Method. This research was conducted from December 2020 to December 2021 in Kutaraja Fishing Port and Laboratory of Marine and Fisheries Faculty, Syiah Kuala University, at vertical and horizontal distances of 120 m and 310 m, respectively (Figure 1). Data analysis was performed on oceanographic factors and water quality parameters. The oceanographic factors which we studied were tides, wind, currents, waves, bathymetry, and sediment composition. The tidal, wind, currents, and waves data around the sampling sites for the last three years were collected from the Meteorological, Climatological, and Geophysical Agency. Furthermore, water depth samples were collected by emitting eco sounder/fishfinder waves to the waters. A grab sampler plugged into the seafloor was used to gather substrate samples and stored them in the sample bag. A total of 100 grams of substrate samples were collected with three replicates per site and then dried and sifted in a dry sieve. The sediment grain size was measured based on the Wentworth scale.

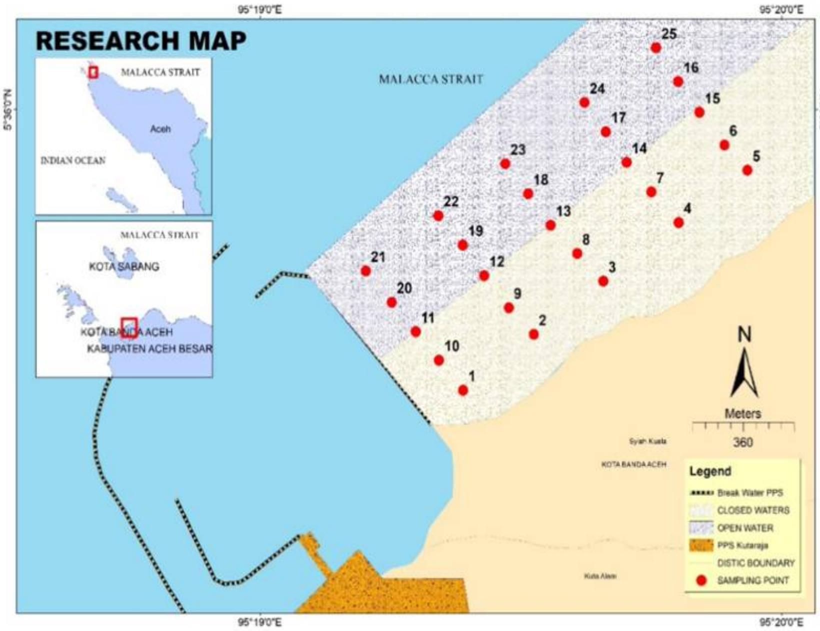

Figure 1. Sampling sites.

Tidal data was analyzed in Ms. Excel software to map the fluctuation for the past three years. Currents and bathymetry data were visualized using QGIS, while wind data was analyzed in WRP Plot. Water quality data was measured to determine the pH, temperature, dissolved oxygen, and salinity. Temperature and dissolved oxygen data were collected with DO meter (Lutron YK-2005WA; Taiwan), the water pH was measured using a digital pH meter (ATC pH-2011; Romania), and salinity was collected with the Salinometer (HANNA; United States). The data collected were analyzed and visualized in QGIS software.

Results

***Currents**.* Currents moved from the northeast and northwest towards the coastal areas adjacent to the breakwater of the eastern part of Kutaraja Fishing Port. The current around the breakwater of Kutaraja Fishing Port moved faster because it is located between two main rivers in the eastern and western parts. Areas colored in light red and light blue show high and low-speed currents ranging from 0.4 to 0.49 m s^{-1} and from 0.14 to 0.23 m s^{-1}, respectively (Figure 2). Most of the currents in this area moved towards northeast waters in the west monsoon due to the dominant wind blowing from southwest to northeast and water mass movement from Krueng Aceh River to the left of Kutaraja Fishing Port.

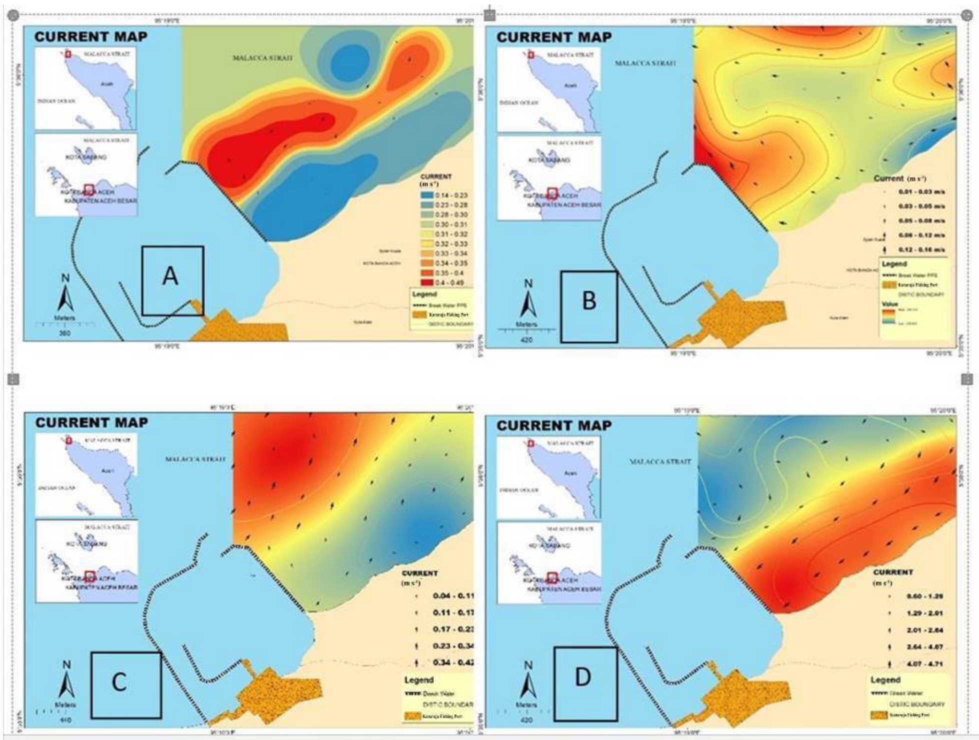

Figure 2. Currents patterns in the study site in east monsoon (A), east-west transition season (B), west monsoon (C), and west-east transition season.

***Bathymetry**.* The water depth in the research area ranges from 1 to 9 meters toward the open ocean. In the bathymetry map, shallow and deeper waters are illustrated using light and dark blue colors. Deeper waters have faster tidal currents than shallow waters. In the east monsoon, silting occurred around the breakwater in Kutaraja Fishing Port because of the current pattern that tends to flow towards this area. Meanwhile, the east-west transition season occurred in other areas outside this port. Silting can occur in areas with a depth ranging from 1.5 to 14.3 meters. Bathymetry did not significantly change from east-west transition season to west monsoon, as shown in Figure 3. The survey and analysis result indicated that in both seasons, bathymetry ranges from 1.5 to 14.34 m.

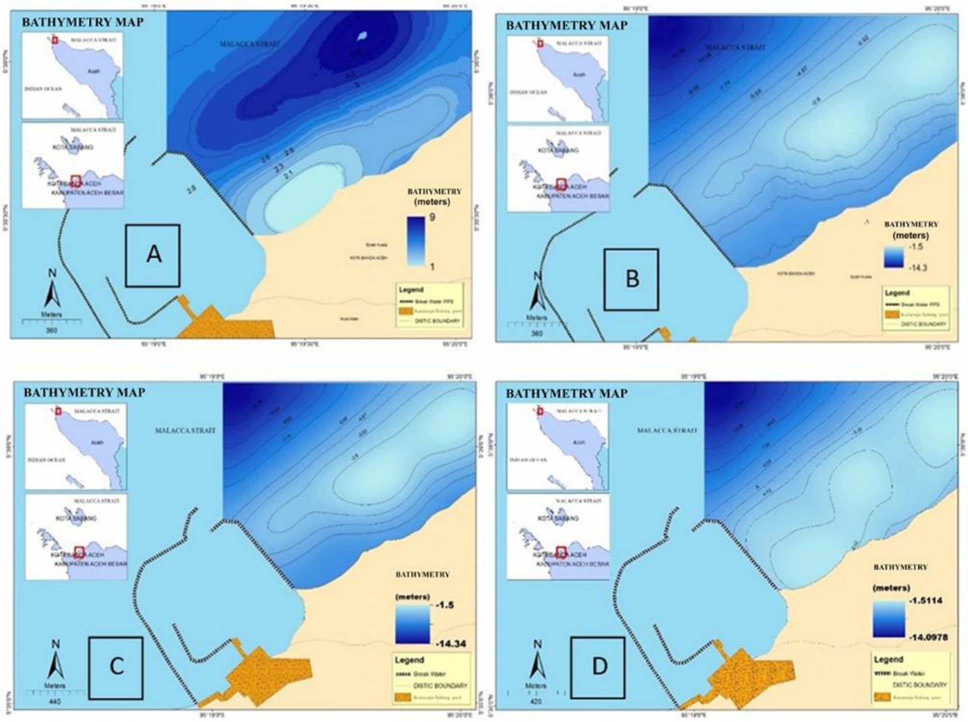

Figure 3. Bathymetry patterns in the study area in east monsoon (A), east-west transition season (B), west monsoon (C), and west-east transition season (D).

Waves. The x-axis and y-axis represent the hourly recorded water and wave heights in the last three years, respectively, as shown in Figure 4. The wave height and period in the research area range from 0.07 to 1.7 m and 21.5 to 22.31 seconds, respectively. Furthermore, the highest average wave height in the east monsoon in December 2020 ranged from 1.2 to 1.7 m. Meanwhile, the lowest average wave height of 0.07 m took place in February 2021, which is a transition season. The lowest and highest wave height in the east-west transition season was detected in April and March, respectively. Wave height in the west monsoon ranged from 0.24 to 1.23 m, with the highest and lowest recorded early July and August, respectively.

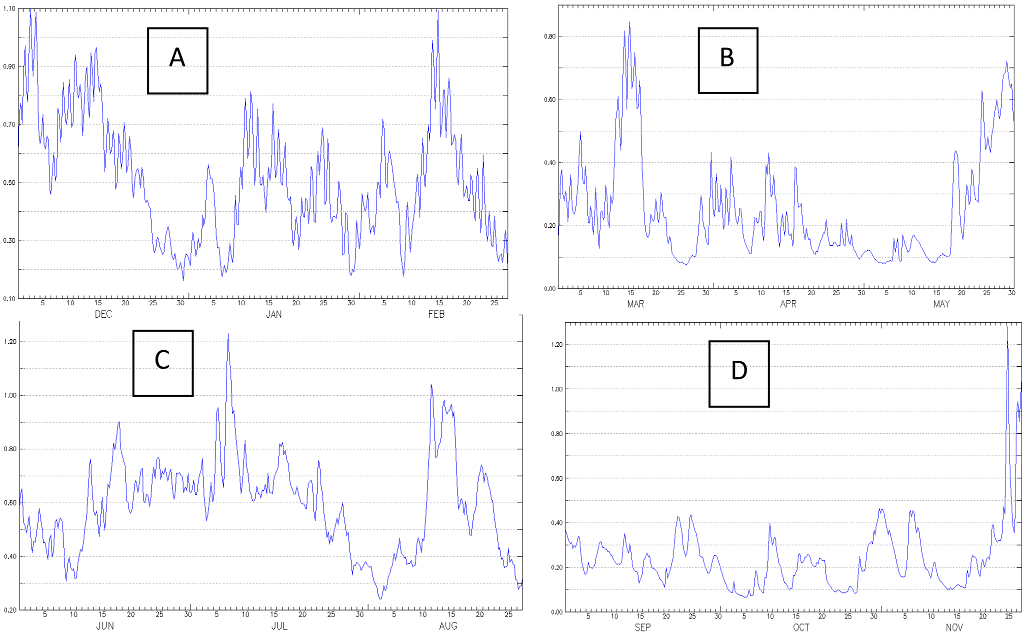

Figure 4. Waves patterns in the study area in east monsoon (A), east-west transition season (B), west monsoon (C), and west-east transition season (D).

***Wind**.* The wind speed recorded from December 2019 to February 2020 were highly varied, with a classification of 3.00-4.00 m s^{-1} mostly obtained in three months (29.6%) at a lower percentage of 1.1%. From March to May 2020, the fastest wind was dominated by the speed of 1.00 to 2.00 m s^{-1} (27.7%), and the lowest was ≥ 6.00 m s^{-1} (1.3%). Wind speed between June and August 2020 was similar to the pattern from March to May 2020, with 27.7% and 1.9%, respectively. Meanwhile, wind speed in the east-west transition season mostly falls into the 1.00-1.50 m s^{-1} category (48.8%), and the lowest is 0.0 m s^{-1}. It lows from the northeast with the highest speed ≥ 1.5 m s^{-1} and dominance of 1-1.5 m s^{-1} (Figure 5).

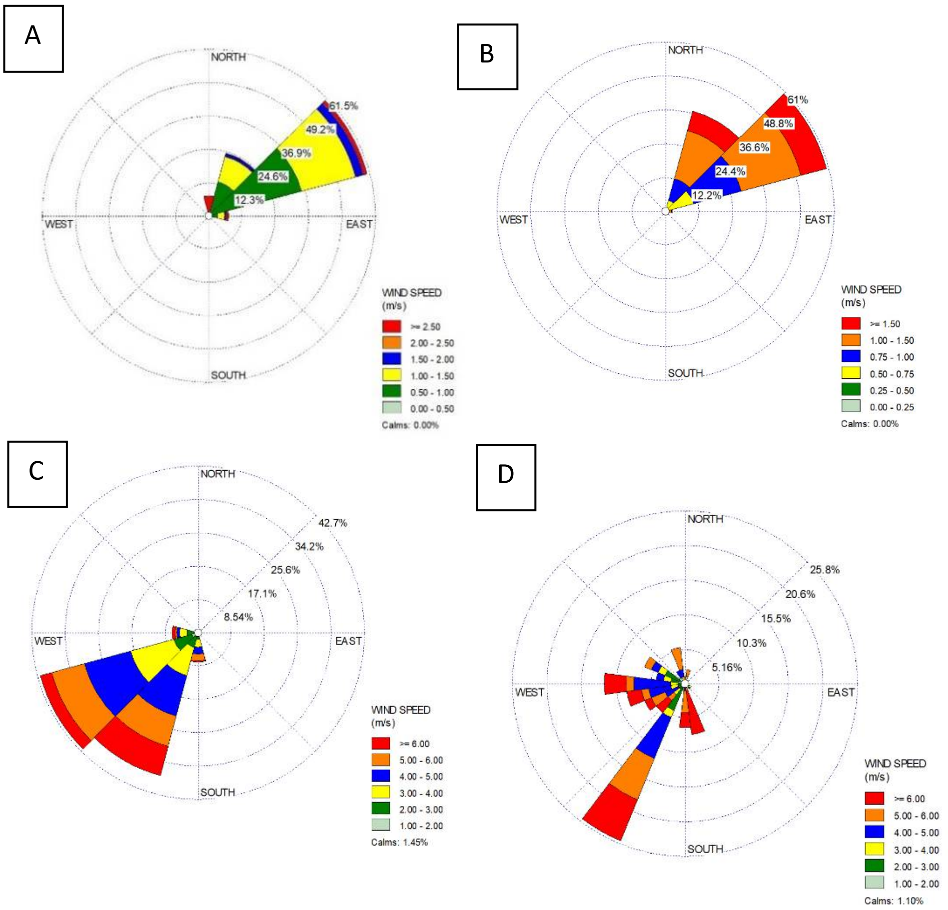

Figure 5. Wind pattern in the study area in east monsoon (A), east-west transition season (B), west monsoon (C), and west-east transition season (D).

***Tides**.* The tides patterns from December 2020 to February 2021 are shown in Figure 6. The highest and lowest tides occurred at noon and 19.00, respectively, with a water height of -0.3855 meters and -1.0485 meters. The highest and lowest tides were recorded in April and March 2021 at 0.849 meters and less than 0.815 meters, respectively. The lowest tide occurred on 23 August 2021, with water height between 1.5 and 0 m.

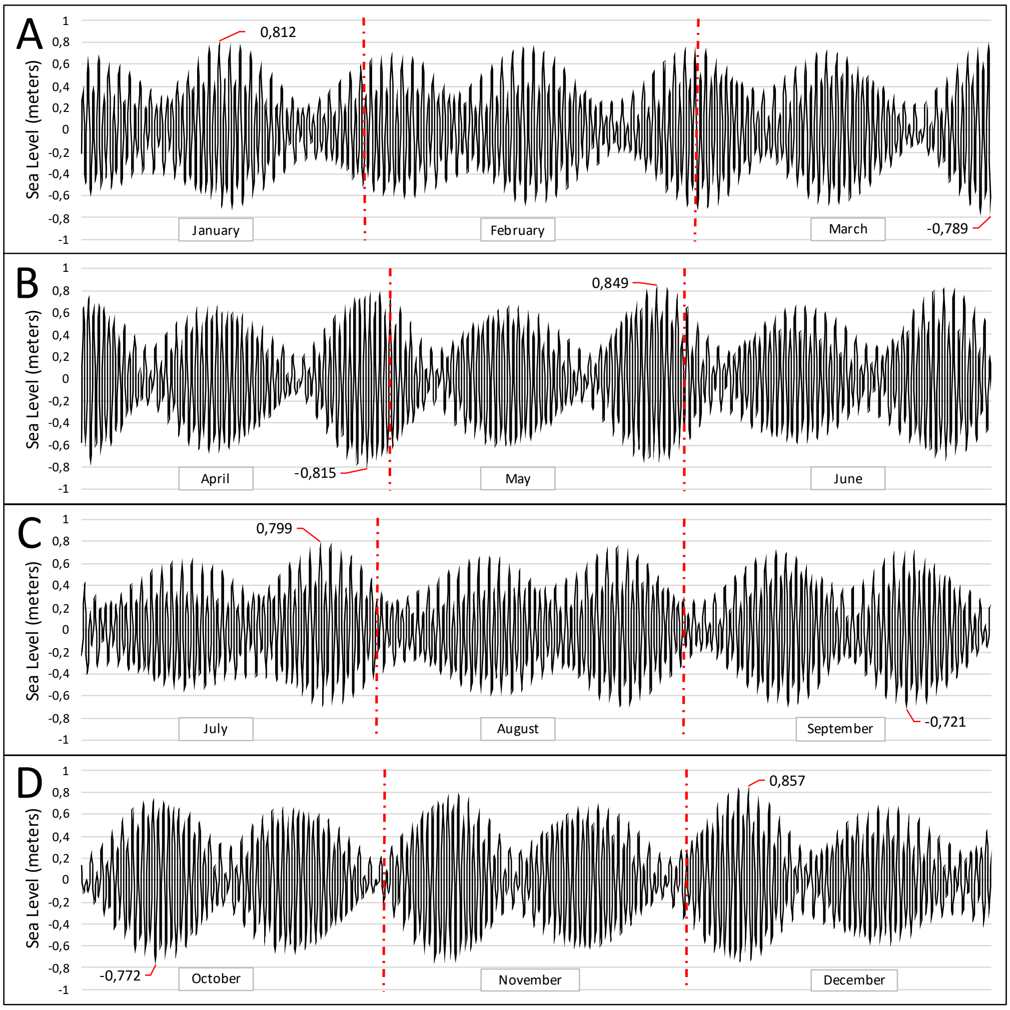

Figure 6. Tidal patterns in the study area in east monsoon (A), east-west transition season (B), west monsoon (C), and west-east transition season (D).

***Temperature**.* The surface temperature around the east and east-west monsoon ranged from 27.5 to 30°C and 28.2 to 31.5°C, respectively. Meanwhile, in the west and west-east transition season, it ranged from 29.13 to 31.97°C and 28.13 to 30.97°C, respectively (Figure 7).

***Salinity**.* The surface water salinity in the east monsoon ranged from 31.7 to 33.4 ppt, with the distribution pattern increasing from the open ocean to the coast. In the east-west transition season, it ranged between 33.8 to 34.5 ppt with low salinity areas located in all stations. Meanwhile, the salinity in the west monsoon and west-east transition seasons ranged between 32.9 to 33.8 ppt and 31.9 to 32.8 ppt, respectively (Figure 8).

***pH**.* The degree of acidity value (pH) in the east monsoon ranged between 7.18 and 8.23. Meanwhile, in the east-west, west, and west-east transition season, it ranged from 6.5 to 8.2, 6.7 to 7.8, and 6.25 to 7.3, respectively. This pH distribution can be seen in Figure 9, showing that the pattern varies each season greatly.

***Dissolved oxygen**.* The dissolved oxygen (DO) surface content in the east monsoon ranged between 7.02 and 9 mg L^{-1}. Meanwhile, in the east-west, west, west-east transition season, it ranged from 7.6 to 8.7 mg L^{-1}, 7.8 to 8.7 mg L^{-1}, and 7.38 to 8.24 mg L^{-1}, respectively. This result can be seen in Figure 10.

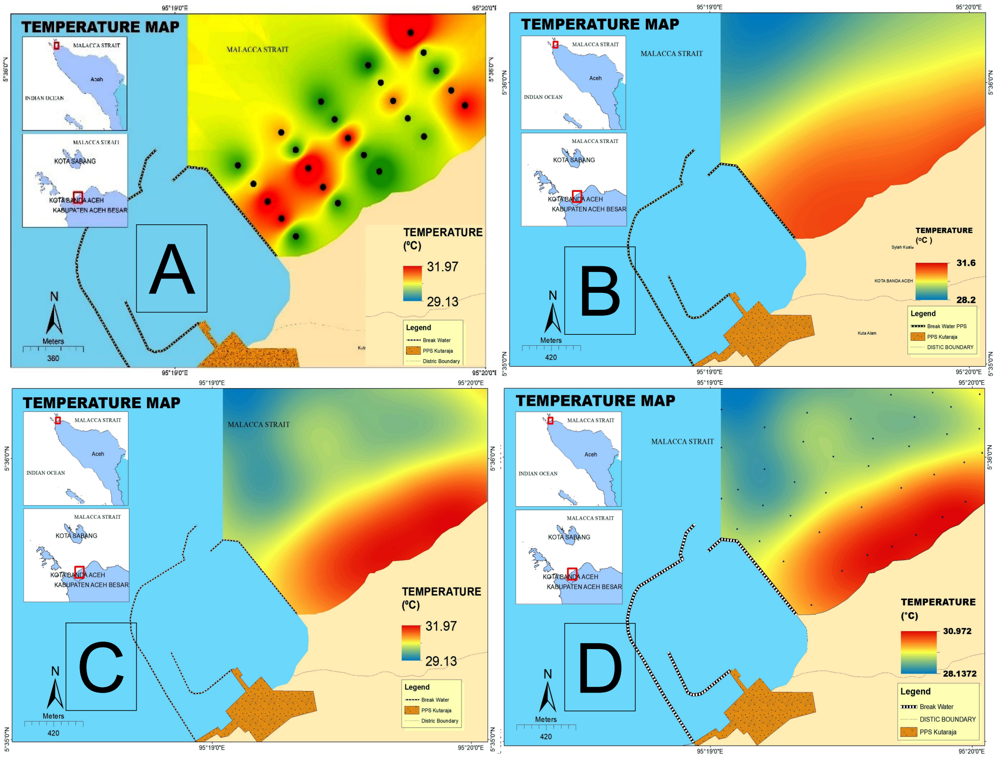

Figure 7. Temperature pattern around the study area in east monsoon (A), east-west transition season (B), west monsoon (C), and west-east transition season (D).

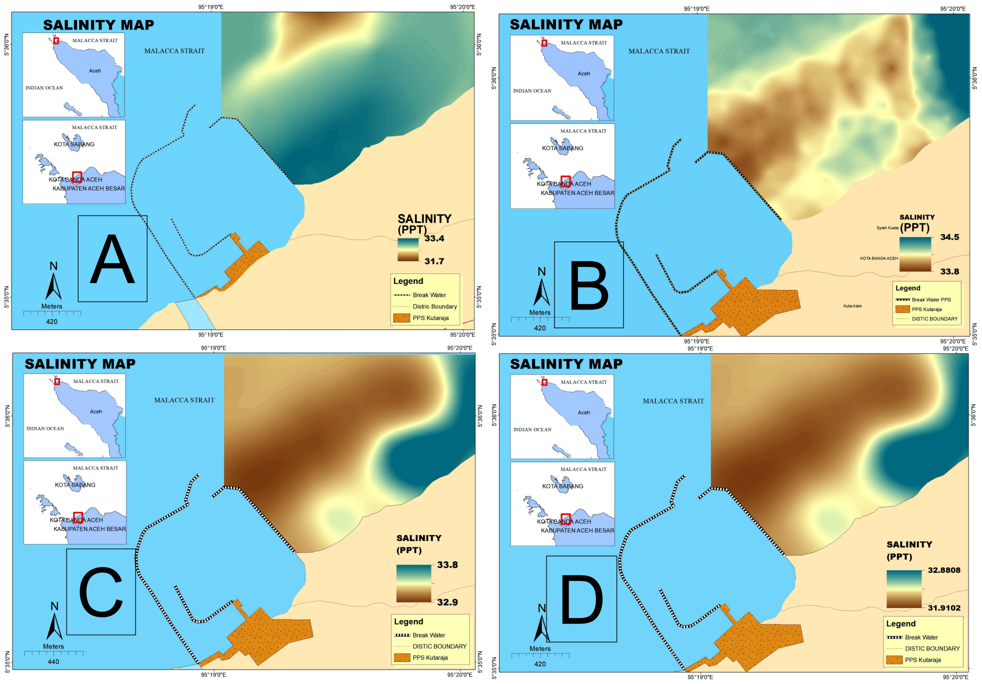

Figure 8. Salinity pattern in the study area in east monsoon (A), east-west transition season (B), west monsoon (C), and west-east transition season (D).

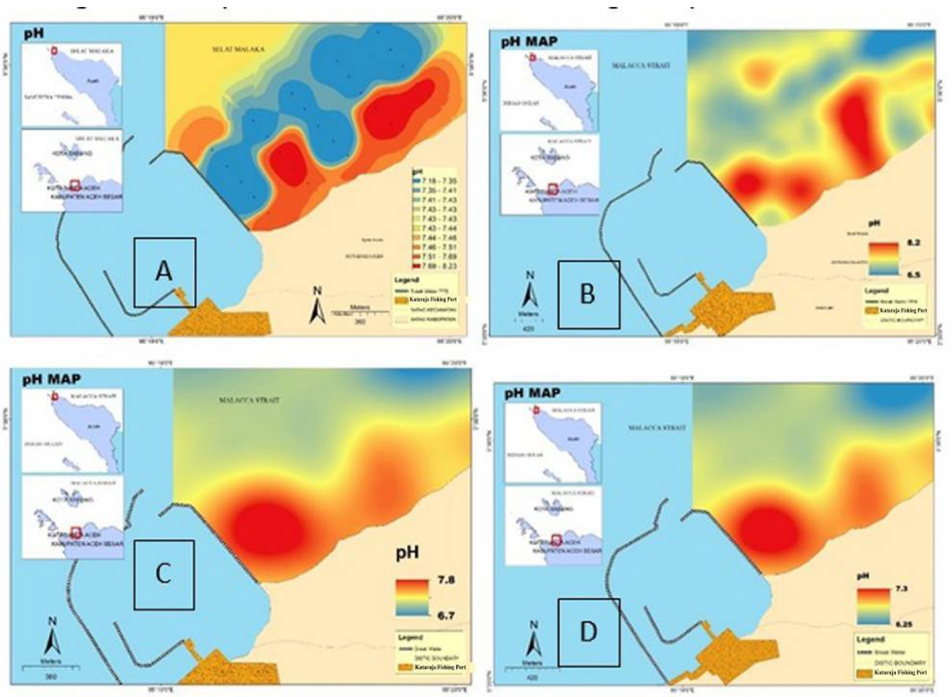

Figure 9. pH distribution pattern at the research station in east monsoon (A), east-west transition season (B), west monsoon (C), and west-east transition season (D).

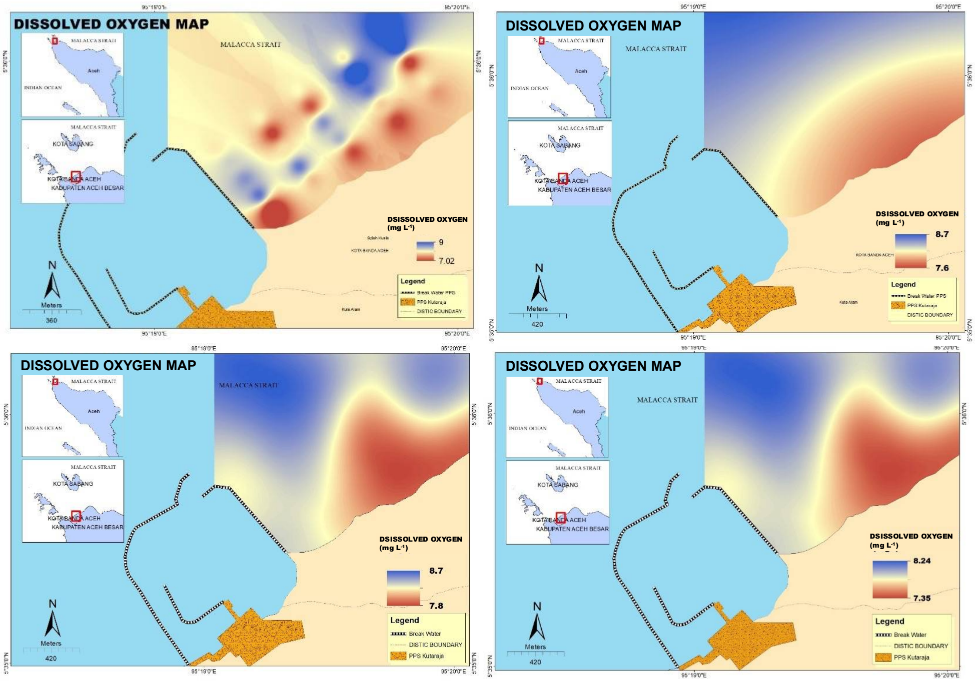

Figure 10. The distribution pattern of dissolved oxygen at the research station in east monsoon (A), east-west transition season (B), west monsoon (C), and west-east transition season (D).

Sediment. The sediment in the east monsoon consists of fine, very fine, coarse, and medium sand types with grain sizes of 1/8-1/4 mm, 1/16-1/8 mm, 1/2-1 mm, and 1/4-1/2 mm, respectively. Sediment grain size with fine sand type was mostly found at 17 research sampling points. Furthermore, three categories of sediment were found in the Kutaraja Ocean Fishing Port during the east-west transition season, namely fine, very fine, and coarse sand types grain sizes of 1/8-1/4 mm, 1/16-1/8 mm, and 1/2-1 mm, respectively, with the fine sand category found in 12 locations. In the previous two seasons, the west and current, three types of sediment classification were also obtained, namely very fine, fine and coarse sand. However, some stations have different sediment sizes from the previous season (Figure 11).

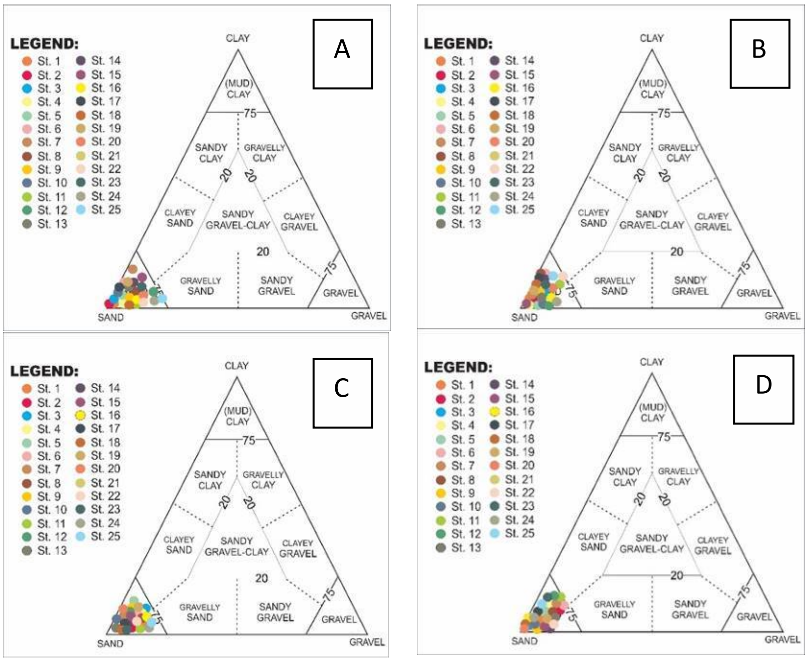

Figure 11. Sediment fraction distribution pattern at the research station in east monsoon (A), east-west transition season (B), west monsoon (C), and west-east transition season (D).

Discussion. In the east monsoon, the currents moved from two directions, the northeast, and northwest, towards the coast close to Kutaraja Ocean Fishing Port breakwater in the east. The currents were slightly faster because the area was flanked by two large rivers in the east and west. Its speed pattern shown in the transitional season at the observation station tends to be weak compared to the east monsoon due to decreasing river activity near the port. The currents pattern in the west monsoon showed the dominant currents to the northeast of the waters. This pattern occurs because it is influenced by the dominant wind blowing from the southwest to the northeast and the movement of water masses from Krueng Aceh River on the left of Kutaraja Ocean Fishing Port. According to Milasari et al (2021), the port's activity can also affect current speed changes. For instance, the current pattern in the west-east transition season shows the dominant currents from the north, which rotate towards the southwest waters. This can occur due to the dominant wind blowing from the southwest waters and mass movements from the Krueng Aceh river on the left side of Kutaraja Ocean Fishery Port.

In the east monsoon, siltation occurs around the port's breakwater due to the flow of the currents towards this area. Meanwhile, in the east-west transition season, it does not occur close to the fishing port. The pattern of water depth (bathymetry) formed in the west monsoon deepens with the rise in the shoreline. In the west-east transition season, the water's depth changes perpendicular to the shoreline and is generally triggered in accordance with the wind direction (Afriady et al 2019). Furthermore, variations in wave height in Indonesian waters are strongly influenced by the occurrence of monsoons (Putra & Koto 2015). In the transition season, the wind speed and strength tend to be lower, hence the height of the sea waves formed is also low. This condition differs from the previous western season (Wardhani et al 2021).

Afriady et al (2019) stated that wind and topography affect currents horizontally and vertically. The surface currents in Indonesian waters are heavily influenced by the speed of the monsoon wind movements, which increases in the rainy season. Therefore, it causes stronger currents in the rainy season and weaker in the dry season (Prayogo 2021).

The tidal pattern in the west monsoon and the east-west transition season undergoes a significant change, which is very low compared to previous seasons. Identical to wind, tides and topography can also affect currents horizontally and vertically (Mustikasari et al 2015). Tidal characteristics in Indonesia are also influenced by wind direction (Hasriyanti 2015).

The highest temperature on the map is colored in red, and this pattern was influenced by the involvement of various intensive economic activities at Kutaraja Ocean Fishing Port. Temperature is one of the essential factors for organisms' existence in the ocean, and it greatly affects both metabolic activity and the development of marine organisms (Rukminasari et al 2014). The seawater temperature in the deep layers tends to be low due to inadequate sunlight and wind speed that affects its movements from one place to another (Juniarti et al 2017).

Generally speaking, the higher the seawater salinity, the greater the corrosion rate. This is because the salinity levels in the world's waters, which are generally traversed by ships, have a salt content of around 3-4% (Nova & Misbah 2012). According to Yihdego & Panda (2017), salinity is a result of geological conditions that are influenced by the atmosphere. Based on the salinity distribution map, it can be seen that the distribution pattern in the east monsoon increase from the high seas to the coast. During the east-west transition season, low salinity areas were found in all research stations. In the west monsoon, the salinity concentration around the fishing port waters was considered low, although it was high in several stations near the shoreline. Only a few research stations have high salinity levels in the west-east transition season, which were lower than those obtained in the previous season.

The increase in pH occurs due to a rise in carbon dioxide production in the atmosphere caused by human activities, which are then absorbed by the waters (Rugebregt & Nurhayati 2020). Sea waters generally have a pH that ranges from 6.5 to 9.0. The degree of acidity is very important in determining water use value for the life of organisms, and it is used to express the acidity or alkalinity levels possessed by a solution. It is generally influenced by several factors, such as photosynthetic activity, temperature, and the presence of cations and anions in the waters (Siburian et al 2017).

The dissolved oxygen distribution pattern in the east monsoon spreads at several points and forms a vertical pattern, where the low and high dissolved contents are found in areas close to the shoreline and the high seas. The dissolved oxygen distribution pattern is similar in the west monsoon and the west-east transition season. The increase in the photosynthetic process in macroalgae organisms led to decreased oxygen used at that location (Rukminasari et al 2014). In the east monsoon, the grain size of very fine sand, fine and coarse sized, was found at 2, 1, and 5 sampling points, respectively. During the east-west transition season, sediments with the fine, very fine, and coarse sand categories were found in 12, 7, and 6 locations. The fine sand category dominates sediment size classification in this season. The analysis results showed different sediment sizes between the east and east-west monsoons, categorized into four and three, respectively.

Conclusions. The research on several oceanographic parameters around Kutaraja Fishing Port showed that the currents move from the northeast and northwest towards the coasts in the eastern area – near the breakwater. The currents in the eastern areas were stronger than in the western area, which is dominated by shallow water. The highest tide of 0.3855 meters was observed at noon, while the lowest value of -1.0485 meters was determined at 19:00. Most of the sampling area has a sediment particle size of fine sand. The acidity degree (pH) value in Lampulo waters is good and ranges from 7.13 to 8.3, with the highest pH value found near the land. Sea surface salinity in the research area ranged from 32 to 34 ppt and increased towards the coastal area. Furthermore, the temperature ranged from 27.5 to 30°C with dissolved oxygen of 7.02 to 9 mg L^{-1}. The water quality parameters are among the crucial factors to be assessed when determining the shipyard location. The result indicated that oceanographic and water quality factors are essential to becoming one of the indicators in shipyard development.

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Conflict of interest. The authors declare that there is no conflict of interest.

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