Analysis of Changes in the Position of the Tidal Front in the Waters at the Mouth of the Pangabuan River, Kuala Tungkal, Tanjung Jabung Barat District, Jambi

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Abstract

This study aims to determine the distribution patterns of salinity and temperature, as well as changes in the position of the front in the waters at the mouth of the Pangabuan River in Kuala Tungkal, Jambi Province. This research was conducted in July 2022 in the waters of the Pangabuan River in Kuala Tungkal, Jambi Province. The analysis was conducted at the Oceanographic Physics Laboratory of the Department of Marine Science, Faculty of Fisheries and Marine Science, Riau University. There were two research stations: Station 1 was located in the river, and Station 2 was in the estuary. The tidal conditions in the waters of Kuala Tungkal are semi-diurnal, with two tides affecting the front in these waters. The highest tide occurs during the full moon (spring tide), reaching 3.1 m, while the lowest tide is 0.5 m. The tides strongly influence the position of the front; at high tide, the front is located deep within the river (2.45 km) from the estuary mouth, making it difficult to see and observe, while at low tide, the front is situated in front of the estuary mouth (1.4 km), making it easier to see and observe. The salinity distribution pattern in the front area shows a significant difference due to the mixing of two water bodies with different salinities: lower salinity comes from the river, and higher salinity from the sea. At high tide, salinity ranges from 20 ppm to 24.8 ppm; at low tide, from 17.3 ppm to 22.1 ppm. The highest temperature at high tide was 31.2°C and the lowest was 26.8°C; at low tide, the highest temperature was 31.6°C and the lowest was 27.6°C.

1. Introduction

The point of river water and seawater naturally holds immense potential for biological resources. However, these biological resources remain largely unknown and underutilized due to a lack of information and technology, particularly among the local community and, in particular, traditional fishermen along the coast of Kuala Tungkal. Information on biological resources, such as fish, can be obtained in part by identifying the upwelling zone, as this area contains abundant nutrients required by marine life. A marine front is an oceanographic phenomenon where two water masses with different characteristics such as temperature and salinity converge; for example, the meeting of the relatively warm Java Sea water mass with the cooler Indian Ocean water mass, with a temperature difference of approximately 0.5 °C (Firman, 2011).

According to Inayah (2015), frontal events are typically marked by foam or bubbles floating on the surface due to differences in density between the two water masses. The location of the front itself can shift due to the rise and fall of the sea level, known as tides. Tides are the periodic rise and fall of the sea level caused by the gravitational pull of celestial bodies, particularly the sun and the moon, on the Earth's water masses (Pasomba, 2019). Tides influence physical processes such as the surging of seawater onto the shore due to waves and the

flushing of water masses in estuaries, lagoons, and bays. Tides also influence biological activities, such as plant zonation and the feeding of birds, fish, and other marine organisms, as well as processes related to the flooding and drying of land surfaces in the intertidal zone, the area between high and low tide (Davidson & Arnott, 2010).

The Pengabuan River is one of the longest rivers in Tanjung Jabung Barat Regency. The Pengabuan River is over 120 km long, stretching from the subdistricts of Merlung, Renah Mendaluh, Batang Asam, Tungkal Ulu, Senyerang, and Tebing Tinggi, and emptying into the Karimata Strait in the South China Sea at the Tungkal Ilir subdistrict, with a mouth width of 841 m. Not only is it an important transportation route, but the Pengabuan River, the second-longest river in Jambi Province after the Batanghari River, serves as the lifeblood of Tanjung Jabung Barat Regency across various sectors (Syamsiatun, 2022).

Agusta (2016) states that fronts are important in terms of marine productivity because they tend to carry nutrients, unlike warmer waters that are nutrient-poor. The physical characteristics of a front can be determined by parameters such as temperature or salinity. A front defined by salinity is known as a salinity front, while one defined by temperature is called a temperature front. These biological resources are certainly strongly influenced by oceanographic parameters, including physical oceanography. The physical oceanographic parameters in question are salinity, temperature, and water density (Minarto et al., 2005).

Given the importance of information regarding frontal phenomena, studies or analyses are necessary to determine the position of the frontal zone and identify the factors influencing changes in its location. These forecasts can be conducted directly by researchers through fieldwork to collect the desired data, or via satellite imagery, which is then processed into maps. Data processing is carried out in a physical oceanography laboratory. Given the importance of data on the position of the front and the factors influencing changes in the front's position for various activities related to the waters of Kuala Tungkal, the researcher is interested in conducting this study because information regarding the position of the front and the factors influencing its changes is of critical importance.

2. Methodology

2.1. Time, Place, and Materials

This research was conducted in July 2022 in the waters of Kuala Tungkal, as shown in Figure 1. The analysis was carried out at the Physical Oceanography Laboratory, Department of Marine Sciences, Faculty of Fisheries and Marine Sciences, Universitas Riau.

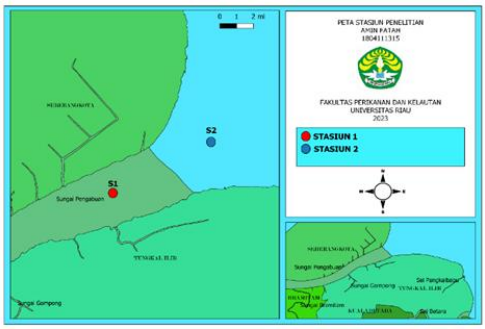

Figure 1. Research location map

2.2. Method

The method used in this study was a survey method, which involved direct observation in the field. The data collection station consisted of a single station at the Pengabuan River Estuary in Kuala Tungkal. The field data were considered representative of the waters of the Pengabuan River Estuary and were subsequently analyzed at the Oceanography Laboratory of the Universitas Riau.

2.3. Procedures

Measurement of Front Distance from the Estuary Mouth

The location for measuring the front distance was in the waters of the Pengabuan River Estuary, Kuala Tungkal, West Tanjung Jabung Regency, during high and low tides. The measurement of the front distance from the estuary mouth used GPS, with a marking system that traversed the sides of the front.

Creation of Salinity and Temperature Distribution Maps

The salinity distribution map was created using the Surfer application by entering the data collected in the field into the application, followed by the desired layout and the process of creating the salinity distribution map. First, the data collected in the field was entered into Microsoft Excel.

Creation of Front-Line Maps

Front-line maps are created using the ArcGIS application by entering the data

collected in the field into the application, followed by the desired layout. The process of creating front-line maps is as follows.

Data Analysis

The data collected in the field were tabulated into tables, depicted in map form, and analyzed descriptively, calculated, and visualized using Microsoft Excel, Surfer, and ArcGIS. Tidal measurements were conducted to calculate and measure the distance of the front at high and low tides, and to determine the difference in distance between the front at high and low tides in accordance with the software used. This was followed by the creation of maps based on the front coordinates obtained from the field.

3. Result and Discussion

Water Quality

The oceanographic parameters measured in this study were salinity, temperature, and tides; the results of the water-quality parameter measurements are shown in Table 1.

Table 1. Oceanographic parameters of the Pengabuan River Waters in Kuala Tungkal

Oceanographic Parameters	High Tide	Ebb
Temperature (°C)	19	26
High tide (Nipe Tides) (m)	2.8	1
Tide gauge (Nipe Tides) (m)	2.5	0.6
High tide (Nipe Tides) (m)	2.1	0.8
Installation of the Nipe Tides (m)	2.7	0.9
Spring tides (m)	3.1	0.5
Salinity (‰)	27	23

Water quality parameters at the Kuala Tungkal River Estuary show a salinity of 23 ‰ at high tide and 19 ‰ at low tide, a temperature of 28 °C at high tide and 29 °C at low tide, with high tide occurring at 3.1 m during the full moon and the lowest low tide at 0.5 m during the full moon. The data above is based on the average values of all collected data.

Position and Pattern of the Front during High and Low Tide

Observations of the position and pattern of the front during spring tides (full moon tides) show that the highest tide reaches 3.1 m, with the front extending 2.45 km into the river. It has a pattern resembling a slightly curved straight line that stretches horizontally and spreads into the river, making it somewhat difficult to see and observe. Meanwhile, during neap tides, the highest tide reached 2.8 m with the front extending 2.18 km into the river, forming a pattern resembling a straight line that stretched horizontally and spread into the river, making it somewhat difficult to see and observe. This can be seen in Figure 2.

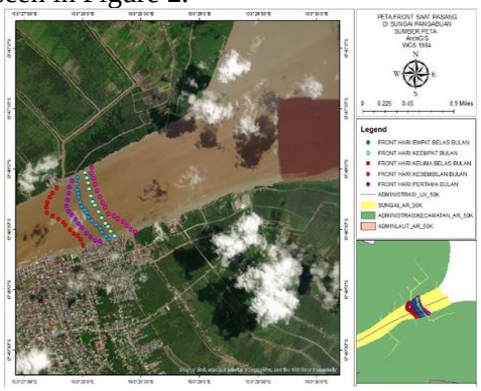

Figure 2. Neap tides

This occurs because the concentration of TSS on the seafloor during spring tides is lower than during neap tides, allowing it to float and disperse with the current. Additionally, during spring tides, strong tidal forces stir up bottom sediments and distribute them vertically (MacDonald & Geyer, 2005).

During low tide, the front line recedes from land to sea during spring tides, reaching 1.4 km from the estuary mouth, with the lowest low-tide water level reaching 0.5 m. It has a curved pattern extending toward the sea that is very easy to see and observe, and during neap tides it reaches 905 m, with the lowest low tide at 0.6 m. This can be seen in Figure 3.

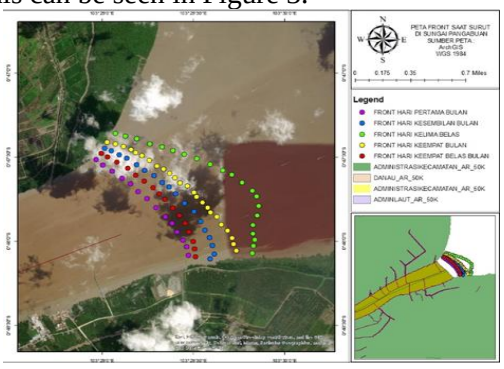

Figure 3. Low tides

This study shows that the farthest and longest fronts occur during spring tides rather than neap tides. The influence of tides on the front can extend the turbid area up to 3 km offshore from the river mouth (Al Hakim, 2022).

This tidal front map was created based on coordinates collected in the field, which were then processed into a map and presented descriptively using ArcGIS. Data collection for the tidal front followed the tides, which are themselves influenced by the lunar phases. There are five lunar phases: the first day (new moon), the fourth day (crescent moon), the ninth day (half-moon), the fourteenth day (waxing moon), and the fifteenth day (full moon). Each phase has a different duration; in this study, the researcher calculated the average value of the estimated tidal data for each lunar phase, then collected data representative of each phase.

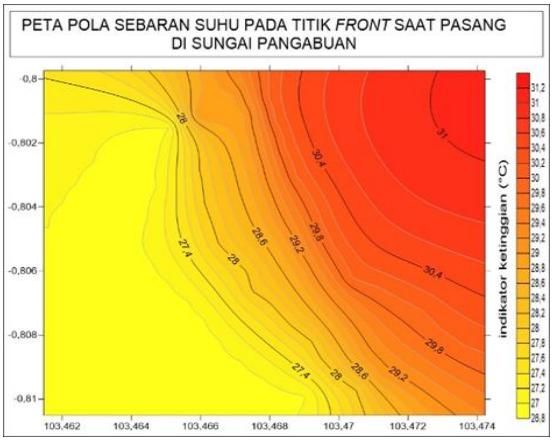

Figure 4. Temperature in high tides

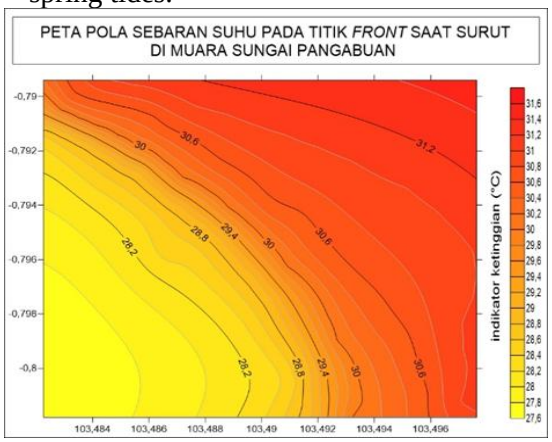

Figure 5. Temperature in low tides

Temperature Distribution Patterns during High and Low Tides

Based on temperature distribution measurements at the front location during high and low tides, the highest temperature occurred at coordinates 103-0.800, namely 31.2 °C. The lowest temperature occurred at coordinates 103.464 -0.080, namely 26.8 °C (Figure 4), and during low tide, the highest temperature was recorded at coordinates 103.498 -0.790, at 31.6 °C, and the lowest temperature was recorded at coordinates 103.484 -0.798, at 27.6 °C (Figure 5). The highest temperature occurs during neap tides, and the lowest temperature occurs during spring tides.

The difference in temperature between high and low tides is due to variations in water depth and the activities of the surrounding community, which affect water density. During high tide, the water is deeper, whereas during low tide, it is shallower. This affects the intensity of sunlight penetrating the water; in shallow water, light penetrates more easily to the bottom compared to deeper water. These differences in water temperature can be caused by topography or depth, which are related to variations in sunlight penetration at the surface layer and deeper layers (Sidabutar et al., 2019)

In addition to depth and sunlight intensity, temperature variations at the front's location are also influenced by the station's position itself. Station 1 is located within the river because, during high tide, the front is positioned there. In contrast, Station 2 is located outside the river at the river mouth because, during low tide, the front is there. The movement of these water masses can generate heat through friction between water molecules, thereby warming the seawater (Sidabutar et al., 2019). Another possibility is that this occurs due to upwelling, a common process in coastal areas (Sartimbul et al., 2010).

The temperature distribution map for this front was created based on the front's coordinates at high tide, which were collected in the field over a pre-determined 5-day period. Thus, the average temperature at the front location was obtained for each coordinate point. A contour is an imaginary line that depicts all points at the same elevation above or below a specific datum surface, such as mean sea level (Hertanto, 2011).

Salinity Distribution Patterns during High and Low Tides

Based on salinity distribution measurements at the front location during high tide, the highest salinity was recorded at coordinates 103.474 -0.800, namely 24.8 ppm. The lowest salinity was recorded at coordinates 103.462 -0.810, which was 20 ppm (Figure 6), and during low tide, the highest salinity at coordinates 103.498 -0.790 was 22.1 ppm, while the lowest salinity at coordinates 103.482 -0.800 was 17.3 °C (Figure 7). The highest salinity

occurs during spring tides, and the lowest salinity occurs during neap tides.

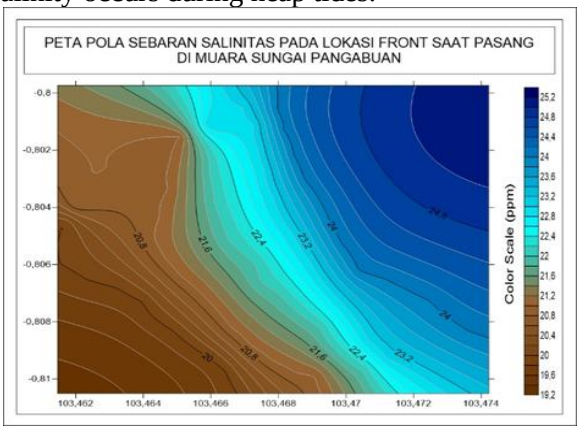

Figure 6. Salinity in high tides

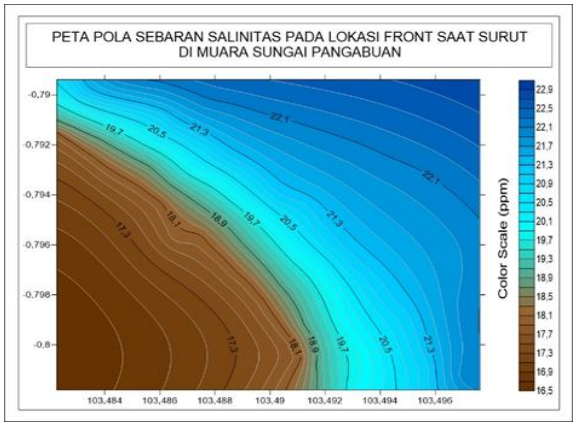

Figure 7. Salinity in low tides

The difference in salinity values at stations 1 and 2 during high and low tides is due to differences in depth and the associated reduction in the influence of freshwater inflow from the land. Station 1 is located in a river. The high salinity values are caused by the influence of the sea, such as mixing with freshwater in the river. This increase in salinity is due to the reduced influence of freshwater inflow from the land as depth increases (Patty, 2013).

Low salinity values are found at Station 2 because Station 2 is located at the river mouth. The low salinity is due to land effects, such as the mixing of freshwater carried by the river current. One factor influencing distribution in the water body is the volume of freshwater entering the marine water. In shallower waters, freshwater intrusion can extend to the bottom of the water body, resulting in low salinity (Ismail & Ankiq, 2012). Freshwater entering the water body has a lower density, so that it will remain above the water with higher salinity (Kalangi et al., 2013)

4. Conclusion

Based on the objectives and results of the study, it was concluded that the tides greatly influence the position of the front; during high tide, the front is located within the river, making it difficult to see and observe, and is quite far upstream, whereas during low tide, the front is located in front of the river mouth and is easier to see and observe. The highest tide occurs during a full moon (spring tides), reaching 3.1 m with the front extending 2.45 km into the river from the river mouth, and the lowest ebb tide is 0.5 m with the front extending 1.4 km in front of the river mouth.

The salinity distribution in the front area shows a wide range due to the mixing of two water masses with different salinities: the lower salinity from the river and the higher salinity from the sea. During high tide, salinity ranges from 20 ppm to 24.8 ppm, while during low tide, it ranges from 17.3 ppm to 22.1 ppm. The highest temperature during high tide at coordinates 103 -0.800 is 31.2 °C, and the lowest temperature at coordinates 103.464 -0.080 is 26.8 °C (Figure 2). During low tide, the highest temperature at coordinates 103.498 -0.790 was 31.6 °C and the lowest temperature at coordinates 103.484 -0.798 was 27.6 °C.

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