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Ocean current circulation modeling in the Bengkalis Strait in the east spring

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Abstract

The waters of the Bengkalis Strait are geographically very strategic, directly connected to the waters of the Malacca Strait and a strategic water transportation route. One of the complex phenomena that appears in the waters of the Bengkalis Strait is the phenomenon of current movement. This survey was conducted from June to August 2022. The survey location was in the Bengkalis Strait, Bengkalis Regency, Riau Province. The research aims to determine current patterns and sea level height during the highest tides and lowest low tides each month during the east season in the waters of the Bengkalis Strait. The method used is a Survey and a quantitative descriptive method. All data is processed using MIKE 21 software. First, Google Earth was used to create bathymetry data, and then the boundaries of the survey area were determined using MIKE 21. After obtaining the bathymetry, we continued with the flow model using MIKE 21 and then displayed the results. Obtained results: the highest tide occurred on 13/06/2022 at 13:00 WIB with an average current discharge of 0.14-0.16 m/s, and the lowest wave occurred on 13/06/2022 at 20.00 WIB with an average flow rate of 0.60-0.75 m/s

1. INTRODUCTION

Bengkalis Regency is one of the districts in Riau Province whose territory covers the eastern mainland of Sumatra Island and the archipelago, with an area of 11,481.77 Km2 (Sutikno, 2014). Bengkalis Regency has a strait, namely the Bengkalis Strait. The waters in the Bengkalis Strait have complex phenomena because many natural processes and human activities occur there. Human activities that take place in the waters of the Bengkalis Strait include physical development interests, economic interests, social interests, and environmental preservation interests. Therefore, the Bengkalis Strait is important and exciting to study.

Geographically, the Bengkalis Strait is strategic, directly connected to the waters of the Malacca Strait, and a strategic water transportation route. Therefore, it is essential to know the phenomena that occur in the Bengkalis Strait. The phenomenon in question is the characteristics that occur in the waters of the Bengkalis Strait.

One of the complex phenomena that occurs in water is the phenomenon of current movement. Furthermore, the current movement is an oceanographic phenomenon that influences existing water conditions, especially in the Bengkalis Strait area. Water conditions are closely related to the distribution of the abundance of biological resources. Gaol and Sadhotomo (2007) state that the distribution and abundance of biological resources in waters are affected by the conditions and variations in current parameters and other oceanographic factors.

According to Hadi and Radjawane (2009), currents are the horizontal movement of water masses that are affected by wind blowing on the sea surface, sea depth patterns, and the influence of sea tides, which cause differences in sea surface height (Sea Surface Height) and the formation of seawater circulation patterns. Current circulation patterns in a body of water vary depending on the conditions of the oceanographic parameters. According to Hutabarat and Evans (1986), ocean currents are the movement of water masses from one place to another. Ocean currents can occur in all parts of the sea. The movement of water on the surface by wind and other forces can be in the form of pressure gradients, density differences, and tides. The current pattern consists of the speed and direction of the current in the research area. Ocean currents have a role in the construction or development of coastal/port buildings. Ocean currents can be helpful as primary data in planning for engineering purposes such as breakwater construction, port development, dredging, and others.

The water area, especially the waters of the Bengkalis Strait, is one of the vast waters, so an alternative is needed to observe the conditions of current movements. The mathematical model is one alternative method to observe the movements. A model is a prototype or imitation of actual natural conditions, and no model, even though it is complex, can represent actual reality. Even though it contains errors, this model is a cheaper and easier alternative for obtaining an overview of the distribution that occurs in the present and predictions for the future. Hydrodynamics using numerical modeling methods is the appropriate model used in this approach to simulate current movement patterns.

Hydrodynamic model studies are widely used in several studies, such as tides, sea surface currents, coastline changes, water and beach pollution, and tidal flood events (Dewi et al., 2019). MIKE 21 is a numerical-based application that can used in modeling current rates, waves, and sediment transport in both open-sea coastal areas and river areas (DHI, 2013). The module used to determine ocean current circulation patterns is MIKE 21 HD Flow Model FM (Sri and Adrianto, 2018) Numerical modeling can simulate current circulation patterns based on the laws of conservation of mass (continuity) and conservation of momentum. The software used in hydrodynamic modeling is MIKE 21, which contains several modules according to the desired study. The MIKE 21 Flow Model FM Hydrodynamic Module is used to model the flow.

The MIKE 21 Flow Model FM Hydrodynamic Module simulates tidal and flow patterns. These modules are based on the numerical solution of the two-dimensional shallow water Navier-Stokes equations (Anisa et al., 2017). Research on current circulation patterns in estuaries, in particular, has been carried out using current circulation pattern research conducted by Anwar (2007), who examined current circulation patterns in the waters of the Rupat Strait using a two-dimensional hydrodynamic model. Research by Denny and Agus (2012) regarding current circulation patterns. Current circulations in the coastal waters of West Sumatra province. Furthermore, research conducted by Okol and Dian (2018) studied the results of running a surface current model using MIKE 21/3 software to determine the location of the Lombok-Nusapenida Strait current energy station. In the waters of the Malacca Strait, information and research data regarding current circulation patterns still need to be improved, so researchers are interested in conducting this research.

The research aims to determine the circulation pattern, direction, and speed of currents at the highest tide and lowest ebb conditions to determine sea level height at the highest tide and lowest ebb conditions each month in the east season in the waters of the Bengkalis Strait.

2. RESEARCH METHODS

Time and Place

This research was conducted in the Bengkalis Strait from June to August 2022. Data analysis was conducted at the Physical Oceanography Laboratory, Department of Marine Science, Faculty of Fisheries and Marine, Universitas Riau.

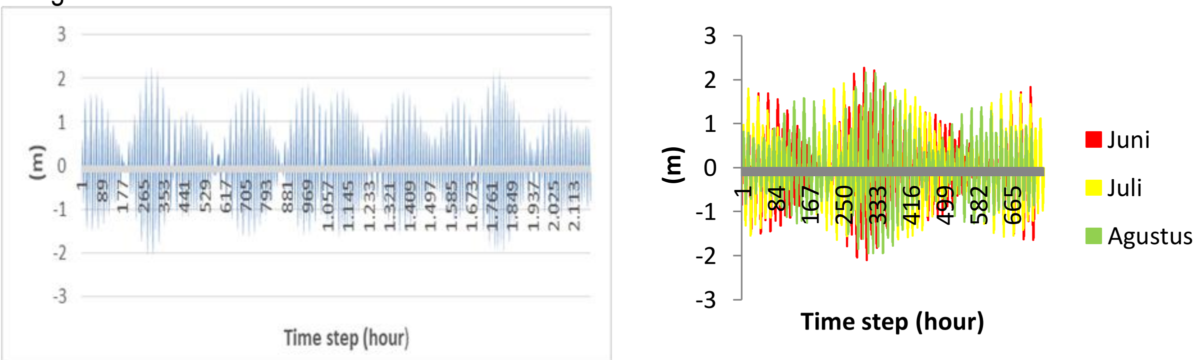
Research method

This research was conducted using quantitative descriptive methods. Quantitative descriptive analysis was carried out to examine current circulation patterns in the Bengkalis Strait during the East Monsoon. The research is divided into several stages: literature study, data collection (including primary and secondary data), and parameter data processing using MIKE 21 software. Apart from using quantitative descriptive methods, this research also uses survey methods where it is necessary to observe current patterns and current speeds in the area. Field as verification of the simulation model results later.

3. RESULTS AND DISCUSSION

NOATide Tidal Value Data

Sea tides are a phenomenon of periodic rise and fall of sea levels due to the tidal generating forces, mainly from the gravitational forces of the moon and sun. There are several types of tides: single daily tides, one high tide, one low tide in a 24-hour 50-minute tidal period (Gumelar et al., 2016), and semidiurnal tides or so-called high tides. Tides occurred with two high tides and two low tides in one month (Wahyudi and Budiman, 2019). The tide graph that occurs on Bengkalis Island can be seen in Figure 1.



(a) (b)

Figure 1. NOATide tidal data (a) east season (b) monthly

The tide graph in Figure 1 shows the differences in tides in June, July, and August. The Bengkalis Strait is semi-diurnal because it has two rising peaks and two falling valleys in 24 hours, so there are two rises and two falls. Aristi et al., 2020 on the Bengkalis Coast stated that the Formzhal value obtained was 0.304, which is included in the semi-diurnal tidal category or what is usually called double-leaning mixed. The results are similar in the Rupat Strait; based on research conducted by Rifardi et al. (2020), the Rupat Strait has tides of the same type, namely semi-diurnal.

In the east season in the Bengkalis Strait, the highest tide occurs in June with a water level of 2.27332 m, and the highest tide occurs on June 13, 2022, at 13:00 WIB. The lowest low tide also occurs in June; this low tide occurs on June 13, 2022, at 19:00 WIB with a water level of -2.10949 m. The results differed significantly from those at the Dumai River Estuary in the Rupat Strait, where the highest tide reached 1.26 meters and the lowest - 1.37 meters (Rifardi et al., 2020).

Bathymetric Modeling of the Bengkalis Strait

Bathymetry is one of the data needed to create current patterns in the Bengkalis Strait, which is processed using the MIKE 21 software. Bathymetry functions to describe the depth of the sea in the Bengkalis Strait. Effendi et al. (2015) also stated that bathymetric maps are information that depicts waters and their depth. The Bengkalis Strait has various depths, from the shallowest 4 m, shown in red; the shallow area is on the edge of Bengkalis Island. The most profound depth is 60 m, shown in dark blue. The average depth in the Bengkalis Strait ranges from 20 - 30 m, shown in green, and is in the middle of the Bengkalis Strait. The research results of Amri et al. (2018) showed that the water depth in the Bengkalis Strait ranges from 6.1-37.3 m (Figure 2).

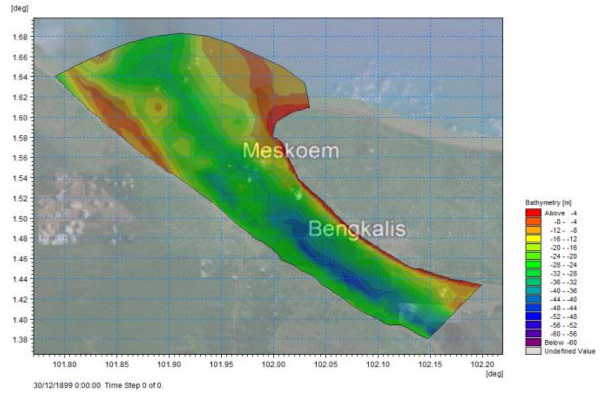


Figure 2 Bathymetry of the Bengkalis Strait

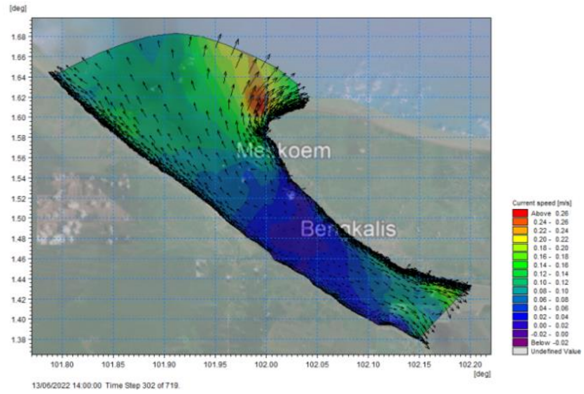


Figure 3. Current Pattern in June in the Bengkalis Strait at Highest Tide

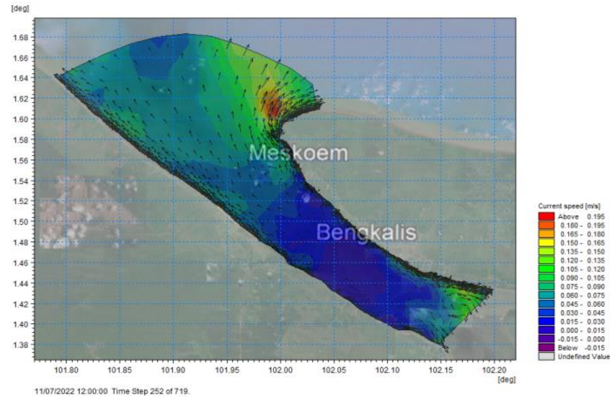


Figure 4. Current patterns July in the Bengkalis Strait at highest tide

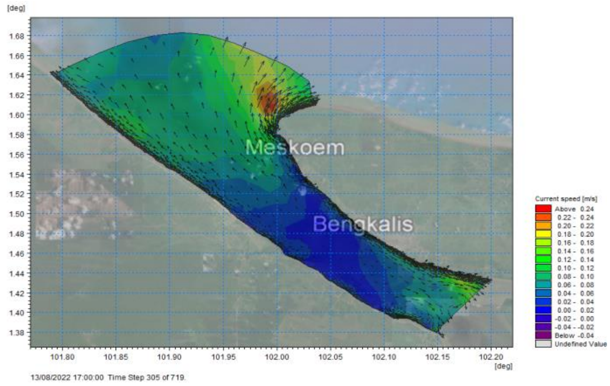


Figure 5. Current Pattern in August in the Bengkalis Strait at Highest Tide

Ocean Current Patterns in the Bengkalis Strait during the East Monsoon

Based on the analysis of ocean current patterns in the Bengkalis Strait in the east season using numerical modeling, it was found that ocean currents in the Bengkalis Strait in the east season experienced significant variations in speed and direction. Ocean currents in the southern part of the Bengkalis Strait tend to flow southwest, while in the northern part, they tend to flow northwest.

Several factors, such as current speed, seabed topography, and tides, influence ocean current patterns in the Bengkalis Strait. Numerical modeling also shows a complex ocean current circulation pattern around the Bengkalis Strait. Dahuri et al. (2013) stated that in narrow and semi-enclosed waters such as straits and bays, tides are the main driving force for the circulation of water masses.

3.4 Current Circulation Patterns at Highest Tide

The highest tide in the Bengkalis Strait is in the east season, June. In the east season, the current generally flows from east to west. Two seawater currents are entering the Bengkalis Strait, and the first is the South China Sea current and the Malacca Strait. The pattern of seawater currents in June in the Bengkalis Strait (Figure 3) is in two directions: towards the east and the west. The slow seawater is caused by two currents that meet, namely the South China Sea current and the Malacca Strait current, which makes the current direction towards the east and west. Because two currents enter the Bengkalis Strait at the meeting point, the currents in the Bengkalis Strait become weak. The slow seawater also happens in other months when the tides are highest in the east season.

The current speed in the Bengkalis Strait in June at the highest tide (Figure 3) is 0.26 m/s, which leads to the east and west. The highest current speed is in the red area, with the average current speed in June, the highest tide is 0.10 m/s – 0.12 m/s, and the weakest current is in the middle of the Bengkalis Strait, which is shown in dark blue, the current speed is - 0.02 m/s.

In July, the current in the Bengkalis Strait at the highest tide (Figure 4) has a current speed of 0.195 m/s, and this is the most substantial current in July, which is above Bengkalis Island, shown in red. The weakest current in July is located in the middle of the Bengkalis Strait, with a speed of -0.015 m/s, and the average current speed in July ranges from 0.90 m/s – 0.105 m/s. The highest tide in July occurs on July 11, 2022, at 12:00 WIB.

On August 13 2022, at 17:00 WIB, the highest tide occurred in August in the Bengkalis Strait (Figure 5). In August, the most substantial current at the highest tide in the Bengkalis Strait is 0.24 m/s, and the weakest current is - 0.04 m/s, with the average current speed in the Bengkalis Strait in August 0.10 m/s – 0 .12 m/s. Meanwhile, in the western season, the current speed at high tide ranges from 0.006 to 0.09 m/s (Aristi et al., 2020).

Current Circulation Pattern at Lowest Ebb

In Figure 6, at the lowest ebb of the current in the Bengkalis Strait on June 13, 2022, at 20:00 WIB, it is not clear where the current is going because the current speed at the lowest tide is minimal, the lowest current in the Bengkalis Strait is - 0.60 m/s. The current visible is only on the shores of Bengkalis Island, with a speed of 1.50 m/s, and in the waters of the Bengkalis Strait, it ranges from 0.045 – 0.060 m/s.

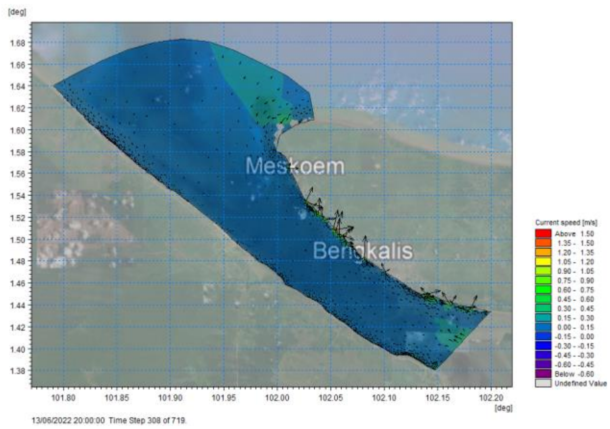


Figure 6. Current pattern June in the Bengkalis Strait at lowest ebb

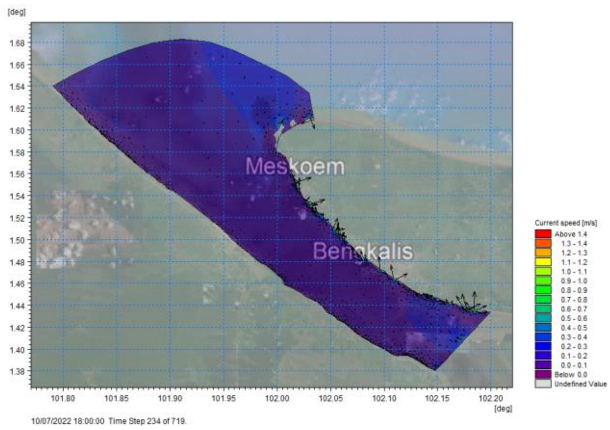


Figure 7. Current pattern in July in the Bengkalis Strait at lowest ebb

On July 10 2022 at 18:00 WIB, at the lowest tide, the current in the waters of the Bengkalis Strait (Figure 7) on the shores of Bengkalis Island looks strong with a current speed of 1.4 m/s and the strongest currents are only on the shores of Bengkalis Island, the weakest currents are in the middle of the Bengkalis Strait with a speed of 0.0 m/s, with the average current speed in the Bengkalis Strait in July at low tide being 0.7 m/s – 0.8 m/s. Due to the small current of the Bengkalis Strait, the direction of the current is not visible.

On August 11, 2022, at 11:00 WIB (Figure 8), the direction of the current in the waters of the Bengkalis Strait cannot be seen, and the speed ranges from 0.0 – 0.2 m/s. At the edge of Bengkalis Island, the current speed is extreme, with a speed of 1.4 m/s, and the weakest in the middle of the Bengkalis Strait, with a speed of 0.0 m/s. Meanwhile, the lowest current speed at low tide occurs in the western season, ranging from 0.006 to 0.084 m/s (Aristi et al., 2020). To see the modeling of current patterns in August in the Bengkalis Strait at the lowest tide, see Figure 8.

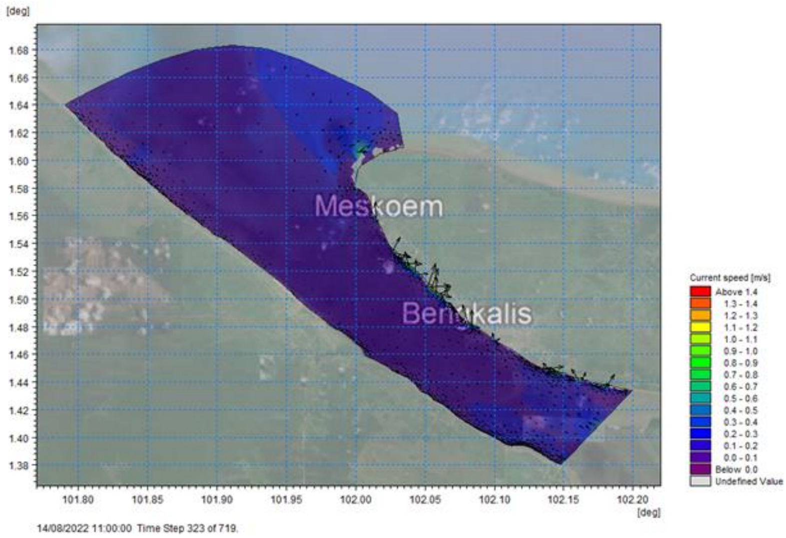


Figure 8. Current pattern in the Bengkalis Strait at lowest tide

The direction of the current in the Bengkalis Strait at the lowest tide could be clearer, but the current on the edge of Bengkalis Island is very strong. Several factors, including seabed topography, influence the strong currents on the shores of Bengkalis Island. The shores of Bengkalis Island have shallow seabed topography, so the currents on the shores of Bengkalis Island are stronger than in the middle of the Bengkalis Strait

4. CONCLUSIONS

The current in the Bengkalis Strait, which is in the middle of the Bengkalis Strait, is relatively weak due to the topography of the Bengkalis Strait, which has deep water in the middle of the water. Apart from that, two currents meet in the Bengkalis Strait, which is a factor in the weak currents in the Bengkalis Strait. Two currents that meet in the Bengkalis Strait at the lowest ebb will have a weak current speed, and the direction of the current at the lowest ebb will not be visible. Current speed is related to tides. When approaching high tide, the sea level will be higher, so the current speed will be faster. Meanwhile, the sea level is lower at low tide, so the current speed slows down. When conditions are high water or maximum tide and low water/minimum low tide, the current speed is relatively minor or close to zero (slack water).

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