The Bottom Surface Sediment Transport Changes in Bathymetry in the Rupat Strait, Riau Province, Indonesia

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Abstract. The Rupat Strait is located at the eastern coast of Sumatera Island, Riau Province, Indonesia, under the influence of the current system flowing from the Malacca Strait into the Strait. The primary purpose of this study is to identify the topography of Rupat Strait prevailed by bathymetry changes, which was analyzed using oceanographic and satellite images. This study was conducted in the Rupat Strait in July 2018 through two steps of research: 1) oceanographic observation; 2) bathymetry measurement. The study of oceanographic observation was carried out along the coastal areas of Dumai City and Rupat Island. The depth of Rupat Strait (bathymetry) was measured using an echosounder at 60 stations in July 2018. The changes in the depth of the Strait were analyzed by comparing data between depth in 1990 by satellite images and the depth in 2018 by the measurement. The results of study indicate that dominantly, the depth of the Strait has increased by 1.5-2.7 meters for 28 years. The depth of the Rupat Strait, based on the interpretation of the satellite image data of MIKE C-MAP (1990) ranges from 0.9 to 29.4 meters, and of the measurement in 2018, ranging from 2.4 to 32.1 meters. The dominant factor causing the changes are the current system flowing from the Malacca Strait through the Strait during high and low tides, and the surface bottom sediments are transported out the Strait by the current, including the bottom current.

1. Introduction

The Rupat Strait is separated from Malacca Strait by Rupat Island, located at the eastern coast of Sumatera Island, Riau Province, Indonesia. The Strait is elongated and has northward/southward openings with a length of about 88 km from north to south and a width of about 8 km. The outlets lead to the Malacca Strait [1]. The Strait is a semi-tidal region and has a double-tidal mixed-coupling type [2]. The Strait undergoes changes in bathymetry, especially the process of deepening. The process occurs due to the current system flowing from the Malacca Strait, and by land-use change of the hinterland. During flood tides, the current from the Malacca Strait flows into the Rupat Strait through the north and east parts of the Rupat Strait, while at ebb tide, the current from the Rupat Strait flows into the Strait of Malacca through the north and east of the Rupat Strait [3].

The phenomenon of coastal hydrodynamics due to the wave, currents, and tides of seawater and other factors has allowed the occurrence of abrasion and sedimentation (accretion) in the Rupat Strait. This phenomenon if it occurs in a long time and without effort to overcome, it will cause bathymetry...
changes. Total sediment supply from inland Dumai City and Rupat Island to the Rupat Strait through river streams and artificial canals as large as 4,999,312-7,013,002 ton/year [4]. This condition leads to high sedimentation and sandbar formation at the estuary of the rivers, as reported by [1]. They clarify that total sediments supplied by the river was of 926 ton/day hence the sediment deposited into the estuary area was 0.024 m/year.

In the last three decades, the Rupat Strait and its environs have become one of the most intensively studied areas in relation to water quality, marine biology, oceanography, and marine sediments [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15]. These studies did not discuss the changes in the bathymetry of the Strait that have an important role in international shipping and ecosystem as described above. The main purpose of this study is to identify the geomorphological of Rupat Strait revealed by bathymetry changes, which was analyzed using data of oceanographic and satellite images.

2. Materials and methods
This study was conducted in the Rupat Strait in July 2018 through two steps of research: 1) oceanographic observation; 2) bathymetry measurement (Figure 1).

![Figure 1. Map of study area](image)

The study of oceanographic observation was carried out along the coastal areas of Dumai City and Rupat Island. Samples of bottom surface sediment were collected from five stations on each coast (St. 1-10). Positions of the sampling stations were determined based on coastal conditions that suffer abrasion and accretion and the locations were measured by using the Global Positioning System (Figure 2).

The depth of Rupat Strait (bathymetry) was measured using echo sounder at 60 stations in July 2018 (Figure 1). The changes in the depth of the Strait were analyzed by comparing data between depth in 1990 by satellite images and the depth in 2018 by the measurement.
3. Results and discussion

3.1. Characters of Oceanographical and Sediments

The results of oceanographical observation and mechanical analysis of the sediment samples are shown in Table 1. The results indicate that the coastal area of Rupat Strait can be divided into three conditions: natural, abrasion, and accretion that occur along the coastal area of the Dumai City (Station 1-5) and of Rupat Island (Station 6-10).

The natural areas located in the north of the coastal area (Station 1 and 9) are occupied by rather weak current velocity (0.13-0.18 m/s) and wave energy (0.79-1.13 Nm/m²). The areas have a rather flat bottom topography, as shown by 2.8-3.0% of the coastal slope. The abrasion areas (Station 2, 5, 6, and 8) are occupied by strong current velocity (0.78-0.90 m/s) and high wave energy (2.25-2.59 Nm/m²). The areas have steep at bottom topography, as shown by 4.4-5.5% of the coastal slope. In contrast, the accretion areas (Stations 3, 4, 7, and 10) are occupied by weak current velocity (0.09-0.16 m/s) and low wave energy (0.56-0.68 Nm/m²). The areas have flat at bottom topography, as shown by 0.7-1.1% of the coastal slope.

Table 1. Results of oceanographical observation
### Table 2. The depth based on the interpretation of satellite image data 1990

| St. | Latitude (N)  | Longitude (E)  | Depth (m) | Note    | Current Velocity (m/s) | Wave Height (m) | Wave Energy (Nm/m²) | Coastal Slope (%) |
|-----|---------------|----------------|-----------|---------|------------------------|-----------------|---------------------|--------------------|
| 1   | 2°0'31.2092"  | 101°19'37.6431"| 3.5       | Natural | 0.13                   | 0.14            | 0.79                | 2.8                |
| 2   | 2°0'29.0677"  | 101°21'36.4972"| 9.4       | Abrasion| 0.78                   | 0.40            | 2.25                | 5.5                |
| 3   | 2°0'25.8554"  | 101°23'24.6437"| 11.9      | Accretion| 0.11                  | 0.12            | 0.68                | 0.7                |
| 4   | 1°59'14.114"  | 101°19'37.6431"| 9.7       | Accretion| 0.09                  | 0.10            | 0.56                | 0.9                |
| 10  | 1°59'14.114"  | 101°19'37.6431"| 9.7       | Natural | 0.16                  | 0.11            | 0.62                | 0.9                |

3.2. Depth Change (Bathymetry)

The depth of the Rupat Strait, based on the interpretation of the satellite image data of MIKE C-MAP (1990) is shown in Table 2, and its bathymetry in Figure 3. In general, the depth ranges from 0.9 to 29.4 meters; the deeper parts can usually be recognized along the middle section of the strait, while the shallow parts can be seen in the northern and eastern areas, which are predominantly coastal regions. The deeper areas can usually be recognized along the middle part of the strait and the shallow parts are occupied in northern and eastern parts, which are found predominantly in coastal areas.

![Bathymetry map of the Rupat Strait in 1990](image)

**Figure 3. Bathymetry map of the Rupat Strait in 1990**
The depth, based on the interpretation of the satellite image data of MIKE C-MAP (1990), is compared to the depth measured using echo sounders at 60 stations in July 2018 (Table 3 and Figure 4), which determined changes in the bathymetry of the strait over 28 years.

The depth of the strait, ranging from 2.4 to 32.1 m in 2018, is deeper than the depth of 1990, and this picture is almost the same as the one in 1990 showing deeper and shallower parts found in relatively the same area. If Figure 3 is compared to Figure 4, it will become clear that the depth (bathymetry) of the strait has been rising from 0.9 to 29.4 m and from 2.4 to 32.1 m for 28 years, meaning that the Rupat Strait has become deeper over time.

This increase in depth has been occurring over the years even though the strait receives a large amount of fine-grained sediment discharged by rivers and channels from the hinterland of Dumai City and Rupat Island. The depth of the Rupat Strait has increased from 1.5 to 2.7 m over 28 years, even though the strait receives a large amount of fine-grained sediment discharged by rivers and channels from the hinterland of Dumai City and Rupat Island. The rapid development of the city of Dumai and Rupat Island has resulted in a large erosion of surface soil leading to a discharge of lithogenous sediments to the shore area by the rivers and channels flowing from the hinterland of the city [19]. The sediment accumulation in the area has been as high as 7.220 tons/ha/year, and from the hinterland of the island by as high as 504 tons/ha/year [6].

| St. | Latitude (N) | Longitude (E) | Depth (m) | St. | Latitude (N) | Longitude (E) | Depth (m) |
|-----|--------------|---------------|-----------|-----|--------------|---------------|-----------|
| 1   | 2°03'1.2092" | 101°19'37.6431" | 20.6 | 31 | 1°43'6.0001" | 101°25'30.2348" | 15.5 |
| 2   | 2°02'9.0677" | 101°21'36.4972" | 11.2 | 32 | 1°43'40.2643" | 101°25'4.6525" | 15.3 |
As can be seen in [20], the movement of sediment caused by wave energy from the north, has led to a significant deposition of sedimentation to the south of Belitung Waters, Indonesia, which is believed to be land-derived. The sediments continue to undergo repeated cycles of resuspension and deposition until they eventually settle in wave-sheltered embayments, or offshore, beyond the depth of wave resuspension [21].
Most of the sediment does not settle on the bottom of the Rupat Strait but is transported out of the strait through tidal currents flowing from the Malacca Strait. During flood tide, the current from the Malacca Strait flows into the Rupat Strait through the northern and eastern parts of the strait, while at ebb tide, the current from the Rupat strait flows into the Strait of Malacca through the northern and eastern parts of the Rupat Strait [3]. The currents transport the bottom sediments of the strait, which are characterized by medium sand to coarse silt-grained sediments with the mean diameter ranging from 1.03 to 4.49\(\mu\) [4]. This feature's same trend is also found by [22] in surficial sediment of the Rangsang Island Indonesia influenced by tidal currents flowing from the Malacca, indicating the presence of silts. Sand-grained sediment is influenced by moderate to strong currents and wave patterns so that the sediment is transported along the coast to the offshore area.

This condition, causing the depth of Rupat Strait, has increased to 1.5-2.7 meters over the last 28 years. However, several estuaries have sedimented as found by [1] in the estuary of the Mesjid River that flows into the strait. They clarified that the sediment supplied by the river is 926 tons/day, causing the deposition at the estuary area to be as high as 0.024 m/year. In addition, the central part of Rupat Strait is also characterized by a weak sediment transport flow, resulting in bathymetry changes due to the high sedimentation rate. This situation is supported by the formation of small islands clusters in the area and is suspected to still be forming new islands there. As explained above, the current from Malacca Strait flows into and out of the Rupat Strait during flood tide and ebb tide. Water currents from two different directions create a confluence in the central part of Rupat Strait during flood tide and reverse during the ebb tide [3]. A large amount of suspended material has been deposited in the confluence area, as also found in the South Yatsushiro Sea of Japan by [15], and in the Mesjid River Estuary by [1]. The material may be accumulated by a downstream current along the frontal interface, which occurs in a rip current area [16], [23]. Rip currents responsible for the deposition are also explained by [24]. Sedimentation in river estuary will result in the emergence of "new land" [25]. Tidal current dynamics and waves have a dominant effect on sediment distribution and sedimentation [26], [27].

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