Value estimating of the sedimentation rate at the shipwreck sites (MV Boelongan Nederland) the Mandeh Bay Region - Pesisir Selatan Regency

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Abstract. Sufficiently high sediment deposit at the shipwreck diving site (MV Boelongan Nederland) the Mandeh bay region - Pesisir Selatan Regency due to infrastructure development has resulted in significant changes in the physical environment and may affect the existence of the shipwreck diving site. The analysis method regarding the sedimentation rate is carried out based on data from sediment traps that have been installed at the location of the shipwreck diving site, river flow, and river estuary. Based on the sedimentation rate measurement from the sediment trap, there is a close relationship between the sediment supply of the Mandeh river flow and the Nyalo river flow that affects the sedimentation rate at the shipwreck diving site. Where it was found the sedimentation rate in the shipwreck diving site was 15.33 g.m⁻².day⁻¹. With the condition of the waters of Mandeh bay region being semi-closed from open water, it is suspected that the sediment contributed from these rivers is mostly trapped and settled in these water areas.

Keywords: bay; mandeh; MV Boelongan; sedimentation; shipwreck

1. Introduction

The Mandeh bay region is targeted to become a major tourist destination in West Sumatra Province in addition to the fisheries sector, which has become the basis of regional excellence for the Pesisir Selatan Regency [1]. This is also stated in the Regional Regulation (PERDA) of Pesisir Selatan Regency No. 7/2011 concerning the Regional Spatial Plan (RTRW) of Pesisir Selatan Regency 2010-2030, where the development of the Mandeh bay region which includes the tourism, fisheries, and port sectors [2]. With a total area of 35,131 ha consisting of 16,241 ha of the mainland and 18,890 ha of marine waters, the KWBT Mandeh has a wealth of rich coastal and marine resources, while the mangrove forest area is ± 494.87 ha [3, 4]. Where this area also holds historical value with the existence of Dutch-owned MV Boelongan Nederland, which sank on January 28, 1942. This ship sank after being bombarded by the Japanese military. The ship was previously outside the Mandeh bay region, then tried to save itself into the bay [5].

In the case of the MV Boelongan Nederland shipwreck, both local and central governments are trying to make the MV Boelongan Nederland shipwreck site a mainstay tourist destination for Indonesia in terms of in-situ management and conservation for diving marine tourism [6]. Based on Government Regulation (PP) No. 50/2011 concerning RIPPARNAS 2010-2025, Pesisir Selatan Regency and its surroundings, including the waters of Mandeh bay region, have been designated as National Tourism Development Areas (KPPN). In addition, the Pesisir Selatan Regency government has also designated...
the waters of Mandeh bay region as an Integrated Marine Tourism Area (KWBT) and is listed in the RIPPD of Pesisir Selatan Regency. Official policy support from the central and local governments is a very important asset for the in-situ conservation of the MV Boelongan Nederland shipwreck.

The principle of in-situ conservation for underwater archaeological remains as stated in Law No. 11/2010 and the United Nations Educational, Scientific and Cultural Organization (UNESCO) Convention 2001 later became the basis for the study of the physical environment of waters and land in this research [7]. Assessment of the physical environment as an effort to protect the environment where underwater historical heritage sites are located is often forgotten, so that conservation efforts only focus on the stage of development and utilization. The neglect of efforts to protect underwater historical heritage from the surrounding environment causes underwater historical heritage to be threatened.

In research of Perez-Alvaro [8] states that underwater historical heritage sites are not only threatened by human activities such as treasure hunting, fishing, mining, infrastructure development, pollution, and also ship movement/traffic. But also threatened by changes in the natural environment (natural factors), and climate change such as earthquakes, storms, temperature variations, changes in currents, coastal erosion, and sedimentation. Therefore, the preservation of underwater historical heritage site remains should not only be seen in terms of formal regulations but also take into account the physical environment in which it is located. In LPSDKP [6] report states, physical impacts that are felt directly that threaten the sustainability and cause damage and loss of the MV Boelongan Nederland ship include sedimentation, coastal erosion, seabed erosions, ocean acidification, and sea-level rise. Meanwhile, the impacts felt indirectly include humidity levels, vegetation, crystallization, pest, biological effects, and chemical changes such as increased corrosion rates on metal artifacts. In more detail, the factors that pose a threat to the MV Boelongan Nederland shipwreck are caused by nature, including 1) Physical-mechanical factors (erosion, abrasion, scoring due to currents, tides, waves, sedimentation); 2) Chemical (corrosion of metal fragments, pollution); 3) Biological (shipworm, fungi, bacteria, especially on fragments of wood or other organic materials).

Management of coastal areas should be directed to achieve optimal physical use and development of coastal resources by taking into account the natural physical elements of the environment and meeting the basic social needs of the environment [9]. Understanding sediment dynamics in a complex environment is correct and important management in the process of mitigating or protecting ecosystems, and historical heritage assets from the impacts of human activities. In the waters of the Mandeh bay region, there are several major and large river estuaries which are one of the triggering factors for increasing sedimentation. Therefore, it is necessary to do an experimental analysis of the sedimentation rate around the tourist site of the Mandeh bay region sub-marine shipwreck [10, 11].

Several previous research related to sedimentation has not been done much. [12] analyzed granulometry in the Mandeh river and Nyalo river, which showed medium to coarse sand grain sizes. In addition, [13] simulate tidal currents and their effects on sediment distribution in the Mandeh bay region. Thus, a study related to sediment accumulation in the Mandeh bay region is important to do. With its geographical conditions, KWBT Mandeh has tourism potential, which includes natural and marine tourism objects and attractions, including fishing, diving, boating, swimming, water skiing, jet skiing, camping, rock climbing, paragliding, and natural panoramas as well as the local cultural potential that can be developed. According to data from the Agency of Central Statistics (BPS) of Pesisir Selatan Regency (2018), the number of tourists visiting Pesisir Selatan Regency from 2015 to 2018 has increased which is very encouraging. Tourists who visit not only come from domestic tourists but also foreign tourists. Based on this, efforts to assess the potential of other marine resources, and assess their vulnerability to water dynamics (sedimentation) and surrounding environmental conditions are very important including analyzing the impact of infrastructure development that can threaten the sustainability of the MV Boelongan Nederland shipwreck.

Based on the potential and opportunities that exist, it is necessary to develop efforts to dive tourism in the Mandeh bay region. The factors that encourage the need for the development of diving tourism in the Mandeh bay region include the tendency of a consistent increase in tourism, the large potential
possessed by the Indonesian people for tourism development. This tourism development is also an effort to make diving tourism in the Mandeh bay region one of the mainstay industrial sources, especially for the West Sumatra Province government, which is expected to be able to realize tourism development by environmental characteristics and be able to provide accurate information to support tourists who come to the Mandeh bay region. The purpose of this study was to identify the characteristics of the sedimentation rate at the site of the MV Boelongan Nederland shipwreck.

2. Methods
The data used in this research is primary data which includes data from direct measurements of sediment samples using sediment traps that have been installed around the location of the MV Boelongan Nederland shipwreck, and secondary data from several reports on government activities, and relevant journals. The sedimentation rate is the amount of sediment mass uplifted through one unit area each unit time [14-16]. The purpose of this research was to determine also to calculate the sedimentation rate, which is indicated to have a significant influence on the presence of the MV Boelongan Nederland shipwreck at seven (7) samples location. Sediment trap placements are placed at several samples location, namely at 1) the water location of the MV Boelongan Nederland shipwreck; 2) the Mandeh
river estuary; 3) the Mandeh river flow, 4) the Nyalo river estuary, and also on the Nyalo river flow. The location of each sediment trap station can be seen in figure 1 and table 1.

2.1. Observation methods

Main Parameter (Sedimentation rate): The main parameter observed is the sedimentation rate which is calculated using the formula [17, 18] as follows:

\[ L_s = \frac{m - L}{t} \quad \text{(1)} \]

Where:

\[ L_s = \text{Sedimentation rate (gm}^2\text{day}^{-1}) \]
\[ m = \text{Weight of moored sediment (g)} \]
\[ t = \text{period of time the sediment trap is installed (days)} \]
\[ L = \text{Sediment trap area (m}^2) \]
\[ r = \text{Sediment trap radius (m)} \]

Where is the sediment trap is made of clear acrylic pipe 30 cm high with an inside diameter of 1.5 inches and a height of 100 cm iron so that it is easily embedded in the bottom of the water and is not easy to be carried away by currents.

2.2. Measurement of supporting main parameters

- Field: Sediment sampling at each station was carried out at one time with relatively slightly different locations with an interval of 24 - 30 days.
- Data Analysis: The sedimentation rate analysis method is carried out in two (2) stages, namely 1) The sediment sample from the sediment trap is transferred to a sample bottle and then deposited; 2) Samples that have been deposited are then weighed and transferred in a measuring cup with a volume of 1 liter which has been filled with distilled water, stirred until homogeneous and then pipetted, pipetting time and sediment sinking distance (table 2); 3) Each pipetting result is placed in a previously weighed sample bottle; 4) The pipetting results were then filtered using 0.45 m\textsuperscript{m}
whatman\textsuperscript{m} filter paper which was previously oven-dried at 105°C, then the sediment samples were filtered using a vacuum pump together with filter paper; 5) The filter results are then placed in an oven at a specified temperature of 105°C and then weighed to determine the weight; and 6) The sample that has been in the oven is then weighed and the sedimentation rate value is calculated using the sedimentation rate calculation formula, namely:

\[ \frac{10}{\pi.r^2}.(A-B) \quad \text{(kg/m}^2\text{day)} \quad \text{(3)} \]

Where : \( A = \) weight of aluminum foil + sediment after heating 105°C (in grams), \( B = \) initial weight of aluminum foil after heating 105°C (in grams), \( \pi = 3.14, \) and \( r = \) radius of the sediment trap circle

| Time (hours, minutes, seconds) | Sink distance (cm) |
|-------------------------------|--------------------|
| 00 00 58                      | 20                 |
| 00 01 56                      | 10                 |
| 00 07 44                      | 10                 |
| 00 31 00                      | 10                 |
| 02 03 00                      | 10                 |

Table 2. Sink distance and pipetting time.
3. Research results

3.1 Literature reviews

Analysis of the sedimentation rate was carried out based on data from sediment traps that had been installed at the location of the sinking ship and at the river mouth (table 1 and figure 1), where the sedimentation rate was the amount of sediment mass lifted through one unit area each unit time [15, 20]. According to Putra et al (2016) and Tanto et al (2017) [14, 16] most marine sediments are material originating from land carried by rivers, where there are several types of sediment according to Hutabarat and Evans (2000) [21] in his book, which are divided by looking at where the source comes from, namely: 1) Lithogenous sediment, which are derived from the remains of rock erosion on land; 2) Biogenous sediment, which are sediments derived from skeletal remains of living organisms that can form deposits of fine particles commonly referred to as ooze and often settle in areas located far from the coast; and 3) Hydrogenous sediment, which are particles formed as a result of chemical reactions.

The condition of the waters and their interaction with the land will greatly affect the sedimentation rate. Some of the parameters of these water conditions include 1) Turbidity: If the turbidity in the waters is high, the sedimentation rate will also be high. The presence of sedimentation can make the waters cloudy, plus the influence of currents and waves, which causes sediments with small and fine particle sizes to be difficult to settle [22]; 2) Depth: Sedimentation is also affected by depth. The process of sediment deposition occurs faster in shallow sea areas compared to the deep sea abyss [23]; and 3) Current Velocity: Ocean currents are large-scale movements of water masses in both horizontal and vertical directions. Measuring the direction and speed of ocean currents is not as simple as with river currents in the direction of the river flow downstream. In the sea, the direction and speed of the current is influenced by one factor, namely the presence of monsoons [23]. The relationship between currents and sedimentation is inversely proportional. If the current in the waters is fast, then the sedimentation that occurs is low, then if the particle size of the sediment is large, then the sedimentation in the waters will be high. In this research, the parameter of aquatic environmental conditions measured was the sedimentation rate that occurred around the waters of the MV Boelongan Nederland shipwreck at KWBT Mandeh.

3.2 Existing condition of research location

Administratively, the site of the sinking ship [MV Boelongan Nederland], which is the location of this research activity is located in Mandeh Village, Koto XI Tarusan sub-district. Astronomically, this sunken ship is at the coordinates of 1°12.052’ South Latitude, and 100°25.502’ East Longitude (figure 1). The location of this shipwreck point is approximately 1.5 km from the location of the Cubadak Paradiso Village Resort. Where the iron shipwreck is located at a depth of 17 - 29 m in the waters of the Mandeh bay region.

From the results of surveys and reports from secondary data from underwater observations [6], it is known that the shipwreck of the MV Boelongan Nederland on the KWBT Mandeh is a shipwreck which as a whole is still relatively intact with damage in several parts and part of the hull has sunk in the sea in the mud substrate. This sunken shipwreck is made of iron material and parts of the ship such as the hull, hatch, windows, bow, and stern can still be seen and can still be identified. The following is a sketch of the reconstruction of the sunken ship’s hull, top view, and side view based on the results of visual observations through a number of diving activities at the location of the sunken shipwreck. This sunken shipwreck was physically almost broken in two (2) in the hull. Part of the walls of the ship and the forepart of the hull was heavily damaged and there were visible marks of holes from the bombing by aircraft. This ship consists of 2 floors, between the 1st and 2nd floors are separated by windows. This ship has 2 large masts made of iron and has broken and collapsed towards the rear (stern) and its position is longitudinal from east to west. The bridge cabin wall appears to have fallen onto the deck at a depth of about 20 m. On the left and right of the ship, there are still many high curved iron poles that are thought to be a place to hang lifeboats, for more details, see figure 2.
From the survey results in the report [secondary data] underwater observations [6], it is known that this ship has a length of ± 75 m, the width of the hull at the bow is ± 10 m, the width of the hull in the middle is ± 11 m, the width of the hull at the stern is ± 13 m, the height of the bow of the ship from the seabed is ± 8 m, while the height of the ship in the middle is ± 4 m. The measured ship height does not represent the actual size because part of the ship's hull is submerged in sediment. The position of the wreck is tilted to the left, while the orientation of the front (bow) of the ship is on the southwest side. The stern is located in the northeast direction, which indicates the ship is heading south with the condition of the bottom substrate being mud which most likely comes from the Mandeh river and the Nyalo river because the position of the sinking ship is right at the Mandeh river estuary.

### 3.3 Result of sedimentation rate analysis

Sediment traps are placed at several samples (see table 1), were from the results of the analysis of the sedimentation rate from the location of each sample using sediment traps and laboratory tests, then modeled with an interpolation model of Inverse Distance Weighted (IDW) for estimates cell values. The average value of the sample data points around each processing cell using a Geographic Information System (GIS) software.

Based on the data on the measurement value of the sedimentation rate from the sediment trap at the location of the sinking ship MV Boelongan Nederland, the sedimentation rate value was 15.33 g.m⁻².day⁻¹. Meanwhile, the measurement value of the sedimentation rate obtained from the Nyalo river flow and the Nyalo river estuary is an average of 48.86 g.m⁻².day⁻¹. And to the measurement value of the sedimentation rate of sediment trap stored at the location of the Mandeh river flow and the Mandeh river estuary is 60.85 – 62.16 g.m⁻².day⁻¹. Taking into account the rainy days that occurred at the time of sediment sampling, it can be seen that the sediment contributed to the waters of Mandeh bay region and its surroundings was mostly contributed by the Mandeh river flow. In addition, the sediment transport process that occurs in the Mandeh bay region waters is also influenced by the currents acting in these waters. For more details, the results of the analysis of the sedimentation rate at the shipwreck sites (MV

| No. | Coordinate        | Locations                        | (results) g.m⁻².day⁻¹ |
|-----|-------------------|---------------------------------|----------------------|
| 1   | 1°12.052′ 100°25.502′ | The point of the MV Boelongan Nederland shipwreck | 15.33                |
| 2   | 1°11.767′ 100°25.996′ | Mandeh river flow             | 60.85                |
| 3   | 1°12.006′ 100°25.841′ | Mandeh river estuary          | 62.16                |
| 4   | 1°10.822′ 100°24.257′ | Nyalo river flow              | 48.86                |
| 5   | 1°10.875′ 100°24.047′ | Nyalo river estuary           | 48.86                |
Boelongan Nederland) the Mandeh bay region - Pesisir Selatan Regency can be seen in table 3 and figure 3.

The sedimentation characteristics in coastal waters occur slowly and continuously as long as the supply of high sediment loads continues [24, 25]. Furthermore Hermon (2014) [26] add changes in sedimentation rate can occur if there is a change in physical environmental conditions in the related watershed. In research [26 – 29] explained that land clearing that increases surface erosion can increase the rate of sedimentation. If the sedimentation is solely due to the transportation of sediment loads along the coast, the rate of sedimentation that occurs is relatively slower when compared to sedimentation that gets a supply of sediment loads from the mainland. The sedimentation process takes place slowly and continuously as long as the supply of a large sediment load from the mainland continues. Land clearing in watersheds that increase surface erosion is the main factor that increases the supply of sediment loads to the sea. In addition, sedimentation on a smaller scale can occur due to sediment transport along the coast.

The case in the field shows that the construction of a new road which is the access to Mandeh Village destroys the aquatic ecosystem along the location with the construction of the new 8 m wide road. Along the road repair section, which is being worked on, the color of the sea waters is brownish. The change in color from blue to brown is strongly suspected because of the sedimentation process due to soil material that has fallen into the expanse of mangrove forests and the waters below. This happened following the activity of cutting hills and the road body being built. This the basis for research that there has been a change in the rate of sedimentation transported by the river watershed in this region which ends at the Mandeh river estuary.

3.4 Development plan as KWBT Mandeh
Until now, Indonesia has not developed a zoning system that can be used as a guideline to clarify the land use potential of an area or area for the development of historical heritage sites (eg, shipwreck ship) for the development of marine tourism. The shipwreck ship can become a diving tourism object for
lovers of diving sports such as at Liberty Wreck - Tulamben Bali, and Manado [30]. Because shipwreck ship sites are usually the center of marine life because shipwreck ship can function as artificial reefs, shipwreck ship can form a separate ecosystem that is fertile, unique, and interesting to dive into. Furthermore, Hermon (2010) [24] explained that the shipwreck ship can be used as an underwater museum for recreational purposes and as a place for training and education that contains educational aspects for visitors. In addition, the site of the sunken ship can also become a pilgrimage tourism object which at this time has begun to become a trend, especially among the Japanese, who often visit the places of their ancestors who died in battle locations during World War II, for example in Samalona, South Sulawesi and in Biak and Raja Ampat in Papua.

In a report LPSDKP (2012)[6] the location of the shipwreck ship MV Boelongan Nederland in the Mandeh bay region can be immediately proposed as a Maritime Conservation Area (KKM). The zoning for the protection of underwater historical heritage must be by the applied principles related to in-situ conservation. For this reason, the zoning [31] required in the Mandeh bay region includes: 1) Zone 1 (Core zone) functions as a core zone of protection and preservation covering the shipwreck point area and its surroundings, for example with a diameter of $\frac{1}{4}$ km. This zone must be determined as the main protected area which must be completely free from fishing exploitation activities by fishermen, exploitation of illegal removal of artifacts, vandalism, and must also be free from fishing boats and transportation visual (maintaining visibility), and the importance of diving tourism (capacity of divers visitors); and 2) Zone 2 (Buffer zone) functions as a buffer zone that functions to provide space for the preservation of the surrounding natural environment and provides space if at any time it is necessary to expand the in-situ preservation area where in the environment around the sinking ship site it can later be used as an area to apply the methods and efforts of in-situ preservation to prevent erosion, sedimentation, surface rise, and fall, and others, for example by planting artificial grass, sandbagging, and others. For the Mandeh bay region, this buffer zone can be defined as approximately as far as $\frac{3}{4}$ km in diameter.

This protected area of the historical heritage of sunken ships must be monitored and controlled strictly and continuously so that there is no deviation from the provisions of protection and there is no damage to objects caused by human activities or the influence of the surrounding natural environment. Supervision and control activities that are law enforcement in nature can be carried out by the competent authorities, including the Directorate General of Supervision of Marine and Fishery Resources, the Indonesian Navy, and the Water Police. Meanwhile, routine monitoring related to efforts to prevent site damage from natural factors can be carried out by research agencies, technical directorates, and local government parties. The protection activity by zoning and establishing it as a Maritime Conservation Area (KKL) is to maintain the shipwreck ship so that it is not lost or damaged due to human activities or natural activities. Zoning to protect the sustainability of shipwreck ship is not only an effort to establish this site as a KKM, it is also a contemporary approach to Cultural Resources Management activities which are currently being promoted in various regions around the world [32 - 34].

4. Conclusion
The existence of this underwater historical site is very important and can be used as an object of further and in-depth research and is also important for the learning process from various aspects and various disciplines have seen from site conditions, findings conditions, and water conditions. The location of this site can be used as one of the pilot projects of in-situ preservation which is very in line with the 2001 UNESCO Convention and is also very in line with the concept of developing KKM as stated in government regulation PERMEN No. 17/2008. The location of the underwater historical site of the Mandeh bay region can be used as a marine tourism destination for diving tourism which has economic value due to several reasons such as calm and protected sea conditions because it is in a bay, clear seawater so visibility underwater is quite good. The high sedimentation at the location of the shipwreck ship MV Boelongan Nederland in the Mandeh bay region has resulted in significant changes in the physical environment of the site and can affect the existence of the shipwreck ship. This can be studied further to determine the value of the sedimentation rate how long the remains of the shipwreck ship will
be buried by silt sediment from the river. It is hoped that this research activity can provide input to relevant agencies and governments at the regency, province, and central levels regarding policies in developing tourism in West Sumatra Province. Based on the results of research and interviews related to sedimentation originating from estuaries which are located in the Mandeh bay region, it has quite an impact on historical heritage sites around the bay. Where the existing sediment load is carried by flowing the Mandeh river and the Nyalo river.

Acknowledgments
The authors would like to acknowledge the Institute for Research and Community Service (LP2M) - Universitas Negeri Padang (UNP), which has provided annual research funding assistance for the Study Center scheme, where this research is a product of the Center of Population and Environmental Studies (PKKLH) UNP in 2021.

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