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Bathymetry and substrate characteristics in Pulo Suwalan coral reef areas for fish apartment development in Rembang coastal area

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Abstract
This study aims to analyze the characteristics of the bathymetry and bottom substrate in the Pulo Suwalan coral reef area for fish apartment development. The research location was carried out in the coral reef area of Pulo Suwalan in the coastal area of Rembang Regency. This research used a survey method. The study research showed that the Pulo Suwalan coral reef area was in the shallow water zone. The depth of the waters at the study site ranges from 0.5-8 m. The bottom morphology of the waters is flat to almost flat. It is known that 81.25% of the bottom substrate in the site location is silt and 18.75% is sand-smooth. The Pulo Suwalan coral reef area has the potential to become a location for installing fish apartments based on the degradation of the environment and the depth of water.

Keywords: Bathymetry, fish apartment, substrate

1. Introduction
The coastal area of Rembang Regency as a location in this study has a demersal fish utilization rate of 83.71% [1] and for pelagic fishes is 44% to 118% [2]. This means that fishing conditions in the study location are in over-exploited and moderately exploited status. The exploitation status of fisheries resources indicated an effort to enrich fisheries resources is necessary. Strategy to enrich fish stock can start by identifying water locations that are fish habitats and mapping their conditions so the methods to increase fish stocks can be applied. Fish apartment is a technology that can be applied to enrich fish stocks in a water area. The principle used is to collect fish in a certain area, where the place is provided with an artificial habitat that resembles a fish sanctuary or coral reefs so that fish will congregate in that area [3-6]. The mechanism of fish gathering in fish apartments takes advantage of fish behavior which naturally requires a place to shelter from predators, feeding ground, nursery ground, and spawning ground [7]. However, installing fish apartments with a poor strategy potentially disrupts fishing activities, and the main purpose of installing fish apartments is not achieved.
Therefore, the location of the fish apartment placement is an important factor so that this artificial habitat can carry out its function as an alternative fish habitat [8]. The right placement will also facilitate the management of fish apartments and the use of the surrounding area for fishing activities. This research will provide information about the potential location for fish apartments in the area around the coral reef area so that it will provide convenience in management and utilization. The local government has made policy directions for developing this location research as a marine tourism area. However, the master plan for this area and its technical planning are not yet available. Therefore, this research will be able to become a baseline in preparing technical plans and can provide an alternative for the development of fish apartments in the area. It is important to know and understand the availability of bathymetry characteristics and the distribution of seabed substrate in the coral reef area to become the basis for the fish apartment development.

2. Materials and Methods

The research used a survey method. The research location is in the Pulo Suwalan coral reef area which is located in the coastal area of Rembang Regency (Fig.1). The focus of the research was to study the bathymetry and the bottom substrate of the waters in the coral reef area of Pulo Suwalan for developing fish apartments.

The primary data for this study consisted of water depth data and bottom substrate. Water depth data collection was carried out using hydrographic survey standards (SNI Hydrographic 7646 of 2010). The survey area is 6.21 km^2 (2.7 x 2.3 km) (Fig. 2). Bathymetric Survey was carried out using a GPS Map 585 type single beam echosounder using a frequency of 50 Hz, the horizontal position accuracy is ±2-5 m (DGPS-WAAS Enable), and the vertical position accuracy is ±0.2 m. The survey was carried out with fishing boats for 3 (three) days with a maximum speed of the vessels during the survey is 7 (seven) knots. A bathymetric line on the survey consists of 55 line perpendicular to the coastline with a spacing of 50 m and 7 (seven) line parallel to the coastline with a spacing of 400 m.

Fig 1: Location of research study

Fig 2: Bathymetric line survey and station of substrate sampling

Bottom substrate data was collected using a grab sampler. Sampling of substrate was carried out at 16 (sixteen) stations with the number of sample per station being 1000 g/station. Furthermore, the substrate samples were analyzed for grain size in the laboratory. Samples of the seabed substrate can be taken using a grab sampler and can represent the character of the sediment which is located in the top layer of a bottom waterbed [9]. The water bottom substrate sampling station points can be seen in Figure 2. Bathymetry analysis is done by calculating the actual water depth. Water depth is actually obtained by making depth corrections based on tidal elevation, transducer draft, and also tides (Z0). To calculate the depth reduction value, an equation is follow [10]:

$$r_t = TWL_t - (MSL + Z_0)$$

Where, r_t is correction of depth at time t, TWL_t is true water level at t time, MSL is Mean Sea Level, and Z_0 is Chart Datum. Furthermore, the calculated depth correction value is used to calculate the actual depth with the following equation:

$$D = d_T - rt$$

Where D is the actual of depth, dT is depth correction from tranducer and rt is tidal correction. To find out the type of tides, Formzahl value calculation analysis is used [11-13]. The following is the calculation formula to get the Formzahl value:

$$F = \frac{AK_1 + AO_1}{AM_2 + AS_2}$$

Where, AK_1 is component amplitudo K_1, AO_1 is component amplitudo O_1, AM_2 is Amplitudo Komponen M_2, and AS_2 is component amplitudo S_2.

3. Results and Discussions

Condition of the Pulo Suwalan Coral Reef Area

Pulo Suwalan is located in a shallow water area with a distance of only 0.54 nm from the nearest coastline. The closest coastline is in the administrative area of Pasar Banggi Village, Rembang District, Rembang Regency (Figure 1). Pulo Suwalan has an area of ± 20 ha with location coordinates S 6° 40' 58.95" and E 111° 23' 05.65". Pulo Suwalan is one of the marine tourism development areas in the coastal area of Rembang Regency. The name of the marine tourism development area is the Alas Samudero Welo area.

Pulo Suwalan has unique characteristics. Geographically, this location is adjacent to mangrove areas, fishing bases, and fishing grounds. Ecologically, the existence of Suwalan Island is a location that supports the sustainability of fish biota as a location for fish habitat. The location close to the mangrove area allows fish biota from the mangrove area to migrate towards the coral reefs on Pulo Suwalan. The location of the mangrove area in the Pasar Banggi Village area has been well managed through the participation of local communities [14-17]. Many studies have been conducted on strategies for developing mangrove areas for ecotourism development [18-23]. However, studies and research on the management of the coral reef area of Pulo Suwalan are very limited.

From the visual observations in the coral reef area on Pulo Suwalan, it is known that the dominant species of coral are the Branching and Brain coral types. At low tide, some of the coral will be exposed to the surface (Figure 3) and on the south side of Pulo Suwalan, sandy land will appear. Conditions at low tide made it possible for the Pulo Suwalan area to be easily accessed by the local community. Field observations also found fishing operations using boat-push nets. The fishing gear operates on the surface of the water in the coral reef area of Pulo Suwalan, during high tide conditions. This condition can certainly increase the high degradation of coral reefs. Worldwide, over 60 percent of the Earth's coral reefs, face endangerment due to local human activities [24].

The existence of mangrove and coral reef ecosystems affects the abundance of fish [25]. Some reef fish during their lifetime perform ontogenetic migration from mangrove forests, seagrasses, and coral reefs [26-29]. For growth and to avoid competition, fish will optimize the advantages of certain habitats and choose suitable habitats with low predation rates [30]. Coral, seagrass and mangrove ecosystems are important ecosystems that support each other for the existence of fishery resources and require regular monitoring efforts so that the sustainability of fishery resources can be maintained [31].

Pulo Suwalan's location is close to fishing bases, marine tourism areas, and fishermen's fishing grounds. The Pulo Suwalan coral reef area has not yet had a management plan

available. Data and information on the field area are also still limited. Its critical condition, coupled with pressure from the surrounding environment, requires a planned and sustainable treatment. The protection and preservation of coral reef ecosystems have the potential to support the welfare of the surrounding community through appropriate management efforts [32-34]. Coral reefs that are properly managed can generate economic value [35]. Some of the economic values of coral reefs include wave barriers, fish growth areas, capture fisheries activities, and seaweed cultivation [36]. Another economic value of the existence of coral reefs is as a marine tourism area [37-39].

Fig 3: The condition of Pulo Suwalan at low tide

Characteristics of Tides and Bathymetry in the Pulo Suwalan Coral Reef Area

There are three types of tides that occur on Earth, namely atmospheric tides, oceanic tides, and solid earth tides [40]. In this study, the type of tide that will be presented is the type of oceanic tide. Tidal analysis is carried out by calculating the harmonic component of the tide which includes the amplitude and phase values of the tidal data. The results of the calculation of the harmonic component of the tides are then used to determine the type of tides and water level elevation. In Table 1 it can be seen the results of calculating the daily components of the tides at the study site. The main daily components of the study locations have higher amplitude values when compared to the main multiple daily components. It is known that the amplitude values of the main daily components are K1 amplitude (AK1) with an amplitude value of 48.07 cm and O1 amplitude (AO1) with an amplitude value of 24.58 cm. As for the main double daily components, namely the M2 amplitude (AM2) with an amplitude value of 6.96 cm and the S2 amplitude (AS2) with an amplitude value of 3.47 cm. The type of tide can be determined based on a comparison of the sum of the main daily tide components (K1 and O1) with the main double tide components (M2 and S2) [41]. The results of this comparison will get the Formzhal value and determine the type of tide following the Formzhal classification.

The results of tidal data analysis show that the type of tide at the study site is a single daily (diurnal) type of tide with a magnitude of Formzhal 6.965. The characteristic of a single daily (diurnal) tide type is one type of tide where there is one high tide and one low tide with an average period of 12 hours 24 minutes. Single daily tide types can be found in the waters of the North coast of Java, including in Jepara waters at a depth of 2.4 m [42], Tuban waters [43], and the waters of Tuban, Lamongan, Gresik [44]. Even so, Java Island waters have 3 (three) types of tidal shapes, namely the mixed tidal type inclined to double daily in the Surabaya, Serang, Cirebon, Ketapang, Sendangbiru, Pemayangsari and Pelabuhanratu, mixed tide types tend to be single daily in the Semarang area and single daily tide types in the Pondokdayung and Tuban areas [45].

Table 1: Tidal Components in Pulo Suwalan Waters

Component	Amplitudo (cm)	g°
S_0	95,50	180,00
M_2	6,96	311,75
S_2	3,47	163,94
N_2	2,84	260,92
K_1	48,07	216,45
O_1	24,58	153,35
M_4	1,43	144,61
MS_4	0,38	272,72
K_2	0,94	163,94
P_1	15,86	216,45

Table 2: Water sea level in Pulo Suwalan Waters

Water Sea Level	Value (cm)
Z_0 (*Chart Datum*)	79,95
HWS (*High Water Spring*)	175,45
MSL (*Mean Sea Level*)	95,50
LWS (*Low Water Spring*)	15,55

The North coast of Central Java [46], the tidal type tends to be mixed single daily inclination such as in Jepara, Semarang, and Pekalongan waters, as well as in Batang waters where the tidal type is a mixed single daily inclination [47]. The results of data recording with an echo sounder and tidal correction show that the depth of the coral reef area of Pulo Suwalan ranges from 0.5 m - 8 m. Water areas with a depth of >8 m are found in the waters to the north of the coral reef area. The coral reef area of Pulo Suwalan includes shallow waters with a flat bottom morphology with an almost flat slope. The topographical conditions of the Java Sea are shallow waters [48]. In Figure 4 it can be seen that in the waters to the east of the coral reef area, the water depth is in the range of 2-5 m, and in the west of the area ranges from 3-6 m. The depth of the waters in the waters to the north of the coral reef area is > 6 m. Coral reefs in Rembang waters are at a depth of 1-8 m [49].

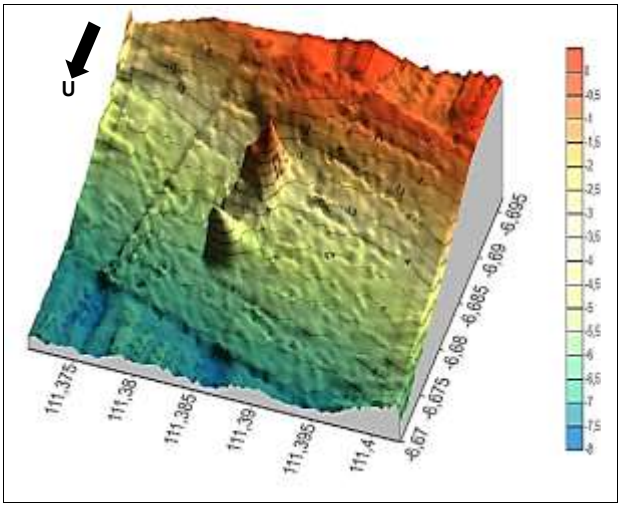

Fig 4: 3D Model of Depth in Pulo Suwalan Coral Reef Area

Characteristic of Substrate in Pulo Suwalan Coral Reef Area: The results of the grain size test for the bottom substrate in the coral reef area of Pulo Suwalan can be seen in Table 3. Based on these data, it can be seen that silt-type substrate dominates around the waters, which is found at 13 station points (81.25%). While as many as 3 (three) station points (18.75%) the type of substrate category is smooth-sand dominant. The location of the waters with fine sand substrate conditions is only found in the waters on the south side of Pulo Suwalan and this is relevant to the location of the existence of sand that appears during low tide conditions. This condition is similar to the closest location in the waters of Pulo Suwalan, namely the waters of Tasik Agung which is only ± 6 km away. In these waters, 70.00% of the bottom sediment is silt, only 26.67% is sand and the remaining 3.33% is silt clay [50]. The types of sediment that flow into the Java Sea are silt and clay, which are sourced from the supply of material from the mainland through existing rivers [51].

Table 2: The Results of Substrate Grain Size Test in the Pulo Suwalan Coral Reef Area

Sampling Point	Category and Value of Grain Size (%)					Grain Size Dominant Per Stasiun
	Pebbles	Coarse sand/ Shells	Sand-smooth	Silt	Clay	
1	0,00	0,00	53,60	46,40	0,00	Sand-smooth
2	6,38	7,50	9,38	74,74	2,00	Silt
3	1,54	4,12	8,50	85,84	0,00	Silt
4	3,92	9,38	12,78	73,92	0,00	Silt
5	0,00	0,00	52,72	47,28	0,00	Sand-smooth
6	0,56	1,56	5,10	92,78	0,00	Silt
7	1,16	5,80	10,48	82,56	0,00	Silt
8	3,30	5,18	5,12	86,40	0,00	Silt
9	0,00	0,00	83,49	16,51	0,00	Sand-smooth
10	2,42	4,36	12,34	75,88	5,00	Silt
11	0,00	3,70	7,06	88,24	1,00	Silt
12	3,24	4,34	2,96	89,46	0,00	Silt
13	0,00	0,00	14,54	85,46	0,00	Silt
14	0,00	0,00	6,88	93,12	0,00	Silt
15	3,74	7,10	8,68	79,48	1,00	Silt
16	4,60	4,18	3,26	87,96	0,00	Silt

The Potential Fish Apartment Development in Pulo Suwalan Coral Reef Area

The coral reef area is an important habitat and home to a variety of fish species. The existence of coral reefs provides support for the passage of complex food chains in the sea and maintains the balance of marine ecosystems [52]. Ecologically, the typology of coral reef habitat plays an important role in maintaining the sustainability of aquatic ecosystems. This is because coral reefs function as spawning grounds, nursery grounds, and feeding grounds [53].

Fish is one of the aquatic organisms that are vulnerable to environmental changes, mainly caused by human activities, both indirectly and directly [54]. The occurrence of damage to coral reef areas can have an impact on reducing the number of fish caught, the size of fish caught is getting smaller, and the extinction of several types of fish, especially reef fish [55]. The degradation of coral reefs in the waters is one of the factors that make it difficult for fish to return to their habitat and makes it difficult for fish to breed [56].

The causes of coral reef degradation include the use of non-environmentally friendly fishing gear, overfishing, ingress of waste into the waters, uncontrolled development of coastal areas, clearing of land in coastal areas, sedimentation, and other uncontrolled human activities in coastal areas [52, 57-59]. Handling and management of coral reef areas need to be done to reduce the impact of more massive damage. One solution that can be applied in handling degraded coral reefs is the installation of fish apartments in coral reef areas. The fish apartment is a technology that can be an alternative to preventing damage to fish habitats [60-63].

A fish apartment is an artificial habitat that is placed in the waters and built for the same purpose as the function of coral reefs as a fish habitat. Fish apartments can be identified as similar to bottom FADs. This is due to the nature of the bottom FADs which can function like coral reefs [64]. Artificial reefs or artificial habitats have a fairly good level of efficiency as fish aggregating devices [61]. Fish apartments can also attract and collect fish and other marine life through the provision of shelter and food sources [65]. Installing fish apartments can also increase fish production and sustainability of fisheries resources [66]. There is a trend of increasing the number of individual herbivorous fish groups after 6 (six) months of fish apartment installation [67]. The condition of live coral cover is correlated with the diversity and abundance of reef fish [68].

Based on the results of bathymetry analysis of the waters in the coral reef area of Pulo Suwalan, it is known that the characteristics of the depth waters are between 0.5 m - 8 m. The grain size test results revealed that 81.25% of the bottom substrate in the waters around the coral reef area of Suwalan Island was silt. The results of identification of fish apartment installation locations at various source locations, it is known that the water depth of fish apartment installation is 3-5 m [67], 10-25 m [60], 11-25 m [69], 5-18 m [70], and 10-30 m [3].

Some of the technical criteria for fish apartment installation locations are degraded aquatic habitats, considerations for installation in dense fishing/overfishing areas, avoiding sediment deposition areas, locations far from river mouths, water depths between 10-30 meters, gently sloping seabed, and outside the conservation area [60]. The technical requirements for the location of the fish house placement based on regulation [71] are priority is an aquatic habitat that has degradation of fish and the environment, avoid polluted waters, the depth ranges from 6 - 30 m or is still exposed to sunlight and at the lowest tide, bottom of sand waters that are sloping, protected from the influence of currents and waves that can damage the fish apartment construction, not far from the location of the fishermen's settlement so that it facilitates

monitoring, and the location was not in a shipping lane.

The condition of the coral reef area of Pulo Suwalan which is degraded fulfills the main parameters for installing fish apartments on the installation criteria contained in regulation. When viewed from the depth of the waters, several research sources note that the pattern for installing fish apartments is at a depth of 3 - 30 m [60-70]. The installation of fish apartments is carried out at a depth of 10-30 m, because at that depth the sunlight is still able to penetrate the water column [60]. In addition, the installation of fish apartments needs to be done on a gently sloping water bottom with the intention that the fish apartment framework can be installed stably on the water bottom. The depth of water required in installing a fish apartment is in principle related to the ability of sunlight to penetrate the water column. As long as sunlight is still able to penetrate the water column, fish apartment installation can be done. Sunlight entering the water column where the fish apartment is installed, will create conditions where the fish apartment becomes a place for the attachment of zooxanthellae which is the beginning of the development of coral reefs in fish apartments [72]. The results of weighting priority criteria in installing fish apartments are degraded environment (28.80%), water depth (20.60%), suspended substrate/sediments (18.20%), topography (16.20%), and distance from the coastline (16.20%) [69]. This shows that the coral reef environment which is in a degraded condition and water depth are the two priority parameters in the fish apartment installation criteria. Thus, based on the degradation conditions that occur and the depth of the waters, the location of the coral reef area of Pulo Suwalan has the potential to become a location for installing fish apartments in order to restore the condition of coral reefs and increase the number of fish resources. Meanwhile, based on the condition of the water depth at the research location, the fish apartments is the potential to be installed in the waters to the north of the existing coral reef area

4. Conclusion

The depth of the waters in the coral reef area of Pulo Suwalan is in the range of 0.5 – 8 m. The bottom morphology of the waters is flat with an almost flat slope. It is known that 81.25% of the bottom substrate of the waters in the coral reef area of Pulo Suwalan is silt and 18.75% is fine sand. The coral reef area of Pulo Suwalan has the potential to become a location for installing fish apartments based on the suitability of degraded environmental conditions and water depth. Further research can be carried out related to the condition of the diversity of coral reefs and fish and the perceptions of local communities in efforts to manage the area for the sustainability of fish and coral reef resources.

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