Coral reefs distribution using Sentinel-2A imagery in Belanda Island, Bira Besar Island and Pramuka Island at Kepulauan Seribu National Park

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Abstract. Kepulauan Seribu is known as the tourism sector, especially marine tourism and has the optimal oceanographic conditions for coral reefs suitability. Kepulauan Seribu National Park is an area as a form of conservation for coral reef ecosystems and other species with strict supervision and some restricted areas. In order to keep maintaining the conservation area, other factors such as economic and social factors are also considered by making the zone according to its location and function. Several zoning used of the area facing different problems or pressure either from natural factors or human activities. The purpose of this study was to analyze the distribution of coral reefs and the differences related to the physical characteristics of the waters in each zoning in the Kepulauan Seribu National Park using Sentinel-2A imagery. After that, data processing of research variables was carried out using bathymetry, sea surface temperature anomaly and ocean brightness data. This study found that the pattern of coral reef distribution on Belanda Island is centered on the Northeast while on Bira Besar Island and Pramuka Island are spread evenly along the reef flat. The highest percentage of coral reef distribution is found in the core zone & protection, which is equal to 6 % of all benthic habitat areas on the research island. In addition, inter-zoning has brightness and depth characteristics that vary according to geographical location.

Keywords: Coral reefs, Sentinel-2A, remote sensing, water column correction, confusion matrix

1. Introduction
Coral reefs that live in shallow water are one of the natural resources, well known in the tourism sector [1]. Coral reefs in Indonesia are also one of the potential marine resources that are very important and beneficial, especially in ecology and economy even though it is very vulnerable towards the environmental changes or human caused even on a local scale [2]. Marine tourism activities over time could also lead to damaged coral reefs [3]. This vulnerability occurs because coral reefs require specific environmental conditions to live [4].

Kepulauan Seribu is well known as the tourism sector, especially marine tourism and also has optimal oceanographic conditions for the life of coral reefs. Kepulauan Seribu National Park is an area as a form of conservation efforts towards coral reef ecosystems and other species, with several zoning uses of the area within it. The utilization of each zoning in Kepulauan Seribu Nasional Park affects the environmental conditions on land and at sea, including the condition of coral reefs. This happens because each zone has a different problem or pressure both from natural factors or human activities.
As the main area of protection, the core zone does not allow human activities in that area. However, the core zone still could be polluted by disturbed waters carried along with the currents to the core zone, especially with its geographical location which is close to the Jakarta mainland, known as its pollutants [5].

Anthropogenic factors such as nutrification of agricultural, domestic and industrial runoff can pollute the sea and also affect coral reef ecosystems. An action to reduce any disruption in coral reefs is very necessary to maintaining the ecosystem [6]. Conservation plan with strict supervision is highly needed. One of the efficient systems to monitor coral reefs is through mapping [7]. Thus, this study purpose was to analyze the distribution of coral reefs and be related to the physical characteristics of the waters by using Sentinel-2A satellite imagery.

2. Methodology
The study area of this research is in three selected islands in Kepulauan Seribu National Park based on its zone (figure 1). Kepulauan Seribu National Park is located in the North of Kepulauan Seribu, Jakarta Province. Belanda Island with a coordinate 5°34'43"S 106°36'33.8"E represents the core zone & protection. The protection zone as a buffer zone in this study belongs to the core conservation zone. Bira Besar Island represents tourism zone on the coordinate 5°36'41"S 106°34'23"E. Pramuka Island which is in a geographical position 5°44'46"S 106°36'55"E is an island that represents the settlement zone in Kepulauan Seribu National Park.

Satellite imagery that was used in this research is Sentinel-2A on September 17, 2018 by combining the True Color Composite band which was band 2 (Blue), band 3 (green) and band 4 (red) with the cloud cover percentages 12 %. Sentinel-2A images can be downloaded for free through the United States Geological Survey website (http://www.usgs.gov). European Space Agency (ESA) as its provider has been corrected both geometric & radiometric calibration so that image data processing becomes more efficient.

Lyzenga algorithm was used in Image processing as the remote sensing for coral reefs is difficult to apply because of the water attenuation, which makes the imagery experiencing the spreading and absorption of reflectant that leads to misinterpretation [8]. The method to minimize Water Attenuation is called Water Column Correction that is based on 2 assumptions which are: water depth as a major factor and water clarity [9]. The result of this method is image accuracy below the water surface or Depth Invariant Index with unsupervised analysis [10].

In addition, data processing of supporting variables of the research is carried out, which are sea surface temperature anomalies, depths, and ocean brightness as the coral reefs environmental conditions to live so that the distribution of coral reefs is obtained and ends with field data validation. Field data survey & validation is done by purposive sampling within 30 points in 3 islands consisting of other classification than coral reefs such as sand, seagrass and mixed substrate using underwater camera for documentation. All data that has been processed will be analyzed using confusion matrix accuracy test to determine the accuracy of image processing in analyzing coral reefs and other classifications.

3. Results and discussion

3.1. Coral reefs distribution
The result of the coral reefs distribution has to be tested first by linear regression on each band to get a linear equation of deep invariant index. The regression on each band is parallel as it's shown in figure 2 and could be applied in coral reefs mapping using Sentinel-2A.

The classification used in this research consists of coral reefs, sand, seagrass and mixed substrate as illustrated on the figure 3 below. The classification used in this research consists of coral reefs, sand, seagrass and mixed substrate as illustrated on the map below. Each resolution shown in the map equals 100 square meters based on Sentinel-2A spatial resolution. Benthic habitats on Belanda Island and
Bira Besar Island are dominated by mixed substrates, which include sand, algae, pebble, and seagrass. The percentage in Belanda Island even shows highest value which was 51%.

In shallow waters on Pramuka Island, seagrass beds dominate with an average percentage of 46% compared to all benthic habitats. The most extensive coral reef distribution based on the percentage is located in Belanda Island which belongs to the core zone and protection, about 6% or an area of 0.89 hectares (table 1). Most of the distribution of coral reefs on Belanda Island is in the Northeast. The distribution tends to cluster in one region only. This shows that Belanda Island is one of the protection zones still protected by its management.

Bira Besar Island, which is included in the tourism zone, has the smallest percentage of coral reefs compared to other research areas, about 2% or around 1.81 hectares. The distribution is mostly in the Southwest, which is used for snorkeling. In addition, the spread of coral reefs on Bira Besar Island is in the North, Northeast, and Southeast. Coral reefs on Bira Besar Island are spread evenly along the reef flat, although the majority of the distribution of benthic habitats on this island is mixed substrate, followed by the distribution of seagrass beds which are almost as much spread evenly on the reef flat of Bira Besar Island.

The settlement zone in this study is Pramuka Island, which has a 5% distribution of coral reefs from all benthic habitats on the island or 6.07 hectares. The island’s coral reef distribution is evenly distributed, almost along the tip of the reef flat. The majority of the distribution is in the Southwest and Northeast of Pramuka Island, and both are often used for snorkeling and diving tours. The distribution of the most benthic habitat on Pramuka Island is seagrass beds, which is about 46%, followed by the percentage of mixed substrate, which is 30%. The pattern of spatial distribution of coral reefs in each zoning has similarities, which tend to surround the main island and include the type of fringing reefs or coral reefs, the majority of which are on the coast of the island.

Figure 1. Sampling points in each study island.
Figure 2. Linear regression test

Figure 3. Benthic habitat mapping
Table 1. Benthic area and percentage in Kepulauan Seribu National Park.

| No | Class            | Belanda Island |  | Bira Besar Island |  | Pramuka Island |  |
|----|------------------|---------------|---|------------------|---|----------------|---|
|    |                  | Area (ha)     | % | Area (ha)        | % | Area (ha)      | % |
| 1  | Coral reefs      | 0.89          | 6 | 1.81             | 2 | 6.07           | 5 |
| 2  | Mixed substrate | 7.4           | 51| 40.24            | 47| 35.01          | 30|
| 3  | Seagrass         | 3.53          | 25| 36.25            | 42| 53.49          | 46|
| 4  | Sand             | 2.58          | 18| 7.21             | 8 | 21.24          | 18|
|    | Total            | 14.4          | 100| 85.51            | 100| 115.81         | 100|

Sources: Data processing and analysis

3.2. Bathymetry in coral reefs distribution

The difference in the distribution of coral reefs in each zonation based on the variable bathymetry was done by combining national bathymetry data by the Geospatial Information Agency (BIG) with data from the processing of benthic habitat in the Kepulauan Seribu National Park (figure 4). Coral reefs in all zones are in reef flat with a depth less than 20 meters, which is in accordance with the requirements of coral reefs living conditions [11].

The distribution of coral reefs on Pramuka Island in the settlement zone of KSNP is in the shallow waters compared to other islands in zones, namely at a depth less than 15 meters. The depth of the waters in Pramuka Island which is not too deep is relatively safe so that it is used by the tourism sector to do snorkeling and diving for beginners or to practice around the habitat of the benthic coral reefs. There are snorkeling and diving spots on Pramuka Island which are northeast and southwest that are utilized because of the spread of coral reefs. The distribution of coral reefs at the diving spot is at a depth of 5-10 meters. Although included in residential zoning, Pramuka Island is also used for tourism activities as a place to live because of the many homestays or shelters on the island.

As an island that belongs to the core zone and protection, benthic habitat on Belanda Island is at a depth that varies between 5 meters to a depth less than 20 meters, and the coral reefs are distributed at a depth over 10 meters, deeper than the island of the study area in other zones. This island is an unpopulated island and includes a protected area of coral reefs. This is indicated by the spread of coral reefs on this island at a relatively high depth, limited for protection and research but cannot be used for diving or snorkeling tours.

Distribution on Bira Besar Island in the tourism utilization zone is at a depth less than 20 meters. Compared to the other two research areas, the distribution of coral reefs on this island is deeper than that of Pramuka Island but is generally shallower than the distribution on Belanda Island. The waters of Bira Besar Island in accordance with the zoning area, often used for tourism activities, one of which is snorkeling on the benthic habitat of coral reefs. One of the spots for snorkeling activities that are visited by many tourists is on the Southwest of Bira Besar Island, with a depth of distribution of coral reefs between 5–10 meters.

3.3. Temperature in coral reefs distribution

Sea surface temperature is a factor that affects the health of coral reefs, so it also affects the distribution of coral reefs (figure 5). The effect of temperature that is not in accordance with the health conditions of coral reefs does not have direct or instant effects but is experienced within a certain time period. According to Coral Reef Watch in 2011, to monitor the appropriate sea surface temperature, anomalous sea surface temperature was used. This variable analyzes changes in temperature during conditions that are different from normal conditions. The anomaly of sea surface temperature is done by comparing the average temperature of the average for the month analyzed for several years.
The processing results of anomalies of sea surface temperature show that the entire zone in the Kepulauan Seribu National Park experienced anomalies within very small sea surface temperatures which are below 0.8 °C. Anomalies in sea surface temperatures with such ranges of values do not endanger the coral reefs and relatively safe.

3.4. Ocean brightness in coral reefs distribution

The processing results of ocean brightness data is done directly at 4 sample points on each research island using a sea brightness measuring device, namely secchi disk. In this study, secchi disks used a 4 meter long rope and were marked on a rope every 10 centimeters. This shows the level of accuracy of the measuring instrument is 10 cm or 0.1 m. Measurement of brightness greater than 4 meters is written with “>” in the table 2.

Belanda Island as its function as core zone and protection, has the highest brightness level compared to other zones. The brightness level of the waters on Belanda Island exceeds the range of measuring instruments used in this study. This has a corresponding percentage of coral reef distribution which is greater than the percentage on zoning of tourism use and settlements. The waters of Bira Besar Island which are included in the tourism utilization zone has a greater brightness than the waters on Pramuka Island. Measurements obtained in the waters of Bira Besar Island show that even though it is used as a tourist area, the condition of the waters on this island is still well maintained because of its high brightness.

The condition of the brightness of Pramuka Island based on the lowest data collection was obtained, even though the waters on Pramuka Island were not categorized as murky waters. This shows that the results are relatively not too low (figure 6). One day before the capture of brightness data at Pramuka Island was carried out, there were floods in a number of areas in East Jakarta and North Jakarta. This happened because of the runoff impact of the flood and affect the waters around Pramuka Island, originating from the mainland of Jakarta to the Jakarta Bay and polluting the waters.

![Graph of Benthic Habitat Distribution at Kepulauan Seribu National Park](image-url)
Pramuka Island is the geographically closest island near the mainland of Jakarta because it is the southernmost compared to other research islands. The distance from Pramuka Island to the mainland of Jakarta is around 42.8 kilometers. While the distance from the mainland of Jakarta to Bira Besar Island is around 58.4 kilometers and is 57.8 kilometers from Belanda Island.

This runoff does not make the sea polluted directly, but this can certainly damage the environment. This condition, if it continues to occur, can disrupt the survival of benthic habitats including coral reefs. This happens because polluted waters inhibit the process of light penetration into the bottom of the water so photosynthesis in the organisms that make up the reef will be disrupted.

3.5. Confusion matrix accuracy test
Accuracy testing in this study was conducted to determine the ability of processing Sentinel-2A imagery in recording objects and analyzing the distribution of benthic habitats, including coral reefs. The results of processing the distribution of this benthic habitat are accurate with the results of an accuracy test of 30 sample points in the entire study area.

![Sea surface temperature anomaly in coral reefs distribution.](image)

**Figure 5.** Sea surface temperature anomaly in coral reefs distribution.

| No. | Belanda Island Brightness (m) | Bira Besar Island Brightness (m) | Pramuka Island Brightness (m) |
|-----|-------------------------------|----------------------------------|-------------------------------|
| 1   | 3.8                           | 3.7                              | 2.9                           |
| 2   | > 4                           | 3.8                              | 3                             |
| 3   | > 4                           | 3.7                              | 2.9                           |
| 4   | > 4                           | 3.5                              | 2.8                           |

**Table 2.** Ocean brightness

*Sources: Data processing and analysis*
Figure 6. Impact of the wet (run off) season in around the waters of Pramuka Island.

The results of the Sentinel-2A image accuracy test using the overall Lyzenga water column correction amounted to 73.33 %. This value shows the value of the suitability of the classification results with conditions in the field. The accuracy of mapping values that can be recommended for inventory activities for monitoring resources ranges from 60–80 % [12]. This indicates that Sentinel-2A image processing in KSNP can be used for data inventory. Information on the distribution of benthic habitat produced by Sentinel-2A imagery using the Lyzenga algorithm is quite representative of the conditions in the field.

4. Conclusion
Coral reef distribution Pramuka Island and Bira Besar Island in Kepulauan Seribu National Park are spread evenly along the reef flat while on Belanda Island is concentrated only in the Northeast. Based on the percentage, the core and protection zone has the most distribution compared to the percentage in other zones, which is equal to 6 %. This shows that the core zone & protection according to its function is still well maintained.

Regarding to coral reefs environmental living conditions, in Kepulauan Seribu National Park has suitable variable in depth & has no anomaly in sea surface temperature even though in the Settlement Zone represented by Pramuka Island the speed of the ocean currents calm but the condition of water brightness is less high due to the impact of Jakarta's flood runoff.

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