INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE

ISSN: 2067-533X Volume 12, Issue 3, July-September 2021: 1129-1138 www.ijcs.ro

# CONSERVATION ZONATION DESIGN OF CORAL REEF AREAS IN DEPAPRE BAY, PAPUA PROVINCE, INDONESIA

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***Abstract***

*Marine Protected Areas are one of the efforts to maintain biodiversity resources that are managed by a zoning system. Zoning needs to be done by integrating ecosystem and community approaches. This research was conducted in Depapre Bay, Jayapura Regency, Papua Province, which has high biodiversity and diverse cultural communities. Zoning carried out in this study integrates Tiaitiki area into the zoning system based on the Minister of Fisheries Regulation Number KP. 10 of 2010. Based on the analysis of around 9 541.137 ha of the Depapre Bay area, the Core Zone found was around 371.11 ha (3.89%), Sustainable Fisheries Zone around 7,597.48 ha (79.63%), Utilization Zone around 1,028.56 ha (10.78%), and Other Zones around 543.98 ha (5.70%) consisting of Rehabilitation Zone around 62.41 ha (0.65%) and the Flow Zone and Port Zone around 481.57 ha (5.05%). The allocation of around 50% of the Tiaitiki area to become a Core Zone is quite proportional and as a "no-take zone" area, the application of the "open-closed" system is no longer allowed.*

*Keywords: Marine Protected Area; Coral Reef Ecosystem; Zonation; Tiaitiki; Depapre Bay*

## Introduction

The development that is increasingly massive without proper planning will cause a decrease in the quality of resources, including biodiversity. Biodiversity degradation has become a global as well as a local issue, including in Papua, especially in the Depapre Bay region. Conservation is one of the efforts to maintain biodiversity resources that have been globally recognized as actions in the sustainable use of resources [1-3], and Marine Protected Areas are the basis of conservation tools [4-6].

The success of a waters conservation area is determined by appropriate management. One of the determining factors for the success of a conservation area is a zonation policy [1, 7, 8]. The determination of zoning does not only focus on bio-ecological aspects but also needs to consider the socio-cultural aspects (systems) of existing communities. The zonation policy is not only limited to involving stakeholders as actors, but it is also necessary to accommodate the rights of communities, especially indigenous communities as owners of customary rights [9]. As we know that the ownership of the sea area in the sea Papua is part of customary rights [10,

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11]. This is what distinguishes it from other regions in Indonesia so that designing zonation becomes interesting, complicated and prudent.

The Papua region (Papua Province, Indonesia) is known as mega biodiversity, and it also has a diverse character and culture of the community including the views and practices of resource management, especially in the management of coastal and marine resources. One of them is the local wisdom of Tiaitiki which has been applied for generations by Tabla tribe community in Depapre Bay [9-11]. Tiaitiki is a temporal "open-closed" management model for certain areas, which is based on the ownership of clans in Tefra tribe [9-10], which is similar to the Sasi system in Maluku, Sasisen system in Padaido Islands [12], but there is a principal difference where Tiaitiki area is not only the authority of the adat community, but also part of the customary rights of certain clan communities.

Therefore, the main challenge in applying Tiaitiki zonation is how to determine the best and acceptable zonation for all parties to achieve management goals that are not in conflict with the Indonesian Minister of Maritime Affairs and Fisheries Regulation No. 30 of 2010 concerning Conservation Area Management and Zoning Plans. The goal of conservation of coral reef areas in Depapre Bay, in principle, is to conserve ecosystems, productivity, target species and maintain customary rights (Fig. 1).

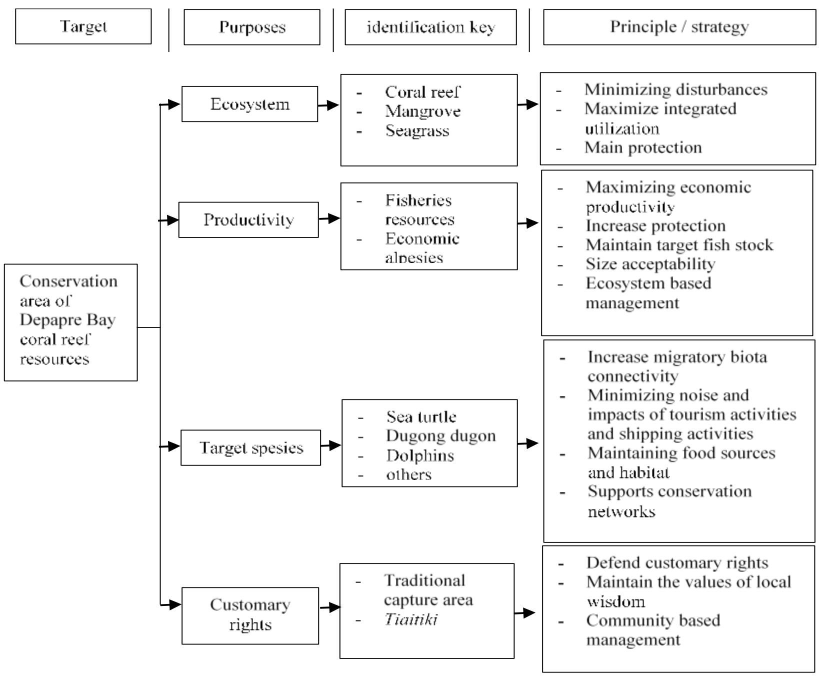


**Fig. 1.** Structure of the objectives, strategies, and principles of zonation of coral reef areas in Depapre Bay

This paper presents the design of development and management of coral reef areas in terms of the determination of zonation that integrates the Tiaitiki (area) system into the zoning system based on the Minister of Maritime Affairs and Fisheries Regulation No. 30 of 2010 concerning Conservation Area Management and Zoning Plans, which emphasizes the involvement of indigenous peoples' rights, characteristics and principles of a management approach.

## Materials and Method

### *Materials*

The equipment and materials used in this study are as presented in table 1.

**Table 1.** Research tools and materials.

| Equipment & Materials | Usefulness / description |
|---|---|
| Temp meter | For temperature measurement |
| Seichi disc (m) | For brightness measurement |
| Handrefractometer | For salinity measurement |
| Roll meter | For distance measurement in determining Transect |
| Underwater cammera | For taking pictures and videos underwater |
| Scuba Diving set | For diving |
| Global Positioning System | For determining coordinates |
| Speed boat 50 PK | For research and transportation |
| Waterproof letter set | |
| Satellite Imagery SPOT 6/7 | For writing in water |
| Computer with ArgMap 10.4.1; ENVI 4.7 and Marxan Zone software | For analysis of the distribution and condition of resource ecosystems |

### *Methods*

The collection of biophysical data such as the distribution of resource ecosystems, especially coral reefs, mangroves and seagrasses, was carried out by processing SPOT 6/7 Satellite Image data obtained from LAPAN PUSTEKDATA, while the lifeform and abundance of reef fish were carried out through surveys. Determination of coral observation stations and reef fish was done by Rapid Reef Assessment (Table 2). Estimation of coral cover used the Point Intercept Transect method with a transect length of 10 meters along the coastline and with repetition 3 times at a depth of about 3 meters and 10 meters. Retrieval of species and abundance of reef fish used the visual census method with reference to [13, 14], and water parameters were collected based on standard provisions for coral reef surveys, namely salinity, surface temperature, current speed, brightness and suspended solids carried out in situ.

**Table 2.** Location of coral observation stations, reef fish and measurement of water parameters.

| Station | Coordinate point | |
|---|---|---|
| | East longitude | South Latitude |
| Kwahkebo Island | 140°21'10.63" | 2°26'34.83" |
| Harlem Bay | 140°21'45.73" | 2°25'0.16" |
| Sarebo Bay | 140°21'36.15" | 2°24'55.50" |
| Tanah Merah Bay | 140°21'15.01" | 2°24'30.01" |
| Amayepa | 140°22'5.83" | 2°24'0.90" |
| Tablasufa Bay | 140°21'47.00" | 2°25'23.00" |
| Amay Bay | 140°21'30.01" | 2°26'30.00" |

*Satellite Image Analysis*

SPOT 6/7 Satellite Image with characteristics of 1.5 m panchromatic, 6 m multispectral, and 1.5 m color combination [15], which is used as Ortho level which has been geometrically and radiometrically corrected by PUSTEKDATA LAPAN, the recording year 2017 and corrected with check results in the field. SPOT 6/7 Satellite Image has been widely used in identifying corals and shallow waters [16, 17]. The image analysis used the Supervised method of the Maximum Likehood [18].

*Analysis of the Condition of Coral and Coral Fish*

Estimating the percentage of coral cover used the Point Intercept Transect Method [19] because it is fast, efficient and provides a good estimate for benthic community cover [14]. In the meantime, the depiction of categories used a category of level 2 adopted from [13, 20]. The percentage of coral cover is obtained from equation [20], as follows (1):

*Percent cover = 100 x Number of points where the category is recorded/*
*/Total number of points on the transect*

The cover value of growth forms and the percentage criteria obtained by the above equation were then categorized with reference to the Minister of Environment Decree No. 4 of 2001 concerning the Standard Criteria for Damage to the Coral, namely closure of 0-24.5% (damaged), 25-49.9% (moderate), 50-74.9% (good), and 75-100% (very well).

Meanwhile, the coral fish that became the units of analysis was the fish that fell into the target fish and indicator fish groups. Both groups of fish were the main factors in the formation of community structure [21]. Target fish were generally fishery target fish catches as a commodity (economic value), while indicator fish were the fish which were usually indicators to determine the health condition of coral fish because they were directly dependent on corals as an energy source [22]. The fish abundance is calculated by the equation (2):

Abundance = Number of Observed Individuals (fish) / area of observation area ($m^2$) (2)

*Analysis of Waters Parameters*

The data from measurements in the field were analyzed qualitatively to explain the parameter values related to the suitability that supports coral growth. The value of suitability for coral growth [14]

*Marxan Analysis*

The use of Marxan is more objective than the qualitative method and its use is widely recognized in developing conservation areas specifically in the conservation of coral reefs [22-25]. The Marxan software based on ecosystem models is a modification of Spexan (Spatially Explicit Annealing) which is popular with conservation planning tools [26]. The Marxan analysis uses a simulated anealing algorithm [27, 28] which aims to find the lowest cost of a conservation space which is a simple combination of selected costs and penalty values that do not meet the target [26], with the equation (2) [23, 29]:

$$\sum_{PUs} Cost + BLM \sum_{PUs} Boundary + \sum_{ConValue} FPF \;\; xPenalty + CostThresholdPenalty\,(t), \quad (3)$$

where:

(a) *Planning Unit Cost* is the combined value of the socioeconomic value in each planning unit in the chosen solution;

(b) *Total Boundary Lenght* is a value set by the user and is related to the level of connectivity of each planning unit. The higher the Boundary Length value, the more compact the solution area;

(c) *Species Penalty* is the value given if the biodiversity protection target is not achieved. Meanwhile, Species Penalty Factor (SPF) is a user-managed value which is related to several important biodiversity target goals. The higher the SPF value is given to a feature, the more Marxan will prioritize the target feature.

(d) *Cost Threshold Penalty* (CTP) is a solution penalty that results in cost even though all features are achieved.

The features of conservation and costs as the parameters of zonation determination consist of coral reefs, mangrove seagrasses, coral cover conditions, an abundance of reef fish (targets and indicators), species diversity, locations of important biota encounters (protected), Tiaitiki area, areas affected by sedimentation, ship channel, port area, cultivation area, traditional fishing area and tourist area (Table 3).

**Table 3.** Consevation featrure and cost feature

| Feature | Weight (qualitative) | Data Source |
|---|---|---|
| Coral Reef Ecosystem | High | Primary Data |
| Cover condition> 50% | High | Primary data |
| Abundance of reef fish (targets & indicators) | | |
| Diversity of reef fish | High | Primary data |
| Seagrass ecosystem | Medium | Paulangan et.al., 2019 |
| Mangrove ecosystem | Medium | Paulangan et.al., 2019 |
| Locations of meeting points of important & protected species | High | Primary data, Report of DKP Jayapura regency (2015) |
| Tiaitiki protected area | High | Data Primer & LMMA (2007) |
| Areas affected by sedimentation | High | Primary data |
| Ship course | High | Dishub Jayapura Regency (2016) |
| Port | High | Dishub Jayapura Regency (2016) |
| Cultivation | Medium | Primary data |
| Traditional Catch Area | Medium | Primary Data & LMMA (2007) |
| Marine tourism | Medium | Primary data |

## Results and discussion

Coral reef and seagrass ecosystems can be found along the coast of Depapre Bay, while mangrove ecosystems are found in groups in several locations such as in Tablasufa Village, Waiya Village, Depapre Bay waters. The large and wide vegetation is in the south, namely in the Yokari District. The area of coral reef is around 335.75ha with a type of fringing reef [9,30]. Based on the percentage of coral cover, it can be categorized as moderate to good (44.67-70.67%). The highest percentage of coral cover was found at Tanjung Sarebo station at a depth of 10-13m, while the lowest at Kwahkebo Island station at a depth of 3-5m. The forms of growth are dominated by massive coral, coral branching and coral foliose. Acropora branching and tabulate acropora can be found at the stations of Tanjung Sarebo, Tanjung Tanah Merah and Amayepa.

The total abundance of reef fish both target fish and indicator fish was 3,666 individuals, which consisted of 130 species from 26 families [31].The target fish encountered were among others the families of Acanthuridae, Labridae (*Wrasse*), Caesionidae, Lutjanidae (*Snapper*), Lethrinidae, Blennidae, Zaclidae, Mullidae (*Goatfishes*), Neptiridae, Haemullidae, and Scaridae. The dominant type found was the family of Acanthuridae, such as *Acanthurus albipectoralis, A. grammoptilus, A. lineatus, A. mata, A. nigricans, a. striatus,* and *Zebrasoma scopas*.  Indicator fish mostly found were the family of Pomacentridae (*Acanthochromis polyacantus, Chromis caudalis, Dascyllus trimaculatus,* and *Stegastes aureus*). Meanwhile, target fish are generally from the family of Acanthuridae family (*Acanthurus grammoptilus, Ctenochaetus striatus,* and *Zebrasoma scopas*), the family of Caesionidae (*Pterocaesio tile*), the family of Lutjanidae (*Lutjanus semicinctus,* and *Macolor macularis*), the family of Labridae (*Anampses meleagrides, Cheilinus fasciatus, Hologymnosus annulatus, Labroides pectoralis, Stethojulis strilineata*, and *Thalassoma lunare*).

The coral cover and the abundance of coral fish in the Depapre Bay region are affected by the relatively good condition of the aquatic environment in supporting coral growth (Table 4), where the ranges of dissolved oxygen (5.24-5.25mgL$^{-1}$), current speed (0.20-0.28mS$^{-1}$), pH (8.0-7.3), salinity (31.20-32.35), temperature (29-31°C) and brightness 100%.

**Table 4.** Coral conditions and coral abundance

| Station | % Life form | Category | Abundance (fish m$^{-2}$) | | Number | |
|---|---|---|---|---|---|---|
| | | | Indicator Fish | Target Fish | Type | Family |
| Kwahkebo Island | 46.33 | fair | 1.81 | 1.49 | 45 | 11 |
| Harlem Cape | 63.67 | good | 2.81 | 1.69 | 28 | 15 |
| Tanah Merah Cape | 68.00 | good | 3.55 | 2.73 | 38 | 14 |
| Amayepa | 57.33 | good | 2.80 | 0.93 | 37 | 12 |
| Tablasufa Cape | 46.67 | fair | 1.17 | 0.27 | 39 | 10 |
| Amay Cape | 64.33 | good | 1.11 | 0.69 | 49 | 8 |

In accordance with the directions in the KP Minister Regulation No. 30 of 2010 concerning Conservation Area Management and Zoning Plans, and RI Law No. 31 of 2004 concerning Fisheries junto RI Law No. 45 of 2009, RI Law No. 27 of 2007 concerning Management of Coastal Areas and Small Islands junto RI Law No. 1 of 2014 concerning amendments to the Management Act for Coastal Areas and Small Islands, protected areas are allocated at 20-30% (Fig. 2). Based on the zoning results, the extent of each zone is obtained as shown in table 5.

*Core Zone*

The Tiaitiki area included in the Core Zone is practically an "open-closed" system and it is no longer valid because it has been allocated as a "no-take zone" area. Apart from the Core Zone, the "open-closed" system is still permitted. Based on the analysis it was found that the

Tiaitiki area chosen as the Core zone were all in a traditional capture area as well as an indicator of the customary land rights of Tabla tribes in Tablanusu Village and Waiya Village (Fig. 3).

Amayepa was chosen as the core zone because it is a turtle nesting area which is located directly facing the Pacific Ocean. Amayepa has sandy beaches which are spawning habitats of several protected sea turtles, such as hawksbill turtles (Eretmochelys imbricata), green turtles (Chelonia mydas) and leatherback turtles (Dermochelys coriacea) [30], which are protected reptiles. Sandy beaches are very suitable for spawning grounds of various types of sea turtles [32]. For local communities around the Depapre Bay area, sea turtles are one of the target biota for consumption and the need for traditional rituals [9].

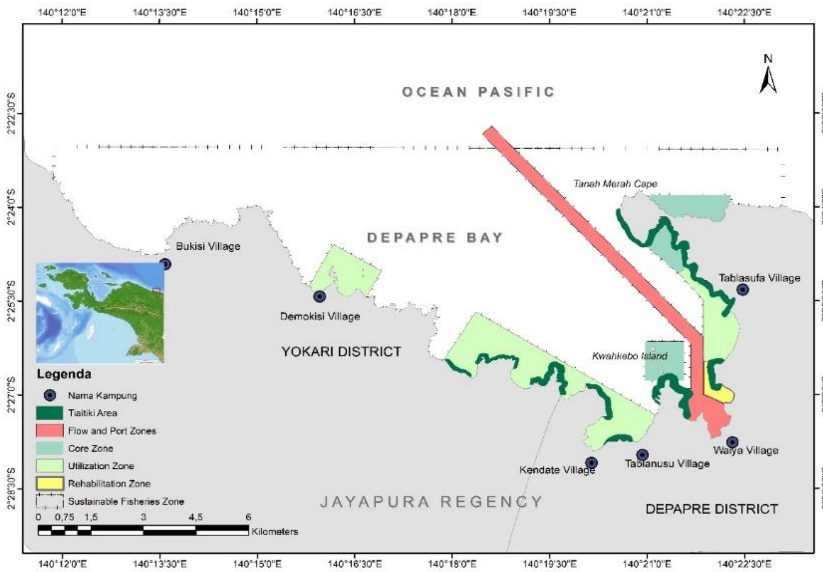


**Fig. 2.** Zoning results on the conservation of coral reef areas in the Depapre Bay

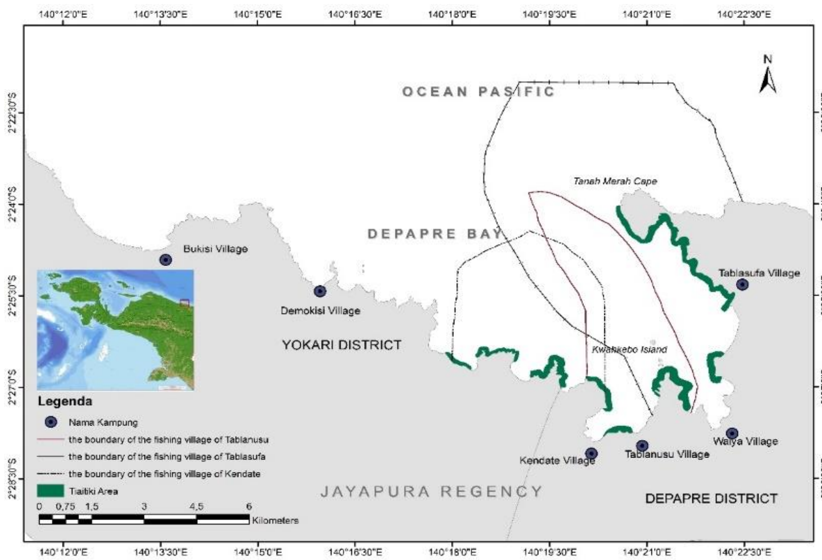


**Fig. 3.** Map of Tiaitiki and traditional capture areas in Depapre Bay

Amayepa is relatively far from residential areas so it is suitable for the core zone. The core zone in Amayepa is around 114.68ha. The average percentage of coral cover in Amayepa is around 57.33% which is dominated by Acropora Branching, Acropora Tabulate, Coral Branching and Massive. The number of species of reef fish found was around 37 species from 12 families. Biodiversity in Amayepa can be categorized as high [31]. The abundance of reef fish is quite high, namely for indicator fish is 1.81m$^{-2}$ and target fish around 1.49m$^{-2}$.

**Table 5.** Result of zoning

| Zonation | Description | Area (Ha) & Percentage | Explanation |
|---|---|---|---|
| Core Zone | Located in Amayepa and Kwahkebo Island, Tanah Merah Cape | 371.11 & 3.89% | It is a Tiaitiki area and or the customary rights of the clans of Tabla tribe in Tablasufa Village, Wauya Village and Tablanusu Village |
| Sustainable Fisheries Zone | Located in eastern Amayepa, Tanah Merah Cape, Kampung Tua Tablanusu, Kampung Bukisi beach and Yokari District beach | 7597.48; 79.63% | Includes Tiaitiki area and or customary rights of all clans in the villages of Tablanusu, Tablasufa, Waiya and Kendate |
| Utilization Zone | Located along Sarebo beach, Harlem beach, Tablasufa village, Tablanusu village, Kendate village and Demoikisi village. | 349.60; 10.78% | ncludes Tiaitiki area and or customary rights of all clans in the villages of Tablanusu, Tablasufa, and Waiya Kendate or Demoikisi |
| Other Zones (Rehabilitation & Flow) | Located in Waiya Village to Amay cape, the port construction area between Waiya Village and Tablanusu Village | 543.98 5.70% | Includes the Tiaitiki area and or the customary land rights of Tabla tribe from the villages of Waiya and Tablanusu |

The core zone in Tanah Merah Cape is around 129.27ha. Tanah Merah Cape has high diversity and abundance of reef fish. The diversity of reef fish biodiversity is categorized high [31]. The number of species of reef fish found was around 32 species at a depth of 3-5m and about 37 species at a depth of 10-13m. The abundance of coral fish was around 3.55m$^{-2}$ for indicator fish and 2.73m$^{-2}$ for target fish. Live coral cover is relatively high, which is around 64.67% at 3-5m depth and 68.00% at 10-13m depth dominated by Acropora Branching, Massive and Acropora Tabulate and Coral Branching. The condition of the waters in Tanah Merah Cape which is still original and has not been much disturbed by humans so it is expected to maintain the viability of these reef fish species to support effective fisheries management and ensure the ongoing process of bio-ecology naturally.

Kwahkeboh Island with a core zone area of around 127.17ha which is located inside the bay and relatively close to the port area, but it has a high resource of reef fish and other economic biotas, which is found around 45 species of reef fish at a depth of 3-5m and 23 species at a depth of 10-13m. The abundance of reef fish is quite high, around 1.81m$^{-2}$ for indicator fish and around 1.49m$^{-2}$ for target fish. During the dive carried out on Kwahkebo Island, there were economic biota namely lobster in large quantities, so it was thought to be a spawning area. In addition to ecological consideration, socially Kwahkeboh Island is an area that is regarded sacred by local communities so it does not become a catching area. The average percentage of coral cover on Kwahkebo Island is around 46.33% which is dominated by Coral Branching, Acropora Encrusting and Coral Massive.

*Utilization zone*

The utilization zone covering an area of 1,028.56ha or 10.78% is in 3 (three) locations, namely around the waters of Tablasufa Village area of 221.52ha, in the waters of Demoikisi Village covering an area of 173.08ha, and in the waters of Tablanusu and Kendate villages covering 633.96ha. The waters of Tablasufa Village and Kendate Village have long been used as one of the tourist areas, but the favorite tourist locations are in Tablanusu Village and Harlem and Amay Beaches in Tablasufa Village. In addition, another use, namely cultivation, has begun to develop in Tablanusu and Kendate Villages. Utilization activities in this zone should be aligned with conservation goals so that their utilization is sustainable, such as ecotourism activities.

*Sustainable Fisheries Zone*

The sustainable fishing zone is a zone outside of the three zones, namely the core zone, the utilization zone and the rehabilitation/flow zone. The Sustainable Fisheries Zone is around 7 597.48 ha or 79.63% of the Depapre Bay area, which is directed towards the high seas. This boundary to the high seas is only a temporary conjecture to facilitate analysis, because the actual boundary for traditional fishing grounds has not been determined by the government. The Sustainable Fisheries Zone is intended for the interests of capture fisheries, especially the communities around the area. This is intended because most of the people in Depapre Bay are very dependent on their livelihoods as a fishing community for generations.

*Other Zones*

Other zones consist of rehabilitation zones and flow zones. Other Zones consist of Rehabilitation Zones covering 62.41ha and Ship and Port Flow Zones covering 481.57ha. Specifically for the Flow Zone and Ports, they have been determined as in the Map of the Work Environment Area and the Port Environment Area Boundary compiled in the Jayapura District Transportation Department Report 2016. The other zones are located around Waiya Village, where besides there are passenger port development, there are also Fisheries Ports and People's Ports.

## Conclusion

The size of each zone has been quite rational in supporting sustainable fisheries and marine tourism in the coral reef area in the Depapre Bay, especially for the Core Zone which is 3.89% or 2% greater than that required in the Indonesian Minister of Maritime Affairs and Fisheries Regulation Number 30 of 2010 concerning Management and Zoning Plans for Marine Protected Areas, which are administratively distributed in Tabla tribe of Kampung Tablasufa, Tablanusu and Waiya. Zone selection is in accordance with the conditions and characters of the resources in each zone. The Tiaitiki area which is included in the Core Zone is practically no longer an "open-closed" system, because it has been allocated as a no-take zone. In addition to the Core Zone area, the application of the "open-closed" system is still permitted, particularly in the Sustainable Fisheries Zone, the Use Zone and Other Zones.

## Acknowledgments

The author would like to thank various parties who have supported this research, including the Director of the Papua Regional Waters Police, the Ministry of Research, Technology and Higher Education (Kemenristek DIKTI), Rector of Cenderawasih University, Dean of the Faculty of Mathematics and Natural Sciences, Conservancy Strategy Fund and FPIK IPB University and LAPAN PUSTEKDATA.

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*Received: July 24, 2020*
*Accepted: August 20, 2021*