Mangrove ecosystem for sustainable tourism in Dampier Strait Marine Protected Area Raja Ampat

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Abstract. Mangrove forests are considered very productive ecosystems in tropical coastal areas. They consist of valuable resources which provide services in terms of physical, biological and socio-economic functions. Human intervention and development have impacted the coastal ecosystems. The research was carried out to assess the biodiversity of mangrove ecosystem for sustainable tourism in Dampier strait, Raja Ampat. The data collected in Manswar islands, Gam islands, and the southern part of Waigeo island, and Batanta islands. Mangrove sampling was carried out at 7 (seven) stations which were selected randomly. The baseline data were used to develop the model of integrated and sustainable mangrove forest management in marine protected area Raja Ampat. The maximum number of visitors to each mangrove destination in Dampier Strait MPA ranged from 376 persons per year for Pandawa Resort to 39,486 person per year for the Nature Reserve Waringkabom. Two management areas were designed for mangrove ecotourism, namely Batanta management area and Gam island, Manswar islands, and South of Waigeo management area. These areas could be assigned as mangrove ecotourism based on resort management, based on property right of local community management and local customary management, and based on partnership and collaboration management.

Keywords: Dampier strait, mangrove biodiversity, marine protected area, Raja Ampat

1. Introduction

Mangrove ecosystem is one of the main characteristic of the marine protected area of the Dampier strait. Its present provides environmental services in terms of physical, ecological and socio-economic functions beneficial to human’s life. Such environmental services are potential for ecotourism, a type of non-extractive use of coastal ecosystem. The mangrove ecosystem in Dampier Strait has been
threatened by land conversion of the mangrove areas into settlement and others. The planning and management of the mangrove ecosystem in this area need accurate data and information for making scientific justification, especially the condition of mangrove ecosystem.

Assessment of the potency and benefits from management of mangrove ecosystem is needed as foundation for developing mangrove-based ecotourism. The ecotourism approach prioritizes the natural condition of mangrove ecosystem. Therefore, the development of ecotourism in Dampier strait requires scientific justification that policies on mangrove ecotourism management in Dampier strait can be established. This study was aimed to find out the dominant vegetation structure and mangrove species, identify potency of mangrove ecotourism, and develop recommendation and protocol guidance for development of mangrove-based ecotourism management in the study area.

2. Materials and method

2.1. The data of mangrove
Field survey was conducted to identify the characteristics, potency and benefits of the mangrove ecosystems in the study area, including the biophysical data of mangrove ecotourism areas. The data was assessed to estimate the carrying capacity of the environment if utilised as tourism destination. Data collection for mangrove was carried out using random sampling method with purposive sampling (Prihadi et al 2017). The research was conducted in Dampier strait marine protected area, where data collected in Manswar islands, Gam islands, and the southern part of Waigeo island, and Batanta islands. Mangrove sampling was carried out at 7 (seven) stations which were selected randomly in Yenbeser (Station 1), Cape of Beser-Kapisawar (Station II), Cape of Kabui (Station III), Pandawa Resort-Waisai (Station IV), and Hatchery of Groupers-Dockside for Tourism (Station V), The Nature Reserve of Waringkabom (Station VI) and Yensawai (Station VII) (table 1). Detailed observation was carried out at in transects of 20×20 m in each station (Bengen 2002) and (Setyobudiandi et al 2009).

2.2. Estimation of carrying capacity
Yulianda (2007) and Yulianda et al (2010) proposed a concept of carrying capacity for marine ecotourism could be used to ensure optimal use of productive resources for sustainable marine tourism. The analysis of carrying capacity of a defined area can be approached by calculating physical carrying capacity (DDK). DDK is the maximum number of visitors that could be accommodated in the area for a particular time period without incurring destructive nature and human life. The formula is:

\[
DDK = K \times \frac{Lp}{Lt} \times \frac{Wt}{Wp}
\]

where:
- **DDK** = carrying capacity of area
- **K** = ecological potential of visitors to unit area
- **Lp** = width or length of areas that can be used
- **Lt** = unit area for certain categories
- **Wt** = time allocated for tourism activities in one day
- **Wp** = time spent by visitors for a particular activity

The ecological potential visitors (K) determined by the conditions of the resources and the activities performed by the tourists (table 2). Ecological carrying capacity should be determined because coastal and marine ecotourism resources are easily destroyed and space to tourists is very limited. The ecological potential of visitors is determined by the condition of mangrove resources and the types of marine ecotourism activities that could be developed. The area of Lp/Lt means that Lt: certain areas can be used by tourists such as beaches, mangrove tracking, and fields sightseeing and Lp: the total area of mangrove areas. The area that tourists can use must pay attention to nature’s ability to accept
Table 1. The positions and locations of research that implemented by the condition of mangrove ecosystem in Dampier Strait marine protected area Raja Ampat.

| Station | Positions | Names of research station |
|---------|-----------|---------------------------|
| 1       | S : 000 29 17.5 - E:1300 40 12.6 | Yenbeser |
| 2       | S : 000 51 77.0 - E:1300 57 06.9 | Cape of Beser-Kapisawar |
| 3       | S :000 42 67.2 - E:1300 56 31.1 | Cape of Kabui |
| 4       | S : 000 24 43.5 - E:130049 14.9 | Pandawa Resort |
| 5       | S : 000 49 85.0 - E:1300 43 03.5 | The Nature Reserve of Waringkabom |
| 6       | S : 000 48 02.6 - E:1300 40 55.3 | Yensawai Village |
| 7       | S : 000 26 05.3 - E:1300 48 26.6 | Hatchery of Groupers-Dockside for Tourism |

Visitor activity so that authenticity is maintained. The formula of Wp/Wt is the time of visitor activity (Wp) is calculated based on the length of time spent by visitors to travel. Visitor time was calculated by the time allocated by the area (Wt) which is the length of time the area is opened in one day for tourism activities.

The assessment of ecological carrying capacity in Raja Ampat marine protected area that used in this research developed from formulation: Cifuentes (1992) and refined by several researchers the other Amador et al (1996), Ceballos-lascurain (1996), Cifuentes et al (1999), Segrado et al (2008), and Zacharias et al (2011)). DDK (carrying capacity) to achieve real carrying capacity modified and corrected by an adjustment factor. The formulation is:

\[ DDK_{Real} = DDK \times (FA_1 \times FA_2 \times \ldots FA_n) \]  

(2)

\[ DDK_{Real} = \text{Real carrying capacity} \]

\[ DDK = \text{Carrying capacity} \]

\[ FA_1\ldots FKn = \text{Adjustment factor} \]

Adjustment factor was calculated following equation:

\[ FA_x = \frac{MP_x}{MT_x} \]  

(3)

\[ Fax = \text{adjustment factor variable x} \]

\[ MP_x = \text{magnitude of the restricting factor of variable x} \]

\[ MT_x = \text{magnitude of the total of variable x} \]

Zacharias (2011) stated that several environmental factor could be used as restricting factors, i.e. rainfall, wind velocity, the intensity of sunlight, and temporary closure (no diving if weather is bad condition).

Table 2. The ecological potential visitors (K) and area unit of tourism activity (Lt).

| Types of activities | K (person) | Unit of area (Lt) | Remarks |
|--------------------|------------|-------------------|---------|
| Diving             | 2          | 2,000 m²          | 2 persons for an area of 200×10 m |
| Snorkeling         | 1          | 500 m²            | 1 person for an area of 100×5 m |
| Seagrass           | 1          | 250 m²            | 1 person for an area of 50×5 m |
| Mangrove           | 1          | 50 m              | based on length of track, every 1 person in throughout a track of 50 m length |

Sources: Yulianda (2007), Yulianda et al (2010)
2.3. Data analysis
The data was analyzed by descriptive statistic method and can used to solve a problem by describing the state of the subject and object of research based on the conditions in the field research stations. The results obtained will be presented in the biophysical table of mangroves and the calculation of the optimum number of visitors in the mangrove ecotourism areas (Yulianda 2007, Yulianda et al 2010).

3. Results and discussion
3.1. Composition and structure of mangrove vegetation
Mangrove ecosystems in the Dampier Strait - MPA Raja Ampat were scattered in several small islands. The ecosystems provide physical barrier in protecting coastlines of the island (figure 1). The mangroves composed with 9 species of mangrove, i.e. Aegiceras corniculatum, Bruguiera gymnorrhiza, Ceriops tagal, Rhizophora apiculate, Rhizophora mucronate, Excoecaria agallocha, Sonneratia alba, Heritiera liitoralis and Xylocarpus granatum (table 3). These types of mangroves were distributed in 7 locations; 6 of the 9 species were found in Yenbeser and Waringkabon. These types of mangroves have different morphology and the nature of adaptation in different substrate and tidal habitats. Such biodiversity was reflected in different views that are potential objects of mangrove ecotourism.

![Figure 1. Mangrove ecosystem distribution in Dampier Strait Marine Protected Area, Raja Ampat.](image)

The physical configuration of mangrove ecosystems is more complex with several types of mangrove associated species. A total of 12 mangrove-associated species from 11 families were only found in two locations, i.e. the Nature Reserve of Waringkabon and Yensawai Village (table 4). The types of mangrove associations found were Acanthus ebracteatus, Calophyllum inophyllum, Hibiscus tiliaceus, Ipoamoea pes caprae, Morinda citrifolia, Pandanus tectorius, Pongamia pinnata, Scaevola taccada, Clorodendrum inerne, Stachytarpheta jamaicensis, Anurium portulacastrum, and Wedelia biflora. The substrare of habitat and water immersion have been influenced the formation of mangrove associations species. The substrate was rather dry and rarely submerged in sea water, and this association plant was not valuable for mangrove ecotourism. The presence of the association shows that the ecosystem area has experienced disruption due to the existence of several activities of local communities in utilizing mangrove ecosystems, including land conversion in forest areas into residential areas and other allotments so that changes in natural landscapes and mangrove ecological systems.
Table 3. True mangrove species at 7 (seven) research stations in Dampier Strait marine protected area, Raja Ampat.

| No. | Species         | Station I | Station II | Station III | Station IV | Station V | Station VI | Station VII |
|-----|-----------------|-----------|------------|-------------|------------|-----------|------------|-------------|
| 1   | MYRISINACEAE Aegiceras corniculatum | -         | -          | -           | +          | -         | -          |             |
| 2   | RHIZOPHORACEAE Bruguiera gymnorrhiza | +         | +          | +           | +          | +         | +          |             |
| 3   | Ceriops tagal | +         | +          | -           | +          | +         | +          |             |
| 4   | Rhizophora apiculata | +         | +          | +           | +          | +         | +          |             |
| 5   | Rhizophora mucronata | +         | +          | -           | +          | -         | -          |             |
| 6   | EUPHORBIACEAE Excoecaria agallocha | +         | -          | -           | -          | -         | -          |             |
| 7   | SONNERATIACEAE Sonneratia alba | +         | -          | -           | +          | -         | -          |             |
| 8   | STERCULIACEAE Heritiera littoralis | -         | -          | -           | -          | +         | -          |             |
| 9   | MELIACEAE Xylocarpus granatum | -         | -          | -           | +          | -         | -          |             |
|     | Total species   | 6         | 4          | 3           | 4          | 6         | 4          | 4           |

Notes: + = present, - = not present

3.2. The condition of water quality in mangrove ecosystem area
The condition of the mangrove ecosystem is strongly influenced by the health conditions of the mangrove plants. In general, mangrove plants have high adaptability, especially for changes in salinity. Nevertheless, mangrove plants are also susceptible to changes in temperature, pH, and changes in dissolved oxygen content in waters (Schaduw 2018). Measurement of water quality in this study was carried out at each of the 7 stations (table 5).

The water quality measurements in each research stations were within the standards set by Environmental Ministry Decree No. 51 in 2004 (table 5). The Indonesia standard temperatures for mangrove ecosystems to grow well are from 28°C to 32°C while the results of measurements in the studied area were from 27.96 to 31.10°C with an average of 28.84°C. Any difference in temperature within mangrove ecosystems is influenced by the canopy of the mangroves and relative mangrove coverage (Schaduw 2018). The standard temperatures, however, are higher than the temperature for growth of mangroves reported by Kolehmainen et al (1974), i.e. 20°C, while Aksornkoae (1993) stated that mangroves can grow well in tropical regions with temperatures above 20°C.
Table 4. Types of mangrove-associated species Dampier MPA - Raja Ampat.

| No. | Species                        | Station I | Station II | Station III | Station IV | Station V | Station VI | Station VII |
|-----|--------------------------------|-----------|------------|-------------|------------|-----------|------------|-------------|
| 1   | Acanthus ebracteatus           | -         | -          | -           | -          | +         | -          | -           |
| 2   | Calophyllum                   | -         | -          | -           | -          | +         | +          | -           |
| 3   | Hibiscus tiliaceus             | -         | -          | -           | -          | +         | +          | -           |
| 4   | Ipoamoea pes caprae            | -         | -          | -           | -          | +         | -          | -           |
| 5   | Morinda citrifolia             | -         | -          | -           | -          | +         | -          | -           |
| 6   | Pandanus tectorius             | -         | -          | -           | -          | -         | +          | -           |
| 7   | Pongamia pinnata               | -         | -          | -           | -          | +         | -          | -           |
| 8   | Scaevola taccada               | -         | -          | -           | -          | -         | +          | -           |
| 9   | Clorodendrum inerme            | -         | -          | -           | -          | +         | -          | -           |
| 10  | Stachytarpheta jamaicensis     | -         | -          | -           | -          | +         | -          | -           |
| 11  | Sesuvium portulacastrum        | -         | -          | -           | -          | +         | -          | -           |
| 12  | Wedelia biflora               | -         | -          | -           | -          | +         | -          | -           |

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The quality standard for the chemical parameters of the waters for mangrove ecosystems are listed in the Agreement of Ministry KP No.53 of 2014: natural salinity of 34‰, pH of 7.9-8.61 and dissolved oxygen > 5 mg/L. Field measurements in the studied are showed water salinity of 32.70 to 52.40‰ with an average value of 34.21‰. The current velocity range was 0.017-0.100 m/s with an average of 0.06 m/s. The pH range was 7.91-8.24 with an average of 8.06. The dissolved oxygen ranged from 3.86-9.28 mg/L with an average of 6.53 mg/L. The difference in pH values in waters is strongly influenced by the oceanographic and geomorphological characteristics of the area. In open waters, pH tends to be higher than in the closed waters or small islands. Waters around large islands with many rivers tend to have lower pH. Mangroves growth well with pH of 6.2-8.00.

3.3. The carrying capacity of mangrove ecotourism area

The maximum number of visitors to each mangrove destination in Dampier Strait MPA ranged from 376 persons per year for Pandawa Resort to 39.486 person per year for the Nature Reserve Waringkabom (table 6). These figures are the carrying capacity of the area after considering levels of susceptibility of the mangrove and space needed by a visitor. Adoption of such calculation is expected to minimize damage of the visited mangrove ecosystem. This carrying capacity can be used as a foundation to design the potential use of mangrove for ecotourism, regulation and controlling management. The carrying capacity can also be used to determine the amount of fund to be collected for the conservation area ensuring optimum utilization in a sustainable way.

3.4. Effective strategies in management of mangrove ecotourism

The development of the mangrove ecotourism management must be synergized and in harmony with the objectives of the conservation areas, such as: (1) maintaining ecological process which support the living systems, (2) protecting biodiversity, (3) securing sustainability and utilization of species and its ecosystem, and (4) promoting local community welfare. Considering factors that may affect visitor activities and susceptibility of certain local features, the area opened for tourism must be limited to certain level. Adjustments should consider: (1) the occurrence of easterly monsoon (June-August) and westerly monsoons (December-February), (2) the probability annual damage of ecosystem due to visitor activities, and (3) the probability of megafauna migration and endemic species (every year). Based on such consideration, the total area for ecotourism is 542.234 m² (table 7).

Table 5. The water quality around the mangrove ecosystem at 7 research stations in Dampier Strait MPA Raja Ampat.

| Parameters | Units | Station I | Station II | Station III | Station IV | Station V | Satsiun VI | Station VII |
|------------|-------|-----------|------------|-------------|------------|-----------|-------------|-------------|
| Physical:  |       |           |            |             |            |           |             |             |
| TDS        | g/L   | 30.1      | 30.4       | 30.4        | 30         | x         | 30.4        | 42.8        |
| TSS        | mg/L  | 0         | 0          | 0           | 0          | NM        | 0           | 0           |
| Brightness | cm    | 12        | 20         | 19          | 20         | NM        | 22          | 18          |
| Temperature| °C    | 27.96     | 28.03      | 28.21       | 30.40      | NM        | 28.08       | 31.10       |
| Salinity   | ‰     | 32.70     | 33.30      | 33.20       | 32.80      | NM        | 33.20       | 49.10       |
| Current    | m/s   | 0.05      | 0.04       | 0.08        | 0.07       | NM        | 0.02        | 0.07        |
| Chemical:  |       |           |            |             |            |           |             |             |
| pH         |       | 7.93      | 7.91       | 8.09        | 8.15       | NM        | 7.94        | 8.24        |
| Dissolved oxygen | mg/L | 6.73 | 6.33 | 6.64 | 9.28 | NM | 3.86 | 7.44 |
If the carrying capacity of mangrove ecotourism is 434 persons/day, then after considering the rotation of visitors in the day trip, the number of visitors to be allocated for mangrove ecotourism is 217 visitors/day. It means, the maximum total number of visitors every year for mangrove ecotourism is 40,125 persons (table 8).

| No | Object Destination of Mangrove Ecotourism (ODTE) | Area (m²) | Coefficient of Rotation | DDK (visitor/day/O DTE) | RCC mangrove ecotourism (visitors/day/m²) | Numbers of visitors (in day/trip) | Adjustment factor season | The numbers of visitors (per year) |
|----|-------------------------------------------------|-----------|-------------------------|-------------------------|------------------------------------------|---------------------------------|------------------------|--------------------------|
| 1  | Yenbeser                                        | 44,100    | 2                       | 71                      | 35                                       | 18                              | 180                    | 1,609                    |
| 2  | Beser Bay-Kapisawar                              | 151,300   | 2                       | 242                     | 119                                      | 61                              | 180                    | 5,521                    |
| 3  | Kabuy Bay                                       | 21,600    | 2                       | 35                      | 17                                       | 9                               | 180                    | 788                      |
| 4  | Pandawa Resort                                   | 10,300    | 2                       | 16                      | 8                                        | 4                               | 180                    | 376                      |
| 5  | The Nature Reserve - Waringkabom                 | 1,082,000 | 2                       | 1,731                   | 854                                      | 433                            | 180                    | 39,486                   |
| 6  | Yensawai Village                                 | 24,800    | 2                       | 40                      | 20                                       | 10                              | 180                    | 905                      |
| 7  | Hatchery of Groupers-Dockside for Tourism        | 18,100    | 2                       | 29                      | 14                                       | 7                               | 180                    | 661                      |
|    | Total                                           | 1,352,200 | 2,164                   | 1,067                   |                                          |                                 |                        | 49,346                   |

Table 7. The scenario of the area utilization for mangrove ecotourism in Dampier strait marine protected area, Raja Ampat.

| Ecosystem | Total area of the ecosystem (m²) | Total area for ecosystem preservation (m²) | Total area for megafauna migration and endemic species (m²) | Total area for ecotourism (m³)(m²) |
|-----------|----------------------------------|------------------------------------------|-------------------------------------------------------------|------------------------------------|
| Mangrove  | 1,352,200                        | 202,830                                  | 135,220                                                     | 542,232                            |

Number of visitors per year for a scenario of 25% potential ecotourism area opened is 10,031 person (table 9) while that for a scenario of 50% to potential ecotourism area opened to tourism 8,025 person (table 10).

The management of mangrove ecotourism carrying capacity (DDK) should be synergies with the management of the ecotourism object and destination (ODTE) in Dampier strait marine protected area. The concept of management based on accessibility and affordability that would be supported by the strategy of the effectiveness of mangrove ecotourism management. The monitoring and controlling the number of visitors could be conducted based on setting and designing supportability scenarios considering preservation of the ecosystem, the velocity of degradation of mangroves, and migration of megafauna and endemic species. There was shown in table 11.
Table 8. The results of the carrying capacity analysis of mangrove ecotourism as the preservation of area to sustainability ecosystem, megafauna and endemic species migration.

| Ecotourism Activity | Number of potential destination | Real carrying capacity (visitors/day) | Coefficient of rotation (day) | Number of visitors/trip/day | Number of visitors per year (person) |
|---------------------|---------------------------------|--------------------------------------|-------------------------------|-----------------------------|--------------------------------------|
| Mangrove Tour        | 7 locations                     | 434                                  | 2                             | 217                         | 40,125                               |

Table 9. The results of carrying capacity (DDK) analysis of the scenario 25 % area management.

| Ecotourism Activity | Area (m²) | Tourism management area in the scenario 25 % | Real carrying capacity (visitors/day) | Coefficient of rotation (day) | Number of visitors/year |
|---------------------|-----------|---------------------------------------------|--------------------------------------|-------------------------------|-------------------------|
| Mangrove tour        | 542,232   | 7 areas                                     | 135,558                             | 108                           | 10,031                  |

Table 10. The results of carrying capacity (DDK) analysis of the scenario 50 % area management.

| Ecotourism Activity | Area (m²) | The potential of tourism spot | Tourism management area in the scenario 50 % | Real carrying capacity (visitors/day) | Coefficient of rotation (day) | Number of visitors/year |
|---------------------|-----------|-------------------------------|---------------------------------------------|--------------------------------------|-------------------------------|-------------------------|
| Mangrove tour        | 542,232   | 7 areas                       | 271,116                                     | 217                                  | 2                             | 8,25                    |

Based on assessment of this research locations in Manswar islands, Gam islands, and the southern part of Waigeo island, and Batanta islands, so there were designed and recomended mangrove ecotourism consists of 2 (two) areas management. The first is management area of Batanta focused on 2 (two) locations: Yensawai Village and the Nature Reserve of Waringkabom. The second is management areas of Gam islands, Manswar islands and South Waigeo. These areas management concept supported by accessibility and affordability from the central of Dampier strait marine protected area (Waisai Town). There could be assigned to: (1) mangrove ecotourism based on resort management, (2) mangrove ecotourism based on property right of local community management and local customary management, and (3) Mangrove ecotourism based on partnership and collaboration management (local government, non-government organization and research institution).

Table 11. Justification recommendations based the purpose of mangrove ecotourism activities (ODTE) management, accessibility and affordability of areas.

| Management areas |  |
|------------------|------------------|
| Gam islands, Manswar islands and South of Waigeo | Batanta Island |
| The potential area for mangrove ecotourism | 1,106,800 | 245,400 |
| Area (recommendation) (m²) | 442,720 | 98,160 |
| Number of ODTE mangrove ecotourism | 2 | 5 |
| Real carrying capacity (day) | 354 | 79 |
| Number of visitors (visitors/day/trip) | 177 | 39 |
| Number of visitors (visitor/year) | 32,761 | 7,264 |
4. Conclusions

Mangrove destination in Dampier Strait MPA were designed and recomended consists of 2 (two) areas management i.e.: Area Management I: Batanta (Yensawai Village and the Nature Reserve of Waringkabom) and Area Management II (Gam islands, Manswar islands and South Waigeo). Areas management concept supported by accessibility and affordability from the central of Dampier strait marine protected area (Waisai Town). There could be assigned to: mangrove ecotourism based on resort management, mangrove ecotourism based on property right of local community management and local customary management, and mangrove ecotourism based on partnership and collaboration management (local government, non-government organization and research institution).

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