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The Strategy for the Effectiveness of Diving Ecotourism Management in the Conservation Area of the Dampier Strait Waters, Raja Ampat

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Study of ecological carrying capacity had been done to design the management strategy of the effective utilization of ecotourism diving spots in Raja Ampat. The research was conducted at the utilization zones of the Dampier Strait marine protected area, Raja Ampat between November 2016 and May 2017. The data of this research consist of primary data and secondary data. The secondary data collected and compiled from the scientific journal, report, and the other source which is related with the objectives of this research. Data collection of the coral reef ecosystems was collected at 10 diving spots by using LIT (Line Intercept Transect) and the data of coral fish was collected by using UVC (Underwater Visual Census). The secondary data was compiled from various sources. The result of the suitability matrix of marine ecotourism for diving category analysis found that these areas were under the category of very suitable area (S1) i.e Five Rock, Melissa Garden, Lolosi Reef and Cape Kri. The areas which are under category of suitable (S2) were found in the Friwen Bonda, the Urun Island, the Wai Island, the Dayan Island, and the Cape of Raspapir and the Yensawai Coast. The carrying capacity of divers for diving ecotourism were found to be 1 834 divers/day. The analyzed number of divers for the utilization of the carrying capacity area has shown 183 divers/day, and 38 559 divers/year. The allocation for the utilization of the diving ecotourism area is proposed 50:50 for foreign tourists and domestic tourists. The total local revenue from the entrance fee to enter the Dampier Strait waters conservation area per day from foreign tourists is Rp917 000 000 whereas from the domestic tourists Rp458 500 000. The strategy of the effectiveness of dive spots utilizes marine ecotourism can be done by arranged distribution of divers according to the certification records.

Keywords: Ecological carrying capacity; dive spots ecotourism destination; marine protected area; Raja Ampat.

1. INTRODUCTION

The assessment of the ecological carrying capacity of diving ecotourism destinations in the Raja Ampat marine protected area has been conducted based on an ecological studies of the coral reef ecosystems. Ecotourism is tourism directed toward to an exotic natural area, which is relatively untouched, with the purpose of admiring, researching and observing the beautiful natural scenery, the wildlife and the culture found in the area [1]. Yulianda [2] stated that marine ecotourism utilizes the characteristics of coastal and marine resources, and human resources which will be integrated as inseparable components for the tourism utilization. The concept of developing ecotourism area has to be in line with the mission of managing conservation areas, such as: (1) maintaining the sustainability of ecological processes continuing to support the living systems, (2) protecting biodiversity, (3) ensuring the preservation and the utilization of species and their ecosystems, and (4) contributing to the public welfare. The research objectives consists of: (1) collect the basic data and the scientific information about the status of coral reef ecosystems at diving spots, (2) analyze the suitability and the carrying capacity of the ecotourism, (3) analyze the data of the wind variability, the rainfall and the hydro-oceanographic conditions. (4) determine the strategy for the effectiveness of diving ecotourism utilization based on ecological carrying capacity of the waters conservation area in the Dampier Strait, Raja Ampat.

2. METHODS AND MATERIALS

2.1 Data Collection

The data of this research assessment of ecological carrying capacity consist of primary data and secondary data. The secondary data collected and compiled from the scientific journal, the research reports, and the other source which is related with the objectives of this research. Data collection of coral reef ecosystem was conducted at 10 research stations in the Dampier Strait, i.e Five Rocks (Gam Island) (Station 1), Friwen Bonda (Station 2), Melissa Garden (Station 3), Lalosi Reef (Station 4), Kri Cape (Station 5), Urun Island (Station 6), Wai Island (Station 7), Dayan Island (Station 8), Raspapir Cape (Station 9) and the Coast of Yensawai (Station 10). The equipment used for this research included a complete scuba diving equipment, underwater paper, motor boat, tape measure (100 m), underwater writing tools, underwater camera and Global Positioning System (GPS).

Data collection on hard coral and coral reef ecosystem components used the Line Intercept Transect (LIT) method or the line transect method [3] with some modifications carried out into two depths, which are 3 m and 6 m for each research station. Observation of the benthic component of the coral reefs was conducted by recording all the components that were passed by a tape measure which pulled along 10 m. The measuring tape (roll meter) was placed 70 m long parallel to the shoreline at the depth of 3 m and 5 m and the LIT data collection was taken at the meters line of 0 – 10 m, 30 – 40 m and 60 – 70 m.

The morphometric code for the shape of the benthic components used is based on publication from the Australian Institute of Marine Science (AIMS) [4]. Identification of hard coral species was conducted onsite in the field, based on an identification book from Veron [5,6] and Suharsono [7,8]. The collection of the data of coral fishes was collected using the Underwater Visual Census (UVC) method [9]. The census was carried out on a 70 m long transect line with an observation width of 5 m, therefore the total area of the observation area of each station was 350 m2. Observations were made at depths ranging from 5 – 7 m.

The observations of the coral fish were divided into 3 categories i.e major fish, indicator fish and target fish. The collection of the wind data includes zonal and meridional winds with an altitude of 10 m for 10 years (01 January 2006-31 December 2016) which obtained from interim reanalysis of the European Center for Medium-Range Weather Forecasts (ECMWF) with a resolution of 0.125o x 0.125o. The measurement of the rainfall were obtained based on the Tropical Rainfall Measuring Mission (TRMM _3B42RT V7) satellite data level 3 which can be accessed on the website page ftp://disc2.nascom .nasa.gov/data/TRMM/Gridded/3B42RT/.

The downloaded data was the daily rainfall data (mm/day) with a spatial resolution of 0.25° x 0.25°. The rainfall data from the TRMM satellite has been corrected with the measurement data from BMKG and the data is capable of representing the rainfall condition of the Indonesian territory [10]. The software used in this research is Ferret PMEL version 6.85 and Matlab version 2016a.

2.2 Data Analysis

2.2.1 Analysis of ecological conditions

The data analysis was conducted by calculating the diversity of species (biodiversity index) and evenness of the species (similarity index) using the Biodiversity Pro.4 application. Percentage of coral covers (%), species diversity (H) and evenness of species (j) of coral and reef fish based on the formulation of Odum [11].

2.2.2 Analysis of wind variability data, rainfall and hydro-oceanographic conditions

The software's used to process the wind, the wave and the rainfall data analysis were using Ferret PMEL version of 6.85 and Matlab version of 2016a.

2.2.3 Diving tourism suitability analysis

The analysis of the suitability of marine ecotourism was conducted through 4 (four) stages of analysis:

a) Constructing the habitat maps of coral reef benthic

The drafting of benthic coral reef habitat maps was carried out using a Geographic Information System (GIS) [12]. The depth invariant index algorithm equation is listed below:

Y = Ln B1 – (ki/kj) Ln B2

Description:

Y = waters floor index; B = selected band; ki/kj = attenuation coefficient

b) The drafting of diving ecotourism suitability matrix

The suitability of ecotourism activities refers to the following table [13-16].

2.2.4 The Analysis of the carrying capacity of diving ecotourism

The Calculation of the Carrying Capacity of the Area (DDK) uses the formula based on Yulianda [13], Yulianda et al. [14] and Yulianda, et al. [15,16]:

$$\mathrm{DDK} = \mathrm{K}\,\mathrm{x}\,\frac{\mathrm{Lp}}{\mathrm{Lt}}\,\mathrm{X}\,\frac{\mathrm{Wt}}{\mathrm{Wp}}$$

Table 1. The matrix of suitability of land for marine ecotourism activities in the category of diving tourism

Parameter	Quality	Category S1	Score	Category S2	Score	Category S3	Score	Category N	Score
Waters clarity (%)	5	>80	3	50 – 80	2	20 - < 50	1	< 20	0
Coral community covers (%)	5	>75	3	> 50-75	2	25-50	1	<25	0
Type of life form	3	> 12	3	< 7 – 12	2	4 - 7	1	< 4	0
Type of coral fish	3	>100	3	50 – 100	2	20 - < 50	1	< 20	0
Waters currents (cm/dt)	1	0-15	3	>15 – 30	2	>30 - 50	1	> 50	0
Coral Reef depth (m)	1	6 – 15	3	> 15 - 20	2	> 20 – 30	1	>30	0
				3 - <6				< 3	

Table notes:
Maximum Value = 54
S1 = very suitable, with value 75 – 100 %; S3 = Conditionally suitable, with value 25 - < 50 %
S2 = Suitable, with value 50 - < 75 %; N = Not suitable, with value < 25 %

Description:

DDK = Carrying Capacity of the Area
K = The visitor ecological potency per unit area.
Lp = The square area or the length of area which can be utilized
Lt = Area unit for specific category
Wt = The time provided by the area for tourism activities in a day.
Wp = The time spent by visitors on each specific activity

According on the government provisions of PP No.18/1994 concerning the Development of Natural Tourism in the Utilization Zone of National Parks and natural tourism parks, the area which is permitted to be utilized is 10% of the area of the utilization zone, therefore the carrying capacity of the area will be limited according to the "Utilization Carrying Capacity" (DDP) with the formula:

DDP = 0.1 x DDK

Yulianda [13], Yulianda et al. [14] and Yulianda, et al. [15,16] argued that the diving category has an ecological potential of visitors which is 2 of people total in a unit area of 2000 m2 (every 2 people in 200 x 10 m2).

The calculation of the physical-ecological carrying capacity of marine protected areas was developed from the formulation of Cifuentes [17,18] and has been refined by several researchers, such as Amador et al. [19]; Ceballos-Lascurain [20]; Cifuentes et al. [21]; Segrado et al. (2008) and Zacharias et al. [22]. The obtained Carrying Capacity Utilization then corrected by a limiting factor, therefore the used formula is:

DDK Real = DDK x (FK1 x FK2 x….FKn)

Description:

DDK Real = The Real Carrying Capacity of the Area
DDK = Carrying Capacity of the Area
FK1….FKn = Correction Factor

The correction factor is calculated based on the equation:

$$FKx = \frac{MPx}{MTx}$$

Description:

FKx = variable correction factor x
MPx = variable limiting magnitude x
MTx = variable total magnitude x
Zacharias [22] states that several environmental factors used as limiting factors are: rainfall, wind speed, sunlight, and temporary closure (temporary diving ban).

3. RESULTS AND DISCUSSION

3.1 The Condition of Existing Diving Ecotourism Resources

1. Coral Reefs

As many as 141 species of hard corals which belong to 16 families were identified during the research. The number of hard coral species in the waters of the Dampier Strait is larger compared to the number of species found in the waters of Nusalaut Island, the waters of Marabatuan and Matasirih of South Kalimantan and in the waters of Bunaken Island [23,24] (Kambey 2014). On the other hand, the number of the species identified are smaller compared to the number of hard coral species found in Tobelo waters (North Halmahera), Tanjung Merah waters and Lembata waters, NTT [23,25,26].

The waters of Dampier strait has a high variety of hard coral species or 30.92% of the number of species found in Raja Ampat Islands waters which has 456 species [6]. This is due to the clear water conditions and also supported by many environmental factors such as salinity ranging 27.00 - 32.67‰, temperature ranging 25.00 - 31.20°C and pH ranging 7.34 - 7.39.

Sukarno et al. [27] argues that the growth of hard corals generally ranges from 25–40‰ salinity, while the ideal temperature for hard coral growth ranges from 25-29 °C in shallow tropical waters [28]. The mean value of hard coral cover at both depths ranged from 62.89% (in the 6 m depth) to 65.69% (in the 3 m depth) which was counted in a good category. If the average cover percentage values are averaged again, the hard coral cover condition value is 64.24%, which means they are still in the good category. This value is larger compared to the waters of Tegal and Sidodadi islands which has 49.87% [29] and in the waters of Tagulandang Island, North Sulawesi 46.21% [30].

2. Coral Fish

According to the results of the research, the number of coral fish species found was 233 species (37 308 individuals) with a composition of 27 species (557 individuals) indicator fish, 96 species (13,578 individuals) target fish, and 115 species (23,173 individuals) major fish. The results of a coral fish study conducted by Allen and Erdman [31] in Nikijuluw [32] in several locations in Indonesia, revealed that Raja Ampat has the highest number of types of coral fish compared to several other locations, such as Maumere Bay, Triton Bay, Halmahera, Bali and Nusa Penida, Cenderawasih Bay, Berau, Komodo Island, Weh Island and Bintan Island. It is estimated there are 1,465 coral fish species in Raja Ampat and 1,347 species of 373 families have been identified.

3.2 The Variability of Wind, Rainfall and Hydro Oceanographic Conditions

The dominant wind direction around Raja Ampat for 10 years (2006-2016) is towards the Northeast and it is strongly influenced by monsoon wind patterns. The dominant wind period (seasonal) has its climax period occurring every 180 days, while the annual period has its climax period every 400 days and between years has a peak of 2.8 years. The seasonal cycle of the wind speed patterns experiences 2 climax periods in 1 year, specifically during the east and west monsoons. The strongest winds are found in the east monsoon and occur in August (v=4.90 m/s). Winds weaken during the transitional season and occur in May with an average speed (v=2.42 m/s) and in November (v=2.30 m/s). The annual period occurs every August which is marked by the maximum wind which blows every year.

The waves occur for 19-116 days/year and a Beaufort scale of 6 occurs for 1-17 days/year. The results of wave forecasting using the SMB (Svedrup-Munk-Bretschneider) method show significant sea wave heights which vary between 0.001-2.19 m/s. The highest sea wave fluctuations are found in the east and west monsoons, while the lowest waves occur in each transitional season.

Annual rainfall ranges from 1432-3819 mm/year. The dominance of rainfall is very light (0-5 mm/day) with the occurancy of 160-293 days, and light (5-20 mm/day) with the occurancy of 56-149 days. Moderate rainfall occurs 13-42 days a year and heavy rainfall occurs 1-6 times per year. Heavy rainfall happens during the east monsoon which occurs every June, July, and August. Mangubhai et al. [33] stated that oceanographic conditions are characterized by strong and complex currents, which are influenced by the position of Raja Ampat in the path transport of mass water from the Pacific Ocean to the Indian Ocean. The Raja Ampat Islands are located at the eastern gate of the Indonesian Sea Current Traffic (Arlindo) which flows from the Pacific Ocean to the Indian Ocean [34-36].

The average of Sea Surface Temperature (SPL) in Raja Ampat is 29.0^{o}C with temperature range between 19.3-36.0^{o}C. The lowest temperature observed occurs around August–September. The result of the research show that Raja Ampat waters have an average spread temperature of 28.1^{o}C with a range between 22.3-30.9^{o}C. The variability of minor temperature changes with a range of 29.4 - 30.0^{o}C occurred almost all year round. Raja Ampat waters are important areas where the identified phenomenon of cold water upwelling takes place, including at the Dampier Strait. The upwelling phenomenon allows the supply of nutrients into the waters. The nutrient is needed for the growth and development of the marine biota [37-39].

3.3 The Suitability of Ecotourism

The suitability of diving ecotourism is divided into 2 (two) criteria, i.e very suitable (S1) and suitable (S2). The area utilized for the diving ecotourism is 4 631 896.14 m2. The total area of the S1 category is 1 654 846.12 m2 meanwhile the S2 category is 2 997 050.02 m2. Wai Island has the highest area of S1 and S2 category for diving spots compared to other locations. Melissa Garden has the lowest S1 category area compared to other areas, while Five Rocks has the lowest S2 category area.

Table 3 represents the Tourism Suitability Index (IKW) at the locations of the research. Based on the ecological research of the coral reef ecosystem at each diving spot, the IKW calculation result shows that the areas included in the S1 category are Five Rock, Melissa Garden, Lalosi Reef and Cape Kri. Meanwhile, the areas included in the S2 category are Friwen Bonda, Urun Island, Wai Island, Dayan Island, Cape Raspapir and Yensawai Coast. The area with the highest IKW score for the S1 category is Five Rocks, followed by Melissa Garden. Lolosi Reef and Kri Cape have the same IKW score and those areas are the lowest compared to the others. The areas with the highest IKW scores for S2 category were Melissa Garden and

Raspapir Cape. The lowest IKW score for S2 category is Yensawai Coast.

3.4 Carrying Capacity of Diving Ecotourism

The result of the research showed that the carrying capacity of the diving ecotourism area of the Diving Spots of Dampier Strait Raja Ampat was 1,834 divers/day. The carrying capacity of the utilization of the area is 178 divers/day, and 38 559 divers/year. Based on these results, if we proposed to allocate the utilization of the diving ecotourism areas (50:50), the total local revenue from the entrance fee to enter the Dampier Strait waters conservation area per day from international tourists is IDR 917 000 000 and from the domestic tourists is IDR 458 500 000. If the management of the diving ecotourism area is regulated based on regulations with a quota system (20:20), the diving ecotourism revenue for the resort and live a board category per day will be counted Rp. 1,834,000,000, the amount for homestays to Rp 641 900 000 and the amount for Raja Ampat association of diving ecotourism Rp495 180 000.

3.5 The Strategy for Effective Management of Diving Ecotourism

Based on adjustment to the results of analysis, the calculation of the carrying capacity of the diving ecotourism area (which is related to the ecological conditions, the wind variability, the rainfall and hydro-oceanographic conditions) will need an effective management system for its utilization. The management of the tourist visit can be done by arranging the distribution of the permitted divers to the S1 and S2 areas. The category for S1 area is addressed for the divers who have the diving certificates in the open water and also the divers who have the advanced diving certification in the open water. Meanwhile, the S2 category is addressed to the divers which have certificates for beginner diving (discover scuba diving) and scuba diver. The controlling of the tourist visits can be done by arranging the distribution of the divers to the locations based on the carrying capacity at each diving spot.

Table 2. Area of diving spots Category of S1 and S2

Diving Locations	Area (m2)	
	S1	S2
Five Rock (Station 1)	49 790.08	6 336.03
Friwen *Bonda* (Station 2)	40 055.95	60 059.51
Melissa Garden (Station 3)	767.22	75 253.94
Lalosi *Reef* (Station 4)	9 222.33	17 337.63
Kri *Cape* (Station 5)	55 912.21	45 442.25
Urun Island (Station 6)	6 956.23	5 807.80
Wai Island (Station 7)	1 022 651.38	2 238 546.84
Dayan Island (Station 8)	105 224.39	131 484.67
Raspapir Cape (Station (9)	52 521.40	76 669.44
Yensawai Coast (Station 10)	280 302.87	250 447.01

Description: S1 (highly suitable); S2 (suitable)

Table 3. Tourism Suitability Index (research locations of 10 diving spots) in the Marine Protected Area of the Dampier Strait

Diving Locations	Tourism Suitability Index (IKW)	
	S1	S2
Five Rock (Station 1)	90.74	---
Friwen *Bonda* (Station 2)	---	74.07
Melissa Garden (Station 3)	83.33	---
Lalosi *Reef* (Station 4)	79.63	---
Cape Kri (Station 5)	79.63	---
Urun Island (Station 6)		68.52
Wai Island (Station 7)		72.22
Dayan Island (Station 8)		68.52
Raspapir Cape (Station (9)		74.07
Yensawai Coast (Station 10)		62.96

Table description: Maximum Value = 54 S1 = very suitable, with value 75 – 100 %; S2 = Suitable, with value 50 - < 75 %; S3 = Suitable Conditionally, with value 25 - < 50 %; N = Not suitable, with value < 25 %

Arrangements for the tourist visits can be also adjusted periodically based on weather conditions and hydro-oceanography. In the east season (in August) and in the west season (in December) there were an extreme weather condition which caused the direction for restriction for the tourists to perform tourism activities in the Dampier Strait waters. In the month of August and December, there is an upwelling phenomenon when the supply of nutrients is available in the waters which will be very much needed for the growth and the development of the marine biotas.

Based on this data, it is necessary to make the arrangements of temporary closed of the area in order to provide an opportunity for the marine biota to cultivate their maximum growth and development as well as to restore their existing natural ecosystem conditions. The effective utilization of diving ecotourism based on its carrying capacity can be performed by building an integrated information system using websites technology and mobile data which can be directly accessed by tourists, tour service managers, tour operators and other stakeholders.

4. CONCLUSION

Based on the results, the research can be concluded as follows:

1. The ecological condition of the existing coral reef ecosystem is in a good category (64.24%) with 141 species of hard coral (16 families). The number of coral fish species found in the area was 233 species (37,308 individuals) with a composition of 27 species (557 individuals) indicator fish, 96 species (13,578 individuals) target fish, and 115 species (23,173 individuals) major fish.
2. The total area that can be utilized for the diving ecotourism is 4,631,896.14, consisting of the S1 category (1,654,846.12 m2) and the S2 category (2,997,050.02 m2). The highest S1 tourism suitability index (IKW) area is Five Rock (90.74) and the lowest is Lalosi Reef and Cape Kri (79.63). The highest index of IKW in the S2 category are Melissa Garden and Raspapir Cape (74.07) and the lowest is Yensawai Coast (62.96).
3. The carrying capacity of the diving spot in the diving ecotourism area in the Dampier Strait Raja Ampat is 1834 divers/day, the Carrying Capacity for the Utilization of the Area is 178 divers/day, and 38559 divers/per year.
4. The strategy for the effectiveness of diving ecotourism utilization can be done by arranging the distribution of divers based on their diving certification, and managing the distribution of divers to the locations periodically based on weather conditions and hydro-oceanography.

5. RECOMMENDATIONS

Based on the results of the research conducted, some improvement recommendations will be given as follows:

It is necessary to have a temporary closure of the area periodically, especially in August and December, because of the upwelling phenomenon which is very important for the sustainability of the ecological condition. This phenomenon can provide an opportunity for marine biotas (coral reef ecosystems) to carry out their maximum growth and development as well as restoring their natural ecosystem conditions.

1. An effective system of utilization management of the diving ecotourism area based on carrying capacity can be performed by building an integrated information system using website technology and mobile data which can be accessed by tourists, tour service managers, tour operators, and other stakeholders. The technology will provide real data and information about the carrying capacity of diving ecotourism, the characteristics and the advantages of each diving spot, the wind variability, the rainfall and the hydro-oceanographic conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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