

A biodiversity assessment of hard corals in dive spots within Dampier Straits Marine Protected Area in Raja Ampat, West Papua, Indonesia

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Abstract. Yuanike, Yulianda F, Bengen DG, Dahuri R, Souhoka J. 2019. A biodiversity assessment of hard corals in dive spots within Dampier Straits Marine Protected Area in Raja Ampat, West Papua, Indonesia. *Biodiversitas* 20: 1198-1207. Hard coral dominates coral reef ecosystems and has important functions and interactions in communities of marine biota. The structure and diversity of hard coral communities is very important to quantify, especially for the management of coral reef ecosystems. The purpose of this research is to identify the diversity of hard coral types, and quantify the condition of hard coral and their distributions in 10 marine stations in Dampier Straits Marine Protected Areas, Raja Ampat. The research method used was line intercept transects measured at two depths, 3 m and 6 m. The results showed there were 141 hard coral species included in 16 families. The percentage live cover of hard coral was in good conditions with an overall average coverage value of 64,24%. The biodiversity index (H) ranged from 0,84-1,23, the evenness index of species ranged from 0,73-0,94, and the species dominance index ranged from 0,05-0,25, indicating a high biodiversity and a lack of dominance by a single species. Although cover was slightly higher at 3m depth, diversity was slightly higher at 6m depth. In general, the 10 research stations in Dampier Straits has hard coral in good condition and the diversity of hard coral species is very productive and has stable growth compared with other sites in Indonesia.

Keywords: Dampier Straits, hard coral, marine protected area, Raja Ampat, structure of community

INTRODUCTION

The waters of Indonesia are home to a very rich biodiversity of corals and reef fish with high economic value. The waters of West Papua's Bird's Head Seascape have the highest biodiversity compared with all other areas in Indonesia. Dampier Straits Marine Protected Area has an area of 366.000 hectares and is located among the Raja Ampat marine protected areas. Marine protected areas in Raja Ampat were promoted by the legacy of Raja Ampat Regency (Peraturan Bupati or government decree) No. 66 in 2007, the legacy in Raja Ampat Regency (Peraturan Daerah or local regulation) No. 27 in 2008 and the legacy of Raja Ampat Regency (Peraturan Bupati or government decree) No. 5 in 2009 (Boli et al. 2014; Mustaghfirin et al. 2012).

The water of Dampier Straits separates the islands of Batanta and Waigeo, and becomes one of the entrance gates of the masses of water in the Pacific Ocean that will flow into the Indian Ocean (Indonesian Throughflow). Dampier Straits water has strong currents and there are frequent occurrences of cold water upwelling phenomena. The resulting stirring of water masses brings together different temperatures, and brings rich nutrients to the surface that will be used by marine biotas, like coral, for

the processes of reef formation. The resulting areas of reef formation consist of specific types of habitat leading to many kinds of reefs seascapes like fringing reefs and patch reefs.

Raja Ampat is an archipelagic regency and consists of three coastal and marine resources ecosystems: coral reefs, sea grass and mangroves. These ecosystems reveal the richness of natural resources in Raja Ampat, being very diverse and having important impacts on the economy and on human lifestyles. Specifically, the coral reef ecosystems produced by the main formations of hard corals play an important role in the function of the marine ecosystem, including their ecological interactions.

The hard corals are included in the Class Anthozoa, order Scleractinia, and live sessile lifestyles, meaning they are attached to the substrate. The hard coral is usually found living in shallow water, in less than 40 m depth (Nybakken and Bertness 2004). Sumadhiharga et al. (2006) stated that hard coral ecosystems are associated with other marine biota including fishes. The hard coral in Indonesia consists of 590 species in 80 genera (Suharsono 2010). The waters of Indonesia has coverages of 69.42 % coral reef, including up to 850 species of coral, and corals have a high diversity of morphologies and functions (McWilliam et al. 2018). The research of coral reefs in Raja Ampat waters

shows high level of biodiversity, composed of up to 553 species, representing 75% coral species in the world (Veron et al. 2009; Wallace et al. 2011 in Mustaghfirin et al. 2012). Suharsono (2010) stated that hard coral growth in Indonesia peaks around Sulawesi, Moluccas, Halmahera, Bali, West Nusa Tenggara, East Nusa Tenggara, Raja Ampat islands, the coasts of Papua Barat, Aru and Kei islands. Consequently, Raja Ampat is the centerpoint of the highest diversity of hard corals in the world (Veron et al. 2009; Allen and Erdmann 2009; Huffard et al. 2009; Mangubhai et al. 2012 in Mustaghfirin et al. 2012). However, the growth of infrastructure development in the coastal area and lack of good management in marine resources leads to degradation of the marine environment in Dampier Straits, and this can impact the hard coral diversity and growth in the ecosystem (Larsen et al. 2011). Consequently, it is important to quantify and monitor the biodiversity of corals in the area.

The the aims of the study is to identify the diversity of hard coral types, and quantify the condition of hard coral and their distributions in 10 marine stations in Dampier Straits Marine Protected Areas, Raja Ampat.

MATERIALS AND METHODS

Study area

The research assessment of hard coral in waters of Dampier Strait, Raja Ampat District, West Papua Province, Indonesia was conducted in April and November 2016. The data were collected from 10 dive spots or research stations. These were Five Rocks (Gam islands) (Station 1), Friwen Monda (Station 2), Mellisa Garden (Station 3), Lalosi Reef

(Station 4), Cape Kri (Station 5), Urun island (Station 6), Wai island (Station 7), Dayan island (Station 8), Cape Raspapir (Station 9) and coast waters of Yensawai (Station 10). The position of the stations is shown in Table 1 and the map of the research stations in Figure 1.

Procedures

The equipment for the collection of the data were scuba diving gear, underwater paper, motor boat, roll meters (100m), underwater camera and Global Positioning System (GPS). The assessment of hard coral and the component of coral reef ecosystem was conducted using the Line Intercept Transect (LIT) method (English et al. 1997) and were done in 3m and 6m depth for every research station. The observation of the coral reefs bentic component had been done by noting all of the components that pass by the meter rollers that is drawn along 10 meters and repeated three times.

Table 1. The position and location of hard coral assessment research stations in waters of Raja Ampat, 2016.

No. station	Position	Location
1	S 00° 4510.7; E 130° 6973.3	Five Rocks
2	S 00° 4777.5; E 130° 6963.2	Friwen Bonda
3	S 00° 5896.7; E 130° 3159.3	Mellisa Garden
4	S 00° 5482.5; E 130° 4963.8	Lalosi Reef
5	S 00° 5575.4; E 130° 6893.5	Cape Kri
6	S 00° 4637.8; E 130° 4049.5	Urun Island
7	S 00° 4144.9; E 130° 4234.1	Wai Island
8	S 00° 4812.8; E 130° 3900.8	Dayan Island
9	S 00° 4800.3; E 130° 3854.2	Cape Raspapir
10	S 00° 4836.4; E 130° 4124.3	Coast waters of Yensawai

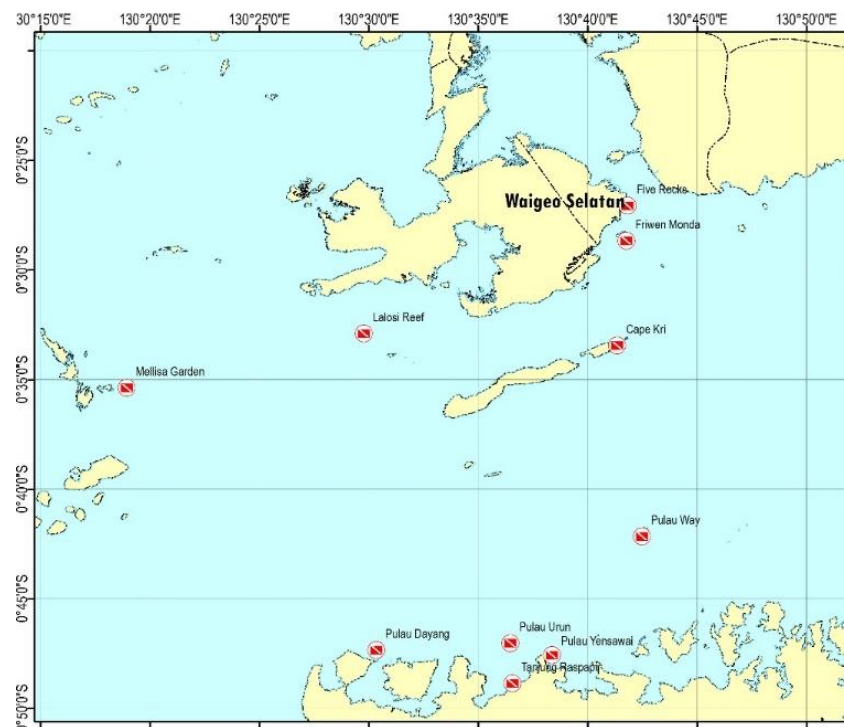


Figure 1. The map of research stations (rectangle in red circle) of hard coral assessment in Dampier Strait waters in Raja Ampat, West Papua, Indonesia, 2016

The diver put out 70m of the roll meter along the shoreline in 3m and 5m depth. The LIT data was collected in 0-10m, 30-40m dan 60-70m. All of the biota under the roll meter were noted to a detailed level every centimeter (cm). The morphometric code of benthic components used was the protocol developed by the Australian Institute of Marine Science (AIMS). The method used for coral reef site identification is COREMAP-Institute of Sciences Indonesia phase I and II. The identification of hard coral was done in the field, but the unknown samples were collected and identified in the laboratory office in Integrated Services Unit for Marine Conservation-Bitung Institute of Sciences Indonesia based on the book of identification published by Veron (1986), Moll and Moka (1986), Huang and Mao (2012), Koh and Chou (1989), and Suharsono (2010).

Data analysis

The data from transects was analysed in hard coral percentage live cover using the Microsoft Excel program, and included the analysis of species biodiversity (biodiversity index) and species evenness (evenness index) with the application of Biodiversity Pro.4. The important value used was by species biodiversity and species evenness, with a number of individuals (colonies) of every species of hard coral. The analyzed live cover percentage (%), species biodiversity (H) and species evenness (j) has been done following the Odum formulae (1971):

The percentage of hard coral life form:

$$\% \text{ life form} = \frac{\text{Length of every colony} \times 100}{\text{Length of transect}}$$

Species biodiversity (H):

$$H = -\sum (ni / N) \log (ni / N)$$

Species evenness (j):

$$j = H / \log S$$

Species dominancy (H):

$$D = (ni/N)^2$$

Where:

- H: a value of species biodiversity
- Ni: number of individuals
- N: a total of individuals
- j: a value of species evenness
- S: a total number of species
- D: value of species dominancy

RESULTS AND DISCUSSION

Biodiversity of coral reefs

The Dampier Straits research stations monitored in this study had characteristics of a coastline that is dominated by coastal plants, mangroves, rock, and sand. The distance of the coral reef assessment was varied from 3 m (Station 5)

until 50 m (Station 10). Station 2, 3 and station 4 were located on an atoll in the center of the waters. The substrate of bottom waters in research stations consists of sand, rubble, and rock. In the analysis of hard corals at the research stations, the number of species found was 141 species and these were included in 16 families (Table 2). The highest species richness was found in Station 6 (77 species included in 15 families), and the lowest was found in Station 10 (49 species that represented 14 families) (Table 2).

The percentage of hard coral life form

The highest percentage of live hard coral cover in 3m depth, Dampier Strait waters was found at Station 5 (86.83%) and the lowest at Station 8 (44.17%) (Table 3). The highest percentage of live hard coral cover in 6m depth was found at Station 3 (87.40 %) and the lowest at Station 2 (51.17%) (Table 4).

The value of hard coral diversity, evenness and dominance index

The value of hard coral diversity index (H), evenness index (j) and dominance index (D) in 3m and 6m depth in Dampier Strait waters research station are listed in Table 5.

Table 2. The composition of hard coral species in Dampier Strait waters, Raja Ampat, 2016

Family/species	Research station									
	1	2	3	4	5	6	7	8	9	10
I. POCILLOPORIDAE										
<i>Pocillopora damicornis</i>	+	-	+	-	+	-	-	-	-	-
<i>P. verrucosa</i>	+	+	+	+	+	+	+	+	+	-
<i>Seriatophora caliendrum</i>	+	+	+	+	+	+	+	+	+	+
<i>S. hystrix</i>	+	+	+	-	+	+	+	+	+	+
<i>Stylophora pistillata</i>	+	+	+	+	+	+	+	-	+	+
II. ACROPORIDAE										
<i>Montipora efflorescens</i>	-	-	-	-	+	-	-	-	-	-
<i>M. danae</i>	-	+	+	-	-	+	+	+	-	-
<i>M. foliosa</i>	-	+	+	+	+	+	-	+	+	+
<i>M. hoffmeisteri</i>	-	-	+	-	+	+	+	+	+	+
<i>M. informis</i>	+	+	+	+	+	+	-	+	+	-
<i>M. monasteriata</i>	-	-	+	-	+	-	-	-	+	-
<i>M. spongodes</i>	-	-	+	-	+	-	-	-	-	-
<i>M. undata</i>	-	-	+	+	+	+	+	+	+	-
<i>Montipora sp.</i>	+	+	-	+	-	-	-	-	-	+
<i>Acropora acuminata</i>	+	-	+	-	+	-	-	-	-	-
<i>A. aspera</i>	+	-	-	-	+	+	-	-	-	-
<i>A. cerealis</i>	-	+	+	-	-	-	-	-	-	-
<i>A. clathrata</i>	+	+	+	+	+	+	+	+	+	-
<i>A. cytherea</i>	-	-	+	+	+	-	+	-	+	-
<i>A. dendrum</i>	+	-	+	+	+	-	-	-	-	-
<i>A. digitifera</i>	+	-	-	-	-	-	-	-	-	-
<i>A. donei</i>	-	-	+	+	-	+	-	-	+	-
<i>A. echinata</i>	-	-	-	-	-	-	-	-	+	+
<i>A. florida</i>	+	+	+	+	-	+	+	-	+	-
<i>A. Formosa</i>	+	+	-	+	+	+	+	+	+	+
<i>A. gemmifera</i>	-	-	-	-	-	+	+	-	-	-
<i>A. granulosa</i>	+	-	-	-	-	-	-	-	-	-
<i>A. grandis</i>	-	-	-	-	+	-	-	-	-	-
<i>A. horrida</i>	-	-	-	-	-	-	-	-	+	-
<i>A. humilis</i>	-	+	-	-	-	+	-	-	-	-

<i>A. hyacinthus</i>	+ + + + +	- - + + -	<i>P. teres</i>	- - - - -	- - + -
<i>A. intermedia</i>	- + - + +	- + - + -	IX. MUSSIDAE		
<i>A. loripes</i>	+ - + - -	- - - - -	<i>Acanthastrea hillae</i>	- - + - -	+ + + + -
<i>A. millepora</i>	+ - - + -	- - - - -	<i>A. lordhowensis</i>	- - + - -	- - - - -
<i>A. nobilis</i>	+ + - + +	+ - - - -	<i>A. hemprichii</i>	- - - - -	+ - - - -
<i>A. nasuta</i>	- - + - -	+ - - - +	<i>Lobophyllia hemprichii</i>	+ + - - -	+ + + + +
<i>A. palifera</i>	+ - - + +	+ + + + +	<i>Symphyllia recta</i>	- + - + +	+ + + + -
<i>A. pulchra</i>	- + + + +	- - + - -	<i>S. radians</i>	- + - + -	- - - - -
<i>A. samoensis</i>	+ - - - -	- - - - -	<i>S. wilsoni</i>	- - - + -	- - - - -
<i>A. subglabra</i>	- - - - -	- + - + -	<i>Symphyllia sp.</i>	- - - - -	- - - + -
<i>A. tenuis</i>	- - - - -	- + - + -	X. MERULINIDAE		
<i>A. valenciennesi</i>	+ - - + +	+ - - + +	<i>Hydnophora exesa</i>	- - + - +	- - - + -
<i>A. yongei</i>	- - + - -	- - - - -	<i>H. rigida</i>	- - + - +	+ + + + +
<i>Acropora sp.</i>	+ + + + +	+ + + + +	<i>Merulina ampliata</i>	- + + + +	+ + + + +
<i>Anacropora puartogalerae</i>	- - - - -	- + - - -	<i>M. scabricula</i>	- - + - -	- - - + -
<i>Astreopora myriophthalma</i>	+ + - - -	- + + + +	<i>Scapophyllia cylindrica</i>	- - + - -	- - - + -
<i>A. gracillis</i>	- + - + -	+ - - - -	XI. ASTROCOENIDAE		
III. PORITIDAE			<i>Stylocoeniella armata</i>	- - - - -	- + - - +
<i>Porites cylindrical</i>	+ - - - -	+ + + + +	<i>Palaustrea ramosa</i>	- - - - -	- - - + -
<i>P. lichen</i>	- - - + -	- + - - -	XII. FAVIIDAE		
<i>P. lobate</i>	+ + + + +	+ + + + +	<i>Favites abdita</i>	- + - + -	+ - - + -
<i>P. lutea</i>	+ + + + +	+ + + + +	<i>F. complanata</i>	+ + + - -	- + + - -
<i>P. nigrecens</i>	+ - - + +	+ - - + +	<i>F. halicora</i>	- + - + -	+ + - + +
<i>P. mayeri</i>	- - - - -	- - - - -	<i>Favites sp.</i>	+ + + + +	+ + + + +
<i>P. rus</i>	- - - - -	- + - - +	<i>Favia maritima</i>	+ - - - -	- - - - -
<i>Goniopora columna</i>	- + + + -	+ + + + +	<i>F. matthaii</i>	- + - + -	- - - + -
<i>G. lobate</i>	- - - - -	- + + - -	<i>F. stelligera</i>	- - + + -	- - - + -
<i>Goniopora sp.</i>	- - - - -	- + - - -	<i>F. danae</i>	- - - - -	- + - - -
<i>Alveopora catalai</i>	- - - - -	- + + - -	<i>F. pallida</i>	- - - - -	- + - - -
IV. SIDERASTREIDAE			<i>Favia sp.</i>	- - - - -	- - + - +
<i>Psammocora digitata</i>	- - + - -	- - - - -	<i>Goniastrea aspera</i>	- - - - +	- - - + +
<i>P. superficialis</i>	- - - - -	- + - - -	<i>G. favulus</i>	- - + - +	- - - - -
<i>Coscinaraea columna</i>	- + - - -	- + + + +	<i>G. pectinate</i>	+ + - - -	+ + - + -
V. AGARICIIDAE			<i>G. retiformis</i>	- - - + -	- - - - -
<i>Pavona cactus</i>	- - - + -	- + - - -	<i>Goniastrea sp.</i>	+ - - - -	+ - + - -
<i>P. decussate</i>	- - - + -	- + - - +	<i>Platygyra daedalae</i>	+ - - - -	- + - + -
<i>P. varians</i>	- - - - -	- + - - -	<i>Leptoria phrygia</i>	+ + - - -	+ + - + -
<i>Coeloseris mayeri</i>	- - - - -	- + - - +	<i>Oulophyllia bennettiae</i>	- - - + -	- - - - -
<i>Leptoseris explanata</i>	+ - + - -	+ - + - +	<i>Montastrea annuligera</i>	+ + - - -	+ - - - -
<i>Leptoseris sp.</i>	- - + - -	- - - - -	<i>M. curta</i>	- + - + +	- - - - -
<i>Gardineroseris planulata</i>	- - + - -	- - - - -	<i>Diploastrea heliopora</i>	+ + + + +	+ + + + +
<i>Pachyseris speciosa</i>	- + - + -	- - + + +	<i>Cyphastrea micropthalma</i>	- - - + -	+ + - - +
<i>P. rugose</i>	- + - + -	+ + - + +	<i>C. chalcidicum</i>	- + - + -	- + - - -
VI. FUNGIIDAE			<i>Echinopora lamellosa</i>	+ - - - -	+ + + - +
<i>Fungia concinna</i>	+ + + - +	+ + + + +	<i>Echinopora sp.</i>	- + - - +	- + + + -
<i>F. danai</i>	- + - + -	- - - - -	XIII. CARYOPHYLLIDAE		
<i>F. fungites</i>	+ - - + +	+ + + + +	<i>Euphyllia ancora</i>	- - + + +	+ + + + +
<i>F. horrida</i>	+ + - - -	- - - - -	<i>E. glabrescens</i>	- - + - -	+ + - - -
<i>F. paumotensis</i>	+ + - - -	- + + - +	<i>Plerogyra sinuosa</i>	- - - - +	- + - - +
<i>F. repanda</i>	- - - + -	- - + - +	<i>Physogyra lichtensteini</i>	- - - + +	+ + - - +
<i>F. scutaria</i>	- - - - -	- + - - -	XIV. DENDROPHYLLIDAE		
<i>Ctactis echinata</i>	+ + + + +	+ + + + +	<i>Turbinaria mesenterina</i>	- - + - +	- - + - -
<i>Heliofungia actiniformis</i>	+ + + + +	+ + - + +	<i>T. reniformis</i>	- - - + -	- - - - -
<i>Herpolitha limax</i>	+ + + + -	+ + + + +	<i>T. frondens</i>	- - - - -	- + - - -
<i>Halomitra pileus</i>	+ - + + -	+ - + - +	<i>Tubastrea micrantha</i>	+ + + + +	+ + + + +
<i>Polyphyllia talpina</i>	- - - - -	- + + - +	<i>T. faulkneri</i>	- + + - -	- - - - -
VII. OCULINIDAE			XV. MILLEPORIDAE		
<i>Galaxea astreata</i>	- + - + +	+ + + + +	<i>Millepora sp.</i>	+ + + + +	+ + + + +
<i>G. fascicularis</i>	- - - - -	- + - - -	XVI. HELIOPHORIDAE		
VIII. PECTINIDAE			<i>Heliophora coerulea</i>	+ - - + +	- + + + +
<i>Oxypora glabra</i>	+ + - + -	- - - - -	Species	52 56 57 62 50 77 61 51 74 49	
<i>O. lacera</i>	- + + - -	- + + + +	Family	12 13 13 14 12 15 15 15 16 14	
<i>Mycodium elephantotus</i>	- - - - +	- - - + +			
<i>Pectinia lactuca</i>	- + + - -	+ + + + +			
<i>P. paeonia</i>	- - - + -	- + - + +			

Table 3. The percentage of hard coral life form, biotic and abiotic component of hard coral (3 m depth) in Dampier Strait waters, Raja Ampat, 2016

Benthic components	Research station									
	1	2	3	4	5	6	7	8	9	10
Life coral (LC)	49.70	52.50	85.33	64.67	86.83	56.31	55.97	44.17	79.10	81.30
Soft Coral (SC)	17.90	35.33	5.33	20.67	10.17	3.00	21.93	40.20	16.23	0.00
Sponges (Sp)	0.83	0.33	1.00	0.67	0.00	3.63	0.00	0.67	1.33	0.00
Macro algae (MA)	1.67	0.00	0.00	0.00	0.00	5.56	0.00	0.00	0.67	2.93
Halimeda (HA)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others (OT)	0.00	1.33	0.00	0.00	0.00	1.53	0.00	0.00	0.00	0.00
Rubble (R)	5.67	1.67	2.00	1.83	0.00	9.33	19.70	8.83	1.33	14.77
Sand (S)	4.43	2.00	0.00	0.00	0.00	10.33	1.10	6.13	1.33	0.00
Silt (Si)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dead coral with algae (DCA)	19.80	6.83	6.33	12.17	3.00	10.30	1.30	0.00	0.00	1.00
Dead coral (DC)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rock (RCK)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 4. The percentage of hard coral life form, biotic and abiotic component of hard coral (6 m depth) in Dampier Strait waters, Raja Ampat, 2016.

Benthic components	Research station									
	1	2	3	4	5	6	7	8	9	10
Life coral (LC)	60.97	51.17	87.40	52.33	52.17	55.93	63.67	66.33	58.70	80.27
Soft Coral (SC)	3.83	27.67	6.00	29.17	21.50	0.33	14.00	25.07	8.10	0.00
Sponges (Sp)	0.00	2.07	0.00	2.33	0.00	0.00	1.37	1.50	1.00	0.00
Macro algae (MA)	0.67	1.17	0.00	0.00	0.00	2.67	0.00	0.00	4.33	0.00
Halimeda (HA)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others (OT)	0.00	1.00	3.50	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Rubble (R)	23.03	0.83	1.33	5.67	19.33	28.03	16.47	1.33	23.53	19.07
Sand (S)	4.00	4.20	0.00	2.00	3.67	4.67	3.50	5.10	4.33	0.00
Silt (Si)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dead coral with algae (DCA)	7.50	11.90	1.77	8.50	3.33	7.37	1.00	0.67	0.00	0.67
Dead coral (DC)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rock (RCK)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5. The value of hard coral diversity index (H), evenness index (j) and dominance index (D) in 3 m and 6 m depth in Dampier Strait waters research station, 2016.

Depth	Components	Research station									
		1	2	3	4	5	6	7	8	9	10
3 m	Number of species	14	20	17	22	19	14	17	9	20	18
	Number of individual	50	52	60	58	47	59	50	23	61	80
	Diversity index (H)	0.99	1.13	1.00	1.23	1.12	1.00	1.09	0.84	1.06	0.93
	Evenness index (j)	0.87	0.87	0.81	0.91	0.88	0.87	0.89	0.88	0.82	0.74
	Dominancy index (D)	0.13	0.10	0.17	0.07	0.10	0.12	0.10	0.18	0.15	0.19
6 m	Number of species	16	31	16	19	19	16	21	15	19	11
	Number of individual	46	58	50	46	55	59	45	41	45	45
	Diversity index (H)	1.07	1.39	1.09	1.20	1.16	1.03	1.13	1.05	1.13	0.76
	Evenness index (j)	0.89	0.93	0.91	0.94	0.91	0.85	0.85	0.89	0.88	0.73
	Dominancy index (D)	0.11	0.05	0.10	0.07	0.09	0.12	0.13	0.11	0.11	0.25

The length measurement of coral reef colony

The length measurement of coral reef colony in 3 m and 6 m depth in Dampier Strait waters research station are listed in Table 6, 7 and 8.

Discussion

Biodiversity of coral reefs

The identification of hard coral in 3m and 6m revealed 141 species of hard coral (Table 2). The total number of

Table 6. The total length of hard coral colonies, presence, and frequency of presence every hard coral species in 3 m depth, Dampier Strait waters research station, 2016.

Species of hard coral	Total length of colonies (% coverage)	Presence	Freq. of presence (%)
<i>Acropora</i> sp.	21.32	10	100
<i>Porites lutea</i>	9.17	9	90
<i>Echinopora lamellosa</i>	6.34	1	10
<i>Seriatophora hystrix</i>	4.15	5	50
<i>Acropora clathrata</i>	3.75	5	50
<i>Porites nigrecens</i>	3.75	5	50
<i>Seriatophora caliendrum</i>	3.72	8	80
<i>Montipora informis</i>	3.61	5	50
<i>Stylophora pistillata</i>	3.55	7	70
<i>Millepora</i> sp.	3.28	2	20
<i>Goniopora columna</i>	2.79	3	30
<i>Acropora hyacinthus</i>	2.67	5	50
<i>Acropora palifera</i>	2.28	4	40
<i>Pocillopora verrucosa</i>	2.20	6	60
<i>Acropora formosa</i>	2.08	4	40
<i>Montipora foliosa</i>	2.06	3	30
<i>Favites</i> sp.	1.56	6	60
<i>Acropora florida</i>	1.52	5	50
<i>Acropora pulchra</i>	1.37	5	50
<i>Acropora vallecienesi</i>	1.37	1	10
<i>Pectinia lactuca</i>	1.27	3	30
<i>Porites cylindrica</i>	1.26	2	20
<i>Hydnophora rigida</i>	1.25	5	50
<i>Galaxea astreata</i>	1.21	4	40
<i>Acropora aspera</i>	1.07	2	20
<i>Fungia concinna</i>	1.02	6	60
<i>Porites lobata</i>	1.02	3	30
<i>Fungia fungites</i>	0.68	4	40
<i>Montipora undata</i>	0.64	2	20
<i>Merulina ampliata</i>	0.62	2	20
<i>Favites halicora</i>	0.56	3	30
<i>Tubastrea micrantha</i>	0.56	1	10
<i>Favia</i> sp.	0.46	2	20
<i>Acropora nasuta</i>	0.42	1	10
<i>Acropora grandis</i>	0.41	1	10
<i>Montipora danae</i>	0.41	1	10
<i>Oxypora lacera</i>	0.41	2	20
<i>Montipora</i> sp.	0.38	3	30
<i>Cyphastrea chalcidicum</i>	0.36	1	10
<i>Diploastrea heliopora</i>	0.36	1	10
<i>Goniastrea pectinata</i>	0.36	1	10
<i>Pachyseris rugosa</i>	0.36	2	20
<i>Symphyllia recta</i>	0.30	1	10
<i>Heliofungia actiniformis</i>	0.30	2	20
<i>Favites complanata</i>	0.25	2	20
<i>Astreopora gracillis</i>	0.23	1	10
<i>Acropora millepora</i>	0.20	1	10
<i>Acropora nobillis</i>	0.20	2	20
<i>Herpolitha limax</i>	0.20	2	20
<i>Goniastrea</i> sp.	0.15	1	10
<i>Palaustrea ramosa</i>	0.12	1	10
<i>Echinopora</i> sp.	0.10	1	10
<i>Halomitra pileus</i>	0.10	1	10
<i>Goniastrea retiformis</i>	0.10	1	10
<i>Acropora echinata</i>	0.06	1	10
<i>Acropora intermedia</i>	0.05	1	10
<i>Porites lichen</i>	0.05	1	10
The total of length	100.00		

Table 7. The total length of hard coral colonies, presence, and frequency of presence every hard coral species in 6 m depth, Dampier Strait waters research station, 2016.

Hard coral species	Total length of colonies (% coverage)	Presence	Freq. of presence (%)
<i>Acropora</i> sp.	14.15	8	80
<i>Porites lutea</i>	9.06	8	80
<i>Echinopora lamellosa</i>	7.61	1	10
<i>Seriatophora hystrix</i>	4.67	7	70
<i>Porites nigrecens</i>	4.19	7	70
<i>Seriatophora caliendrum</i>	4.11	7	70
<i>Montipora informis</i>	3.86	6	60
<i>Acropora hyacinthus</i>	3.82	4	40
<i>Montipora foliosa</i>	3.68	6	60
<i>Stylophora pistillata</i>	3.19	7	70
<i>Goniopora</i> sp.	2.49	1	10
<i>Acropora vallecienesi</i>	2.44	3	30
<i>Porites cylindrica</i>	2.18	3	30
<i>Pocillopora verrucosa</i>	1.88	4	40
<i>Acropora palifera</i>	1.84	4	40
<i>Montipora danae</i>	1.70	2	20
<i>Acropora clathrata</i>	1.53	6	60
<i>Merulina ampliata</i>	1.43	3	30
<i>Millepora</i> sp.	1.40	2	20
<i>Favites</i> sp.	1.38	4	40
<i>Fungia concinna</i>	1.38	8	80
<i>Acropora formosa</i>	1.27	4	40
<i>Acropora echinata</i>	1.25	1	10
<i>Echinopora</i> sp.	1.25	3	30
<i>Oxypora lacera</i>	1.18	1	10
<i>Galaxea astreata</i>	1.18	5	50
<i>Goniopora columna</i>	1.17	3	30
<i>Diploastrea heliopora</i>	1.01	3	30
<i>Montipora</i> sp.	0.87	2	20
<i>Montipora undata</i>	0.85	5	50
<i>Pectinia lactuca</i>	0.85	4	40
<i>Porites rus</i>	0.85	2	20
<i>Porites lobata</i>	0.75	3	30
<i>Acropora aspera</i>	0.74	1	10
<i>Astreopora gracillis</i>	0.74	2	20
<i>Pachyseris rugosa</i>	0.69	3	30
<i>Acropora horrida</i>	0.53	1	10
<i>Acropora intermedia</i>	0.48	1	10
<i>Acropora millepora</i>	0.45	1	10
<i>Acropora nasuta</i>	0.42	2	20
<i>Favia matthaii</i>	0.42	1	10
<i>Acropora digitifera</i>	0.37	1	10
<i>Acropora nobillis</i>	0.37	2	20
<i>Acropora florida</i>	0.34	2	20
<i>Fungia fungites</i>	0.32	2	20
<i>Pavona decussata</i>	0.32	1	10
<i>Anacropora puartogalerae</i>	0.29	1	10
<i>Acropora grandis</i>	0.26	1	10
<i>Goniastrea pectinata</i>	0.26	2	20
<i>Lobophyllia hemprichii</i>	0.26	2	20
<i>Favites complanata</i>	0.21	2	20
<i>Herpolitha limax</i>	0.21	2	20
<i>Hydnophora rigida</i>	0.21	2	20
<i>Leptoseris</i> sp.	0.21	1	10
<i>Symphyllia</i> sp.	0.21	1	10
<i>Acropora yongei</i>	0.16	1	10
<i>Favites abdita</i>	0.16	1	10
<i>Pavona teres</i>	0.16	1	10
<i>Tubastrea micrantha</i>	0.16	1	10
<i>Cyphastrea chalcidicum</i>	0.12	1	10
<i>Acropora pulchra</i>	0.11	2	20
<i>Euphyllia ancora</i>	0.11	1	10
<i>Heliofungia actiniformis</i>	0.11	1	10
<i>Coscinaraea</i> sp.	0.08	1	10
<i>Acropora humillis</i>	0.05	1	10
Total of length	100.00		

Table 8. The total length of hard coral colonies of 10 species which dominates (3m and 6m depth), in Dampier Strait marine protected area research station, 2016

Depth	Species	Total length of colonies (% coverage)										
		1	2	3	4	5	6	7	8	9	10	Total
3 m	<i>Acropora</i> sp.	4.77	1.31	4.53	4.77	15.50	4.91	12.40	18.84	30.00	2.98	100.00
	<i>Porites lutea</i>	24.33	9.70	28.27	17.18	0.55	9.42	3.05	4.43	3.05	0.00	100.00
	<i>Echinopora lamellosa</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100.00
	<i>Seriatophora hystrix</i>	0.00	28.19	9.80	0.00	2.45	25.74	0.00	0.00	0.00	33.82	100.00
	<i>Acropora clathrata</i>	4.34	0.00	17.62	25.07	48.78	0.00	0.00	0.00	4.20	0.00	100.00
	<i>Porites nigrecens</i>	0.03	0.00	0.00	0.00	0.58	0.16	0.12	0.00	0.00	0.09	100.00
	<i>Seriatophora caliendrum</i>	21.89	31.46	5.47	4.10	0.00	27.36	3.56	0.00	4.79	1.37	100.00
	<i>Montipora informis</i>	4.93	22.54	46.48	21.83	4.23	0.00	0.00	0.00	0.00	0.00	100.00
	<i>Stylophora pistillata</i>	7.88	0.00	14.33	0.00	14.33	2.87	17.05	0.00	37.11	6.45	100.00
	<i>Millepora</i> sp.	0.00	0.00	0.00	0.00	27.09	72.91	0.00	0.00	0.00	0.00	100.00
6 m	<i>Acropora</i> sp.	0.00	2.51	6.37	4.61	9.74	1.87	38.58	13.11	23.22	0.00	100.00
	<i>Porites lutea</i>	11.40	8.36	30.23	7.02	14.62	2.34	0.00	24.56	1.46	0.00	100.00
	<i>Echinopora lamellosa</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100.00
	<i>Seriatophora hystrix</i>	0.00	7.37	17.01	0.00	9.64	22.00	0.91	0.00	2.27	40.82	100.00
	<i>Porites nigrecens</i>	48.10	0.00	0.00	7.59	3.16	29.75	3.80	2.53	5.06	0.00	100.00
	<i>Seriatophora caliendrum</i>	27.06	6.44	15.46	0.00	15.46	29.64	3.35	0.00	2.58	0.00	100.00
	<i>Montipora informis</i>	8.93	25.82	28.85	12.36	13.05	0.00	10.99	0.00	0.00	0.00	100.00
	<i>Acropora hyacinthus</i>	26.39	0.00	47.92	21.53	0.00	0.00	0.00	0.00	4.17	0.00	100.00
	<i>Montipora foliosa</i>	0.00	6.34	53.31	0.00	9.80	0.00	3.46	22.77	4.32	0.00	100.00
	<i>Stylophora pistillata</i>	0.00	3.32	22.43	16.61	13.29	6.81	4.98	0.00	32.56	0.00	100.00

species identified is significantly high compared to the total number in Nusalaut islands waters (123 species, Souhoka 2007), Marabatuan and Matasirih South Borneo (98 species, Munasik and Siringoringo 2011) and in Bunaken island waters (67 species, Kambey 2014). In contrast, the number of this species found in this study was smaller than the number of species found in Tobelo, North Halmahera (146 species, Souhoka 2012), in Tanjung Merah waters (165 species, Souhoka 2007) and in Lembata, East Nusa Tenggara (313 species, Abrar et al. 2012). The high number of hard coral species in Dampier Strait waters show that this location has quite a high variety of hard coral 30,92% of the total number of hard coral species that are found in Raja Ampat Regency waters (456 species, Veron 2002). The high number of hard coral species in Dampier Strait may be facilitated by the good condition of waters, with a range of salinity of 27.00-32.67‰, a temperature range of 25.00-31,20°C and range of pH of 7.34-7.39 (in situ measurement). Sukarno et al. (1981) stated that the growth of hard coral is generally possible in a range of salinity (25-40 ‰). The ideal temperature for the growth of hard coral ranges from 25-29°C in shallow tropical waters (Salm and Clark 1989).

Benthic components of coral reefs

The assessment of hard coral and the other of a benthic components in 3m depth (Table 3) has shown that the highest hard coral was found in Station 5 (86.83%) and the lowest in Station 8 (44.17%). The value of percentage live hard coral in 3 m depth consists of categories moderate to very good by Gomez and Alcalá (1978) i.e 0-24.9 % (bad), 25-49.9% (moderate), 50-74.9% (good) and 75-100% (very

good). The highest hard coral cover in 6m depth was found in Station 3 (87.40%) and the lowest in station 2 (51.17%). The average hard coral cover in two depth was found to range from 62.89% (6m depth) to 65.69% (3m depth). This indicated that these sites were in overall good condition. The average hard coral percentage cover in 3 and 6 m depth (64.24%) also implied that the hard coral in Dampier Strait waters is in good condition. This value is significantly higher than other sites in Indonesia such as the Tegal and Sidodadi islands (49.87%) (Hartoni et al. 2012) and Tagulandang, North Sulawesi (46.21%) (Souhoka 2014).

A comparison of the hard coral percentage cover (Figure 2) shows that there was some variation between the research stations at 3 and 6 m depth. The value of category of bad condition (0-24.9% cover) was not found at any site. The moderate category (25-49.9% cover) was found at 3m depth (2 research stations), good condition (50-74.9% cover) was found at 4 research stations in 3m depth and 8 research stations in 6m depth and very good condition (75-100% cover) was found in 4 stations (3m depth) and 2 stations (in 6 m depth). Generally, the hard coral condition in 3m depth had better cover than in 6m depth. The high value of coral cover at 3m depth may be because sunlight penetration was good enough so that the photosynthesis done by hard coral (zooxanthellae) would be continued. It is as stated by Wells (1956), that hard coral in the waters depended on the condition of around the waters i.e. sunlight, salinity, temperature, the movement of current, substrate and the brightness of water. The hard coral should not be limited horizontally but may be limited vertically by the depth of waters (Suharsono 2010).

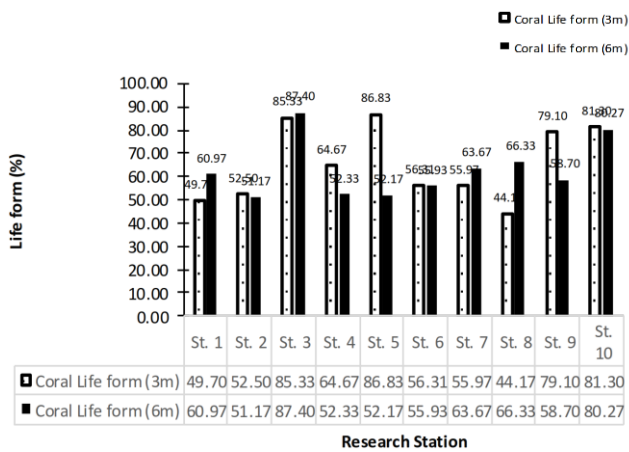


Figure 2. The percentage of hard coral life form in 3m and 6m in Dampier Strait marine protected area research stations, 2016

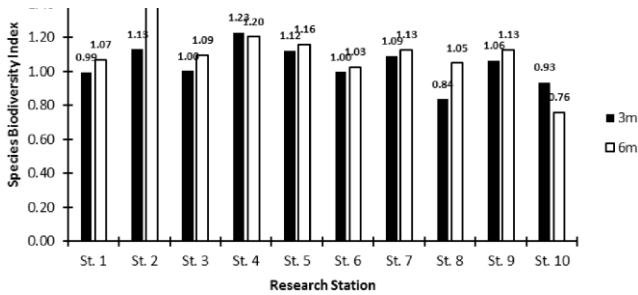


Figure 3. The value of species biodiversity index (H) in 3m and 6m depth, Dampier Strait research station, 2016

Species diversity index

The result of species diversity (H) analysis showed that the highest diversity (3m depth) was found in station 4 (1.23) and the lowest in station 8 (0.84). In 6 m depth, the highest value of species diversity index (H) was found in station 2 (1.39) and the lowest in station 10 (0.76) (Table 5). The high value of species diversity index (H) implies that the community of biota was highly varied and was not dominated by one or two taxa (Romimohtarto and Juwana 1999). The comparison of species biodiversity index values between 3 and 6 m depth (Figure 3) showed that diversity was highest in 6m depth, and the was found in 8 of the 10 stations. In contrast, a lower value of diversity was found in 6m depth at station 4 (1.20) and station 10 (0.76).

The value of hard coral species diversity index (H) in Dampier strait (Figure 3) in 3 and 6 m depth, generally showed that hard coral around of the waters had categories of productive and very productive (0.76-1.39) based on the criteria by Stodart and Johnson in Manuputty (1990) i.e 0.00-0.25 (no productive), 0.25-0.50 (a little productive), 0.50-0.75 (moderate productive), 0.75-1.00 (productive) and more than 1.00 (very productive). Alternatively, the value of species biodiversity (diversity index) found in the Dampier strait showed that the status of hard coral species biodiversity is in moderate condition, based on the criteria's

Krebs (1972) i.e. $0 < H \leq 1$: low, $1 < H \leq 2$: moderate and $H > 2$: high (stable).

The value of species biodiversity was very high at station 2 (6 m depth), showing that hard coral in this location consists of a great variety of species. In contrast, the hard coral community in station 10 (6 m depth) consists of a relatively low species variety. The highest hard coral species especially was found from genus *Acropora* (19 species). Manuputty (1990) stated that hard coral from genera *Acropora* sp had a very small polyp and it is difficult to polyp to refresh by itself from any particle in coral's body. Consequently, these species need a strong current and waves as found in the Dampier straits to survive.

The value of hard coral species evenness (j) in Dampier (Table 5) in both depths ranged from 0.73 (station 10) 6m depth to 0.94 (station 4) 6m depth. The value of evenness index is usually used to assess the distribution pattern of biota i.e. evenly distributed or unevenly distributed (Romimohtarto dan Juwana 1999). The high value of evenness index in station 4 shown that hard corals are distributed in a homogeneous way and there are no dominant colonies (patches). Meanwhile at the station 10, hard corals distributed less homogeneously than at any other station, especially because of the species *Seriatophora hystrix* and *Echinopora lamellosa* that were found a lot at this station. According to Suharsono (2010), the coral reef species *Seriatophora hystrix* and *Echinopora lamellosa* are generally common in around Indonesian waters and scatter around the reef flat. The value of evenness index found in 10 Dampier strait research stations indicated that hard coral communities are in a stable condition, based on criteria by Krebs (1972) $0 < E \leq 0.50$: stressed community, $0.50 < E \leq 0.75$: label community and $0.75 < E \leq 1.50$: stable community.

Species dominance index (D) revealed the presence and absence of species dominance throughout the sampling area. The result showed that the dominance index ranged from 0.05 (station 2) to 0.25 (station 10). The high value of species dominance in station 10 showed that dominance of hard coral species was greater here than at other sites. The highest dominance of hard coral species was found *Seriatophora hystrix* and *Echinopora lamellosa* and was distributed in quite wide areas. Veron (1986) found these species were also common from the Great Barrier Reef, Coral Sea, Moreton Bay, and Lord Howe Island in the east to west coast of Australia.

The length of coral reef colony

The length of a hard coral colony in 3m and 6m (Table 6 and Table 7) showed that the species *Acropora* sp had the total length of 4194 cm. The highest length was found in station 9 (1258 cm) (Table 8) and was found in every research station (10 stations) in Dampier strait waters (Table 6). *Acropora* sp has found living in quite wide areas. Suharsono (2010) stated that hard coral from the genus *Acropora* was found in almost in every Indonesian water, and Veron (1986) found this coral in Madagascar, the east island of Marshall, Great Barrier Reef, south of Coral Sea to the east island of Lord Howe and Scott Reef in the west

coast of Australia waters. Another hard coral species found to be quite long *Porites lutea* (1804 cm) in 3m depth and this species found dominance in station 1 (439 cm) (Table 8). *Porites lutea* was formed a massive coral, where the part of a surface colony impressed smooth with the form of corallite uniform and distributed across Indonesian water and found very generally on reef flat (Suharsono 2010). *Porites* have well adapted to changes of environment in the waters. According to Tomascik and Sander (1987) they, found the hard coral species *Porites* lived in waters with eutrophication.

In conclusions, the number of hard coral in Dampier Strait waters, Raja Ampat regency consists of 141 species that represented 16 families. The average hard coral condition in categories good with the percentage of life form in range 62.89% (6m depth) to 65.69% (3m depth). The highest percentage of hard coral life form was found in station 3 (6m depth) in 87.40% and the lowest was found in station 8 (3m depth) in 44.17%. The biodiversity of hard coral is productive to very productive with moderate stability growth. The total length of a hard coral growth area in 10 Dampier Strait research station is 39.35% (3m depth) and 37.74% (6m depth) from the total length of the transect.

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