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Research Article

Reef Fish Diversity in Jayapura City, Indonesia: A Preliminary Study

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ABSTRACT
As one of the marine areas included in the world's Coral Triangle region, Yos Sudarso Bay have a potential reef fish diversity that needs to be studied. However, there is very little information about reef fish diversity in these waters to date. This study aims to determine the species diversity of reef fish in Yos Sudarso Bay, Jayapura City, Indonesia. The study was conducted in April 2020 at seven sites; six of them located inside the Yos Sudarso Bay and one more located outside the bay. Sampling was carried out using the Underwater Visual Census method (25 m long and 5 m wide). Relative abundance by species, and diversity (H´), evenness (E), and dominance (C) indices were calculated. A total of 1,075 individual reef fish was recorded in seven study sites, representing 122 species and 26 families. Locations showed differences in reef fish abundance (86 to 215 individuals/125 m^2), diversity (H' = 2.462 to 3.358), evenness (E = 0.770 to 0.887), and dominance (C = 0.047 to 0.155). This study has provided preliminary information on species diversity, fish abundance, and the ecological index of reef fish in Yos Sudarso Bay, Jayapura City.

INTRODUCTION
Coral reefs are a complex and productive ecosystem in coastal areas (Marshell & Mumby 2015). This ecosystem provides many important habitats that have high biodiversity and provide benefits to people in many tropical regions (Veron 2002; Madduppa et al. 2012). Several important ecological functions of coral reef ecosystems including a habitat for protection from predators, spawning ground, nursery ground, and feeding ground for various species of reef fish (Cole et al. 2008; Madduppa et al. 2012).

Indonesian waters have the highest number of reef fish species in the world. There are 2,139 species of reef fish in Indonesia reported in the FishBase (Froese & Pauly 2020) and about 197 species are endemic (Allen & Erdmann 2012). The reef fish species are spread from the Western to the Eastern part of Indonesia with a variety of different habitat types, causing differences in the structure of the community. In particular, Papua's waters in the world's Coral Triangle region have a high level of reef fish diversity. Ac-

cording to Allen and Erdmann (2009), 1,511 species have been identified in 451 genera and 111 families of reef fish around the Bird's Head peninsula and surrounding waters in West Papua Province. Live coral cover and diversity of coral lifeforms are important indicators of reef fish species abundance and diversity (Garpe & Öhman 2003; Komyakova et al. 2018; Paulangan et al. 2019a), including variations in coral species and coral reef habitat zones (Bell & Galzin 1984; Paulangan et al. 2019a). The diversity of reef fish species correlates with the condition of coral reefs, where the loss of more than 20% corals can reduce the richness of reef fish species (Wilson et al. 2006). Therefore, the diversity of coral reef habitats is one of the key factors and can explain a large number of reef fish species and individuals in the ecosystem (Roberts & Ormond 1987).

As one of the marine areas included in the world's Coral Triangle region, Yos Sudarso Bay also has a potential reef fish diversity need to be studied. However, there is very little information about reef fish diversity in these waters to date (Tebaiy et al. 2014; Hamuna et al. 2019) who evaluates only reef indicator species (Chaetodontidae) and species present in seagrasses respectively. Data and information on reef fish diversity are very important because they are one of the components for the management and development of the fisheries and tourism sector in coral reef areas. Based on the results of research by Hamuna et al. (2019), the condition of coral reefs in Jayapura City in several locations is still in moderate to good condition with the percentage of live coral cover ranging from 32 to 60%. This shows that the coral reef ecosystem in Jayapura City has the potential to become a habitat for various species of reef fish. This study aims to determine the number of reef fish species, and to analyze the abundance and ecological index of reef fish in the coral reef ecosystem of Yos Sudarso Bay, Jayapura City, Papua Province, Indonesia.

MATERIALS AND METHODS

Study Site

Yos Sudarso Bay is one of the bays in Jayapura City, Papua Province, Indonesia. Geographically, Yos Sudarso Bay is directly adjacent to the Pacific Ocean. Generally, as one of the coastal areas in tropical waters, the coastal waters of Jayapura City, including Yos Sudarso Bay, are an area that is quite rich in natural resources, including the three main ecosystems in the coastal area, namely mangrove and seagrass ecosystems in Youtefa Bay (Rumahorbo et al. 2019; Rumahorbo et al. 2020) and coral reef ecosystems located in the Yos Sudarso Bay (Hamuna et al. 2019; Rumahorbo et al. 2020), as well as high potential fishery resources (Tebaiy et al. 2014; Hamuna et al. 2020; Pujiyati et al. 2021). In particular, the condition of coral reefs in Yos Sudarso Bay is in a moderate to good category with live coral cover ranging from 32 to 60% (Hamuna et al. 2019). However, at certain sites, the condition of the coral reefs has been damaged due to destructive fishing as indicated by the amount of rubble.

The observation of reef fish was conducted in April 2020 in seven sites (Table 1; Figure 1). Six of them were inside the Yos Sudarso Bay (S2-S6) and one more was outside the Yos Sudarso Bay (S1).

Table 1. Location of study sites and coordinates in Yos Sudarso Bay, Indonesia.

Site code	Site name	Coordinates	
		S	E
S1	Base-G coastal	2° 31' 15.062"	140° 44' 36.441"
S2	Southern of the Argapura coastal	2° 33' 24.036"	140° 43' 15.442"
S3	Northern of the Argapura coastal	2° 32' 55.921"	140° 43' 9.863"
S4	Eastern of the Kosong Island	2° 32' 51.458"	140° 43' 37.533"
S5	Western of Kosong Island	2° 32' 49.226"	140° 43' 22,136
S6	Kayupulo Island	2° 32' 41.64"	140° 43' 19.458"
S7	Lampu Merah reefs	2° 32' 31.598"	140° 43' 5.847"

Data Collection

Before conducting reef fish observations, a field survey was conducted to determine the reef fish observation points. Observations of reef fish only during the day using the Underwater Visual Census (UVC) method refers to English et al. (1997). UVC is a method that has been widely used for monitoring or evaluating reef fish resources. At each study site, observation of reef fish was only carried out on one transect at a depth of 3 to 5 m depending on the condition of the coral reef. The 25 m transect line was placed parallel to the coastline and reef fish observations were carried out 15 to 20

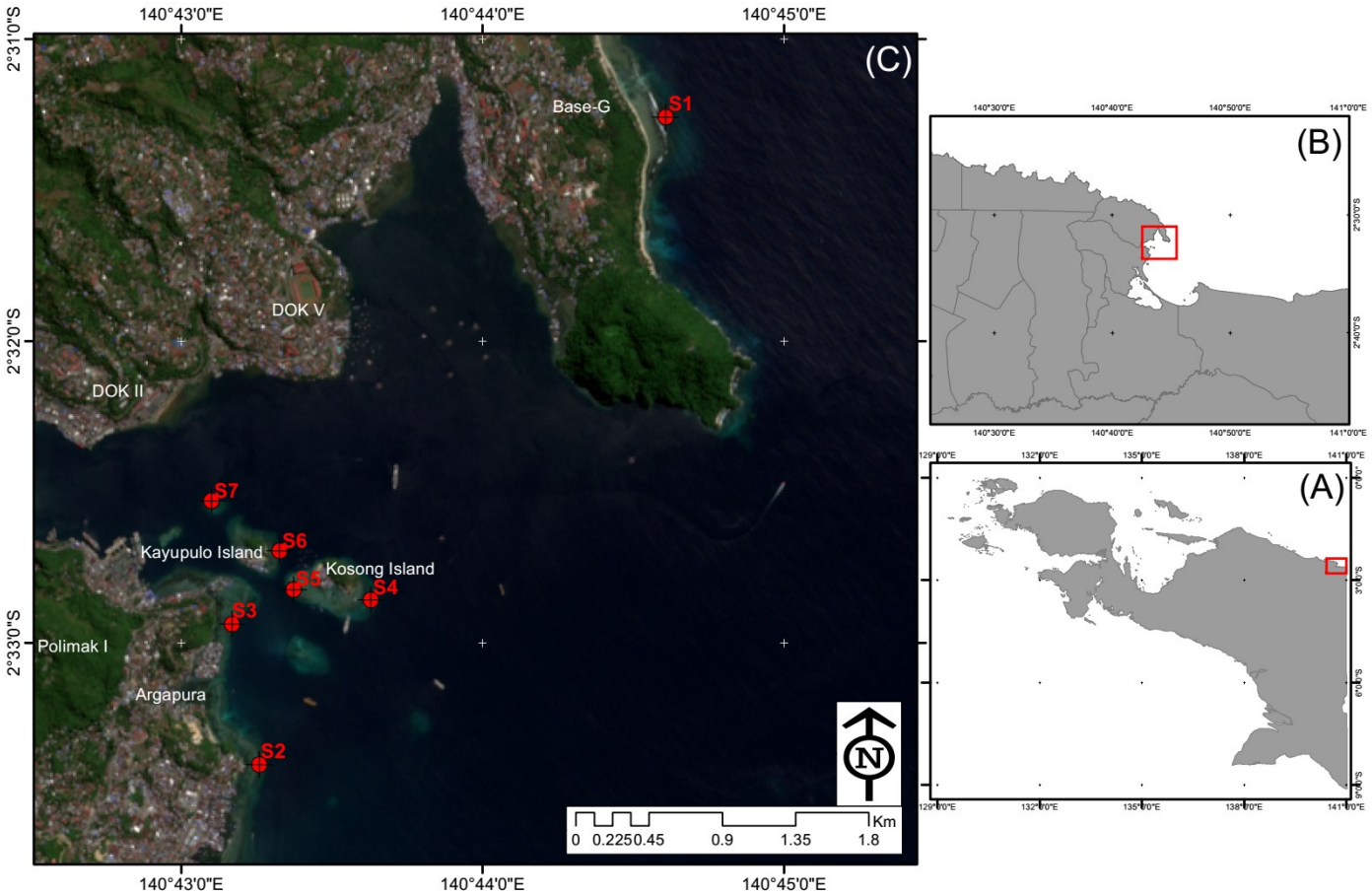

Figure 1. Map of study sites; (A) Papua Island (Papua and West Papua Provinces), (B) Jayapura City, and (C) seven sites (S1-S7) for reef fish observation in Yos Sudarso Bay, Papua Province, Indonesia.

minutes after that. The number of individuals of each reef fish species found was counted to the observation distance limit of 2.5 m on both sides of the transect line (transect area = 125 m^2). In addition to direct field observations, underwater photos and videos were also taken to re-identify certain species and families of reef fish that were not recognized during field observations, where re-identification refers to Allen et al. (2000).

Data Analysis

Analysis of reef fish diversity was carried out at the species and family level. Furthermore, reef fish are grouped based on their role, namely major fish, target fish, and indicator fish according to English et al. (1997) and Madduppa et al. (2012). The major fish group includes colored small ornamental fish (generally 5-25 cm in size) which tends to be territorial, such as the families Pomacentridae, Apogonidae, Balistidae, Labridae, Gobiidae, and Blenniidae. Target fish are represented by economically important species for human consumption, such as the families Acanthuridae, Lutjanidae, Serranidae, Holocentridae, Nemipteridae, and Haemulidae. Target fish groups were confirmed based on direct interviews with several local fishermen. Indicator fish are reef fish species that typically inhabit coral reef ecosystems and as indicators of the fertility of these ecosystems, such as reef fish from the Chaetodontidae family.

Data on the number of individuals from each type of reef fish were analysed to determine the abundance of reef fish in each location. Abundance of reef fish was determined based on the ratio between the numbers of individual reef fish with the area of observation (English et al. 1997). Ecological indices of reef fish, including the diversity index (Shannon-Wiener), evenness index (Pielou's), and dominance index (Simpson) were determined referring to the following equations (Magurran 1991):

$$H' = -\sum_{i=1}^{s} [p_i \ln p_i] \; ; \; p_i = \frac{n_i}{N}$$

$$E = \frac{H'}{\ln S}$$

$$C = \sum_{i=1}^{s} p_i^{\,2}$$

where H', E, and C are the diversity index, the evenness index, and the dominance index, respectively. Whereas S is the number of reef fish species, n_i is the number of individuals of each reef fish species, and N is the total individuals of all reef fish species.

Multivariate analysis is used to determine the level of similarity between sites. The data used to determine the similarity index is the relative abundance of each species of reef fish. Non-metric Multidimensional Scaling (nMDS) based on Bray-Curtis Similarity is used to visualize the level of similarity between sites (Clarke 1993) using PRIMER 7 software. The quality of MDS 2-dimensional plots can be determined based on stress value, namely

stress value <0.2 (poor representation), stress value <0.1 (good representation), and stress value <0.05 (excellent representation) (Kruskal 1964; Field et al. 1982).

RESULTS AND DISCUSSION

Species Diversity and Abundance

The results of reef fish observations showed that the number of families, species, number of individuals, and abundance of reef fish found varied in the seven study sites. There were 1,073 individuals from 122 reef fish species representing 26 families during the observation in seven study sites (Table 2). The reef fish species that was most frequently found during the observation at the seven study sites were *Ctenochaetus cyanocheilus, Zanclus cornutus, Zebrasoma scopas, Ctenochaetus binotatus, Ctenochaetus striatus, Nectamia savayensis, Pomacentrus moluccensis, Neopomacentrus filamentosus, Pomacentrus taeniometopon*, and *Chromis ternatensis*. However, only *C. cyanocheilus* and *C. binotatus* were found at all study sites. Pomacentridae and Acanthuridae were the most common reef fish families, as many as 348 individuals (35 species) and 308 individuals (11 species), respectively. Both families reached 61.02% of the total reef fish individuals surveyed.

Based on the composition of the roles of each species, the reef fish found were dominated by major fish groups of 68 species and 581 individual fish. The number of species and individual groups of target fish and indicator fish was 42 species (376 individuals) and 12 species (118 individuals), respectively. Although English et al. (1997) and Madduppa et al. (2012) classify Labridae species as major fish, several species were included in the target fish group due to their importance to Papua fishermen., such as *Bodianus anthioides*, *Bodianus mesothorax*, *Cheilinus chlororus*, *Cheilinus fasciatus*, *Cheilinus tribolatus*, *Halichoeres argus*, and *Hemigymnus melapterus*.

Abundance and Ecological Index of Reef Fish Communities

The abundance of reef fish at the study sites ranged from 112 to 215 individuals/125 m^2 (Table 3). Ecological indices values ranged between 2.468 to 3.358, 0.770 to 0.887, and 0.047 to 0.155 for diversity index, evenness index, and dominance index, respectively. The higher diversity and evenness index values are inversely proportional to the lower dominance index. However, there are certain reef fish species that have a high dominance index compared to other reef fish species, such as *N. filamentosus* (C = 0.031) at S1 site, *Z. cornutus* (C = 0.025) at S2 site, *N. savayensis* (C = 0.079) at the S3 site, *C. ternatensis* (C = 0.122) at the S4 site, *C. cyanocheilus* (C = 0.012) at the S6 site, and *P. moluccensis* (C = 0.018) at the S7 site.

Analysis of Similarity Index

The results of the analysis of the similarity index between sites using nMDS showed a stress value of 0.06 so that the resulting nMDS plot had a good representation (Figure 2). Based on the number of individuals for each reef

Table 2. Richness of reef fish species in each site surveyed in Yos Sudarso Bay, Jayapura City, Indonesia (M = major fish; T = target fish; and I = indicator fish).

Family and Species	S1	S2	S3	S4	S5	S6	S7	Total	Fish Category
Acanthuridae									
Ctenochaetus cyanocheilus	14	15	11	4	13	23	15	95	T
Ctenochaetus binotatus	4	4	7	7	10	9	12	53	T
Zebrasoma scopas	-	18	13	1	10	9	2	53	T
Ctenochaetus striatus	4	8	-	-	9	20	10	51	T
Acanthurus nigrofuscus	3	-	-	-	11	4	11	29	T
Acanthurus lineatus	2	1	-	-	-	12	-	15	T
Acanthurus maculiceps	-	4	-	-	-	-	-	4	T
Acanthurus pyroferus	-	-	-	2	-	1	-	3	T
Acanthurus thompsoni	3	-	-	-	-	-	-	3	T
Acanthurus leucosternon	1	-	-	-	-	-	-	1	T
Naso lituratus	-	-	-	-	-	-	1	1	T
Apogonidae									
Nectamia savayensis	-	-	45	-	-	-	-	45	M
Taeniamia zosterophora	-	-	28	-	-	-	-	28	M
Cheilodipterus artus	-	-	2	-	-	-	-	2	M
Ostorhinchus multilineatus	-	-	-	-	1	-	-	1	M
Balistidae									
Sufflamen chrysopterum	-	1	-	-	-	1	1	3	M
Balistapus undulates	-	-	-	-	-	1	-	1	M
Blenniidae									
Meiacanthus grammistes	-	-	-	-	-	-	2	2	M
Centriscidae									
Centriscus scutatus	-	13	-	-	-	-	-	13	M
Chaetodontidae									
Chaetodon trifasciatus	-	7	7	3	6	1	3	27	I
Chaetodon vagabundus	-	9	-	9	5	4	-	27	I
Chaetodon triangulum	-	6	1	-	4	4	3	18	I
Heniochus chrysostomus	-	8	1	2	2	-	2	13	I
Chaetodon citrinellus	-	2	-	-	-	9	1	12	I
Chaetodon kleinii	-	-	-	-	4	1	2	7	I
Chaetodon rafflesi	-	-	1	2	-	-	2	5	I
Chaetodon ornatissimus	-	-	3	-	-	-	-	3	I
Chaetodon meyeri	-	-	-	-	1	-	-	1	I
Chaetodon oxycephalus	-	1	-	-	-	-	-	1	I
Forcipiger longirostris	-	-	-	-	-	-	1	1	I
Heniochus varius	-	-	-	-	-	1	-	1	I
Cirrhitidae									
Paracirrhites forsteri	1	-	-	-	-	2	-	3	M
Amblycirrhitus bimacula	-	-	-	-	1	-	-	1	M
Cirrhitichthys falco	-	-	-	-	1	-	-	1	M
Diodontidae									
Lophodiodon calori	-	-	-	-	1	-	-	1	M
Gobiidae									
Cryptocentrus cinctus	-	-	-	-	1	-	-	1	M
Eviota punctulata	-	-	-	-	-	1	-	1	M
Haemulidae									
Plectorhinchus lineatus	-	2	-	-	-	-	-	2	T
Plectorhinchus polytaenia	-	1	-	-	-	-	-	1	T
Holocentridae									
Myripristis kuntee	-	-	3	-	-	-	2	5	T
Neoniphon sammara	-	-	4	-	-	-	-	4	T
Myripristis amaena	-	-	-	-	-	-	2	2	T
Sargocentron diadema	-	-	-	-	-	1	1	2	T

Table 2. Contd.

Family and Species	S1	S2	S3	S4	S5	S6	S7	Total	Fish Category
Myripristis berndti	-	-	1	-	-	-	-	1	T
Labridae									
Thalassoma hardwicke	2	8	1	-	2	3	1	17	M
Thalassoma lunare	-	-	-	-	1	2	5	8	M
Cheilinus chlorourus	-	1	-	2	1	1	1	6	T
Labroides dimidiatus	-	1	4	1	-	-	-	6	M
Halichoeres argus	-	3	-	-	-	-	-	3	T
Hemigymnus melapterus	-	-	3	-	-	-	-	3	T
Labrichthys unilineatus	-	-	3	-	-	-	-	3	M
Stethojulis trilineata	-	2	-	-	1	-	-	3	M
Anampses elegans	-	1	-	-	1	-	-	2	M
Bodianus anthioides	-	-	-	-	-	2	-	2	T
Bodianus macrourus	-	-	-	-	2	-	-	2	T
Bodianus mesothorax	-	-	-	-	1	1	-	2	T
Halichoeres biocellatus	-	-	-	-	2	-	-	2	T
Stethojulis interrupta	-	-	-	-	2	-	-	2	M
Cheilinus fasciatus	-	1	-	-	-	-	-	1	T
Cheilinus trilobatus	-	-	-	-	1	-	-	1	T
Halichoeres hortulanus	-	-	-	-	1	-	-	1	T
Monacanthidae									
Cantherhines pardalis	-	-	-	-	2	-	-	2	M
Cantherhines dumerilii	-	-	-	-	-	1	-	1	M
Mullidae									
Parupeneus multifasciatus	-	2	-	-	2	3	-	7	M
Parupeneus bifasciatus	-	1	-	-	-	1	-	2	M
Nemipteridae									
Scolopsis bilineata	-	-	-	1	1	-	-	2	T
Scolopsis lineata	-	-	-	-	1	-	-	1	T
Scolopsis taenioptera	-	-	-	-	1	-	-	1	T
Ostraciidae									
Ostracion cubicum	-	1	-	-	-	1	-	2	M
Ostracion meleagris	-	-	-	-	-	-	1	1	M
Pempheridae									
Pempheris adusta	-	6	-	-	1	4	-	11	M
Pinguipedidae									
Parapercis hexophtalma	-	-	-	-	-	2	-	2	M
Parapercis millepunctata	-	1	-	-	-	-	-	1	M
Pomacanthidae									
Centropyge bicolor	-	3	-	-	-	-	2	5	M
Pomacentridae									
Pomacentrus moluccensis	-	-	11	1	-	9	22	43	M
Neopomacentrus filamentosus	19	20	-	-	-	-	-	39	M
Pomacentrus taeniometopon	-	-	-	-	10	13	10	33	M
Chromis ternatensis	-	-	-	30	-	-	-	30	M
Plectroglyphidodon dickii	5	-	-	-	8	9	3	25	M
Chromis margaritifer	2	-	4	1	-	9	5	21	M
Chrysiptera cyanea	-	-	-	-	-	9	10	19	M
Plectroglyphidodon lacrymatus	14	-	-	-	-	-	-	14	M
Chrysiptera unimaculata	-	-	-	-	-	13	-	13	M
Chromis caudalis	8	-	-	-	-	-	3	11	M
Pomacentrus reidi	-	-	-	-	11	-	-	11	M
Abudefduf vaigiensis	10	-	-	-	-	-	-	10	M
Chromis xanthura	7	-	-	-	2	-	-	9	M
Pomacentrus armillatus	2	-	-	-	-	-	6	8	M
Neoglyphidodon nigroris	-	7	-	-	-	-	-	7	M
Amblyglyphidodon aureus	-	-	-	6	-	-	-	6	M

Table 2. Contd.

Family and Species	S1	S2	S3	S4	S5	S6	S7	Total	Fish Category
Pomacentrus lepidogenys	-	-	-	-	-	-	6	6	M
Amblyglyphidodon leucogaster	-	-	-	-	4	-	-	4	M
Pomacentrus brachialis	2	-	-	-	-	-	2	4	M
Pomacentrus emarginatus	4	-	-	-	-	-	-	4	M
Amphiprion frenatus	-	-	-	-	-	-	3	3	M
Amphiprion sebae	-	-	-	3	-	-	-	3	M
Chromis lepidolepis	-	-	-	-	3	-	-	3	M
Chrysiptera brownriggii	-	-	-	-	-	3	-	3	M
Pomacentrus littoralis	-	-	-	3	-	-	-	3	M
Amphiprion clarkii	-	-	-	-	-	-	2	2	M
Amphiprion polymnus	-	-	-	2	-	-	-	2	M
Chromis atripectoralis	-	-	1	-	-	1	-	2	M
Chromis retrofasciata	2	-	-	-	-	-	-	2	M
Pomacentrus bankanensis	-	-	-	-	-	1	1	2	M
Pomacentrus nigromarginatus	-	-	-	-	-	-	2	2	M
Abudefduf septemfasciatus	-	-	-	1	-	-	-	1	M
Abudefduf sexfasciatus	-	-	-	1	-	-	-	1	M
Chromis opercularis	-	-	-	-	-	1	-	1	M
Dascyllus reticulatus	-	-	-	-	1	-	-	1	M
Scaridae									
Calotomus spinidens	-	4	1	-	-	1	-	6	T
Chlorurus bleekeri	-	4	-	-	1	1	-	6	T
Scarus oviceps	-	-	1	-	1	-	-	2	T
Scarus globiceps	-	-	-	-	1	-	-	1	T
Scarus hypselopterus	-	-	1	-	-	-	-	1	T
Scorpaenidae									
Pterois volitans	-	-	-	-	-	1	-	1	M
Serranidae									
Cephalopholis argus	-	-	-	-	-	1	-	1	T
Siganidae									
Siganus canaliculatus	-	-	-	2	-	-	-	2	T
Tetraodontidae									
Arothron caeruleopunctatus	-	-	-	-	-	2	-	2	T
Arothron nigropunctatus	-	-	-	-	1	-	-	1	T
Canthigaster papua	-	-	-	-	-	1	-	1	T
Canthigaster valentini	-	-	1	-	-	-	-	1	T
Zanclidae									
Zanclus cornutus	-	31	2	2	2	15	2	54	M
Number of species	20	34	26	22	45	46	37		

fish species, three groups were obtained that had similarities based on the similarity index analysis. The three groups are group A consisting of one sub-district (S1), group B consisting of four sub-districts (S2, S5, S6, and S7), and group C consisting of two sub-districts (S3 and S4). The average similarity of groups B and C was 42.12% and 30.33%, respectively. Five fish species that contributed to group B were *C. cyanocheilus* (11.90%), *C. striatus* (9.35%), *C. binotatus* (8.02%), *Z. scopas* (7.05%), and *C. triangulum* (5.93%). Meanwhile, five fish species that contributed to group C were *C. binotatus* (19.18%), *C. cyanocheilus* (14.50%), *C. trifasciatus* (12.56%), *Z. cornutus* (10.25%), and *Z. scopas* (7.25%).

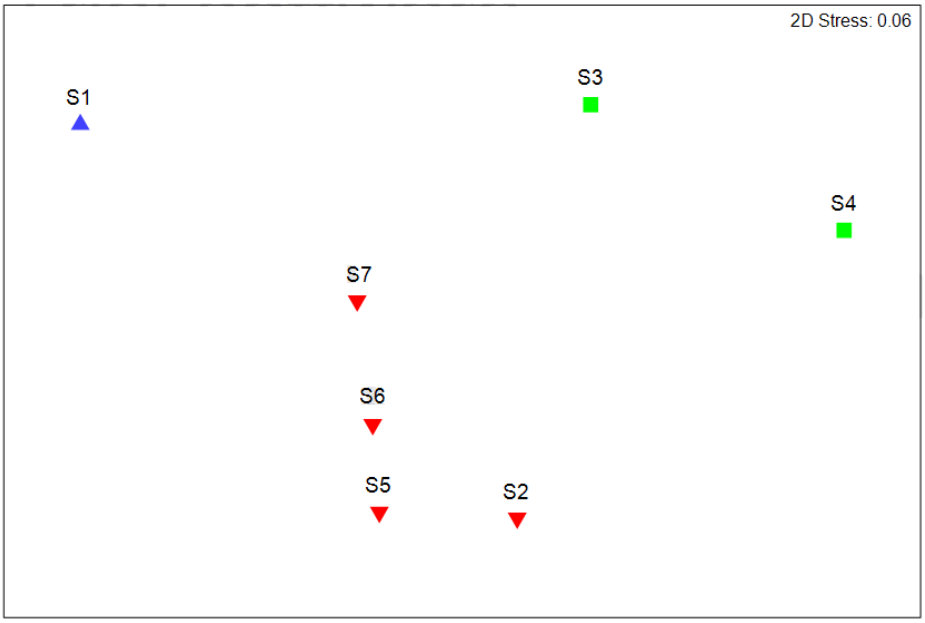

Figure 2. nMDS plot based on Bray-Curtis similarity showing three group associations of 123 species of reef fish at seven sites.

Discussion

The results of this study provide an overview of the diversity of reef fish species in the Yos Sudarso Bay, Jayapura City. The number of reef fish species and families found in this study is relatively the same as the reef fish diversity in Depapre Bay (Tanah Merah Bay) Jayapura Regency. The results of the study by Paulangan et al. (2019a), found 130 species of reef fish from 26 families in seven observation sites in Depapre Bay, Jayapura Regency. However, several species and families of reef fish found in the Depapre Bay were not found at this study site, such as reef fish species which belongs to the target fish group of the Caesionidae, Lutjanidae, and Lethrinidae families, as well as major fish groups from the Pseudochromidae family. Besides, the number of individual reef fish found was greater than the results of this study. Generally, apart from their relatively close location, the characteristics of the coral reef ecosystem in the two locations are also relatively similar, namely fringing coral reefs with live coral cover in the moderate to good category (32.00-60.00% in Yos Sudarso Bay and 46.33-68.00% in Depapre Bay) which is dominated by Coral Massive, Acropora Branching, Acropora Tabulate, and Coral Branching (Paulangan et al. 2019b; Hamuna et al. 2019).

In this study, the number of individuals from the target fish group of the Acanthuridae family, such as *C. binotatus*, *C. cyanocheilus*, *C. striatus*, and *Z. scopas* (only *C. binotatus* and *C. cyanocheilus* found at all study sites) were found to be higher compared to reef fish species from the Pomacentridae family (major fish group). The high abundance of target fish from the Acanthuridae family can indicate that all study sites are potential reef fishing grounds. This result was shown from interviews with several fishermen that medium to large size reef fish of the Acanthuridae family were their catch targets, in addition to target fish from the Labridae, Scaridae, Siganidae, and Holocentridae families. Generally, diversity, presence, and absence of target fish species

can be used as a guide in monitoring the condition of coral reef ecosystems and the status of coral reef capture fisheries (Gisawa & Lokani 2001), can also be used as a guide to the level of disturbance anthropogenic (Obura & Grimsdith 2009), especially reef fish species of the Serranidae, Lutjanidae, Lethrinidae, and Haemulidae families (Suharti et al. 2014).

The ecological index is an indicator that indicates the health status of the community, where higher ecological parameter values will indicate the community is stable, and vice versa (Magurran 1991). According to Galib et al. (2013), the diversity index provides more information to determine the condition of species in a community than mere information on the number and abundance of species. In this study, the results of diversity index analysis showed that the reef fish community in S5, S6, S7, and S2 sites were classified as high and more diverse, and the reef fish community was stated to be more stable than S1, S3, and S4 sites (reef fish diversity is classified as moderate). The higher diversity of fish species results in a more stable fish community (Albaret & Lae 2003). The evenness index in each study site is high, on the contrary, the dominance index shows a low value. The values of these two indicate that the abundance and distribution of reef fish species in each study site are almost the same (high level of evenness) and no specific reef fish species dominate (there is no concentration of individual fish in one particular species in each study site). However, the nMDS plot shows that the six sites inside Yos Sudarso Bay form a separate group from those outside Yos Sudarso Bay. This shows that the reef fish community structure (number of species and abundance) between the two types of sites is different.

Overall, the results of this study have provided preliminary information on the species diversity and ecological indices of reef fish in Yos Sudarso Bay, Jayapura City. We realize that there are still many limitations to this study so that some reef fish species that have been reported in previous studies were not recorded in this study, such as several types of reef fish from the Chaetodontidae family found by Hamuna et al. (2019) and several reef fish species found in seagrass ecosystems reported by Tebaiy et al. (2014). Therefore, to improve the database of reef fish species diversity in Jayapura City, further studies are needed by considering the addition of the number of sites and observation transects, placement of transects at different water depths, and different seasons. This is very important because it will have an impact on the diversity and abundance of reef fish found. To preserve the coral reef ecosystem as a habitat for reef fish, it is necessary to have regulations from the local government. This is due to the practice of destructive fishing on coral reefs using explosives (although with a low incidence) carried out by local communities which is still common today. This regulation is expected to suppress the destruction of coral reef ecosystems which have a direct impact on increasing the diversity and abundance of reef fish.

CONCLUSION

In this study, preliminary information was obtained about the diversity, abun-

dance, and ecological index of reef fish in Yos Sudarso Bay, Jayapura City. The diversity of reef fish species and families is quite high. The results also showed that the reef fish diversity index was moderate to high with an even distribution of reef fish species in each study site. Further research is needed to determine the exact diversity of reef fish by considering the addition of the number of locations and observation transects, placing transects at water depths and in various profiles of coral reef habitats, as well as conducting observations in different seasons. This is very important because it will have an impact on the diversity and abundance of reef fish found.

AUTHORS CONTRIBUTION

Research design: BH, LD; field data collection: BH, LD; data analysis: BH, LD, AA; financial gain: BH, LD; original manuscript writing: BH, AA; manuscript revision: BH, AA.

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CONFLICT OF INTEREST

The authors declare no competing interests regarding the research or the research funding.

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