Biodiversity of Reef Fishes in Three Small Outer Islands of West Papua, Indonesia

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Abstract

Coral fish groups have a very strong dependence on coral reef ecosystems. Nusa Manggala Expedition was carried out for twenty days to explore basic data on the diversity of species of coral reef fish in the Liki, Bepondi, and Miossu Islands. Assessment of coral fish assemblages using Underwater Visual Census (UVC). Four hundred and thirty-two species of fifty families of reef fishes found during the 2nd session the Nusa Manggala expedition in Liki, Bepondi, and Miossu islands, northern Papua. Four species (Mobula tarapacana, M. alfredi, Oxymonacanthus longirostris, Bolbometopon muricatum, and Plectropomus areolatus) and one species (Cheilinus undulatus) categorized of IUCN as Vulnerable (VU) and Endangered (EN), respectively, were recorded in this study. There is unique pattern of reef fishes' composition in small outer islands location in pristine location that shows Pomacentridae and Labridae were almost in the same number as Gobiidae, Apogonidae, Serranidae, Chaetodontidae, and Acanthuridae. In addition, the results showed that the Liki and Miossu islands and Bepondi Island included at the Coral Fish Diversity Index (CFDI) as an extraordinary and excellent category of marine fish, respectively. The results of the expedition showed that the Liki Islands and Miossu Island had an extraordinary category of marine fish, and Bepondi Island had an excellent category of sea fish. The culture of local people in Papua called "Sasi" prove to provide full protection to the ecosystem and have a positive impact on high diversity of reef fishes.

Keywords: Biodiversity, Marine Fishes, Liki, Bepondi, Miossu Islands

Introduction

Coral reefs are the most biological diverse marine ecosystems in the world (Kench and Owen, 2014) and most diverse animal community associations in nature (Corrales *et al*., 2015) both by species richness and the number of interrelations between species (Planes *et al*., 2012) in spatial and temporal variations (McClanahan, 2019). Coral reefs are a unique system that represents a balance between ecological and physical processes (Kench and Owen, 2014) and supports social and economic development (Hughes *et al*., 2003). The highest coral reef diversity and marine biodiversity in the world lies in the Coral Triangle (CT) region (Tornabene *et al*., 2015) and the most important center of marine biodiversity in Asia (Hoeksema, 2007). The Coral Triangle stretching across six countries in Southeast Asia and the Pacific (Indonesia, Philippines, Malaysia, Papua New Guinea, Solomon Islands, and Timor Leste) (Ferrigno *et al*., 2016) with total diversity of up to 76% of the total complement coral species in the world (Veron *et al*., 2009). The high biodiversity in CT is due to its position across the boundary between the Indian Ocean and the Pacific Ocean (Tornabene *et al*., 2015) and Indonesia, Malaysia and the Philippines

islands (IMP) are centers of high biodiversity of marine organisms in CT (Bellwood *et al*., 2014). The IMP Islands has been proposed for the past several decades by biogeographers (Veron *et al*., 2009). The CT is also known as the highest global fish diversity on coral reefs distributed (Allen, 2008; de Brauwer *et al*., 2019) and tends to accumulate in the IMP Islands region (Hubert *et al*., 2012) with North Sulawesi (Indonesia) as the center of reef fishes diversity (Allen, 2008).

Global report and investigated from (Burke *et al*., 2012) the CT's reefs in increasing stresses and threaten more than 85 % of the CT's reefs, and maybe the numbers can change because there are still many locations in the CT area that not yet known about the condition of coral reefs and marine biota, especially in outer islands location in Indonesia. The critical problem is the lack of research on the outer island due to relatively far away from the mainland, high risk, high-cost studies, and limitation of transportation, and one of the best for research in the outer island by conducting expedition activities. The expedition experiments on the function of ecosystem biodiversity in the outer reef have provided new insights into community and ecosystem ecology (Gamfeldt and Hillebrand, 2008) with the primary goal of the expedition is to uncover ecological function causes of variation species diversity (Arias-González *et al*., 2008), especially in reef fishes. One of the main challenges in this expedition experiment is to explain the existing patterns of reef fishes biodiversity in the outer island based on ecology (de Brauwer *et al*., 2019) so that the main focus in expedition studies is to build a theoretical framework for understanding reef fishes biodiversity (Harborne *et al*., 2006) and related to structural complexity in the outer island. Several studies have shown fish diversity is related principally to structural complexity and coral cover (Chabanet *et al*., 2016) and there is a positive correlation between structural complexity with abundance and diversity of reef fish in temperate and tropical ecosystems (Rogers *et al*., 2014). The structural complexity of habitat coral reefs resulting from species diversity and forms of coral growth provides a host the highest diversity of reef fish and coral species in different spatial and temporal scales.

The COREMAP-CTI and Research Center for Oceanography, Indonesian Institutes of Sciences (PPO-LIPI), has initiate conducted a comprehensive study in outer islands of the heart of the CT area with Nusa Manggala Expedition. This expedition is an exploration research activity that provides baseline data and information on natural and non-natural resources on the small outer islands (SOI) in eastern Indonesia. SOI targeted by Nusa Manggala expeditions including three outer islands of Papua. Twenty days of expedition exploring the baseline data of coastal ecology and identify the condition of all flora and fauna species in SOI comprehensively, including coral reefs, reef fish, and mega benthos. From this research, the main goal is to understand the condition of the diversity of coral fish related to structural habitat complexity in Indonesia's outer islands at the center of the world's coral triangle (Papua).

Materials and Methods

Study sites

The three (3) locations of Small Outer Islands (SOI) in the eastern part of Indonesia were chosen for this expedition. These included Liki Island, Bepondi Island, and Miossu Island belong to West Papua, which directly facing the Pacific Ocean. A total of 13 study sites were 6 sites in Liki Island (LIKC.02, LIKC.04, LIKC.06, LIKC.09, LIKC.21, and LIKC.26); 3 sites in Bepondi Island (BEPC.01, BEPC.04, and BEPC.07) and 4 sites in Miossu Islands (MIOC.02, MIOC.12, MIOC.25, MIOC.34) (Figure 1.).

Assessment of reef fishes

Assessment of marine fish assemblages using Underwater Visual Census (UVC) (Corrales *et al*., 2015; Putra *et al*., 2018; 2022). The UVC methodology is universally used in marine studies to assess the diversity and abundance of invertebrates, macroalgae and reef fish (Jones *et al*., 2015), also to be able to estimate biomass in reef fishes by recording total length of fish encountered (Cresson *et al*., 2019). Marine fish species recorded by modification of belt transect from (Chabanet *et al*., 2016) encountered along the 70 m transect line with maximum depth 30 m using SCUBA diving equipment were laid out parallel to the shore (Corrales *et al*., 2015; Putra *et al*., 2019). The primary method to record the reef fish species was based on Allen and Werner (2002) with underwater observations sampling time of 50–80 min dive at each site and set in the area of study of 350 m². The name of each species encountered was written on an underwater sheet attached to a slate and was identified to the lowest taxonomy possible (Corrales *et al*., 2015). More comprehensive taxon identifies marine fishes based on (Allen *et al.,* 2003) and FishBase.

Fish IUCN status

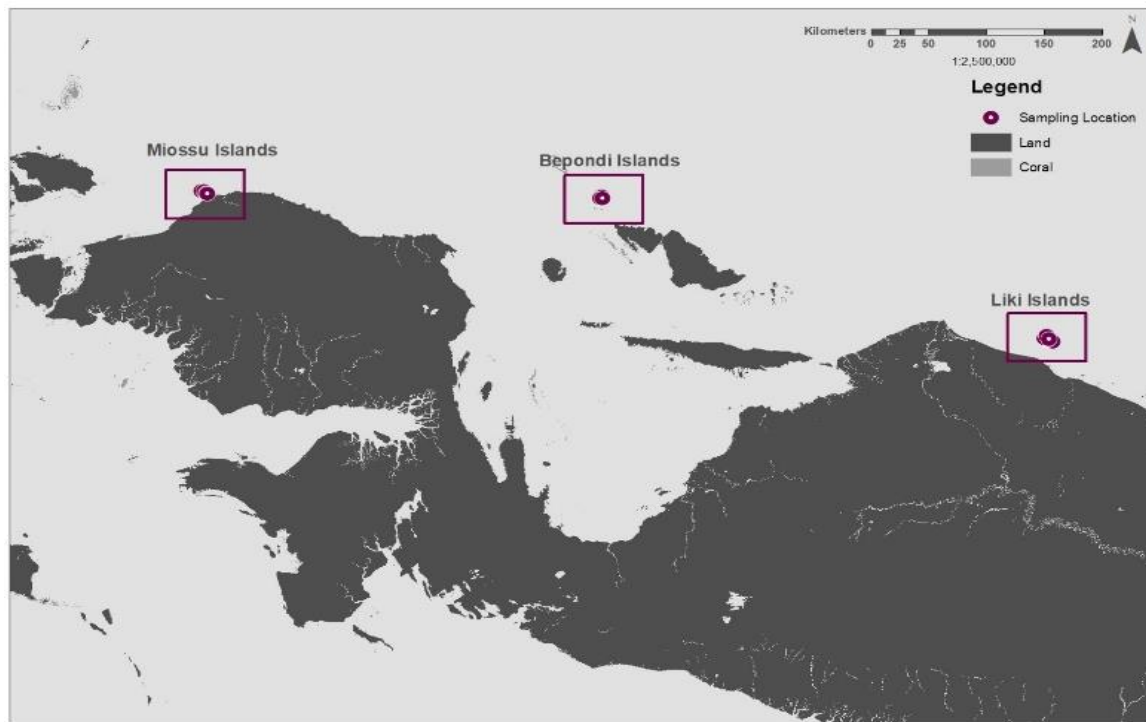The IUCN status was retrieved from https://lsland.iucnredlist.org for coral reef fishes and

Figure 1. The Map of study sites in Nusa Manggala Expedition 2nd session for Small Outer Islands (Liki Islands, Bepondi Island, and Miossu Islands) – Papua

was grouped by their threat level categories, i.e. Critical Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), Not Applicable (NA) and Not Evaluated (NE). For interpretation of IUCN status Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) species as "Threatened"; Near Threatened (NT), Least Concern (LC) species as "Not Threatened"; Data Deficient (DD) as "Data Deficient"; Not Applicable (NA) and Not Evaluated (NE) as species without known status as "Not Evaluated' (Grenié *et al*., 2018)

Diversity analysis

Reef fishes indices such as the Coral Fish Diversity Index (CFDI) have been established to qualify the conditions of reef fish diversity and populations (Gomez, 2004). CFDI indices by Allen and Werner (2002) can be applied to determine the number of conspicuous species missed during the visual census (Fordyce, 2018). The CFDI is one of important tools to identify the status of reef fish in shallow coral reef ecosystem and was used as indicator analysis of diversity reef fishes. The CFDI values can estimate the total coral reef fish of a particular locality by means of regression formulas accurately (Donnelly *et al*., 2003). The CFDI value devised a convenient method for assessing and

comparing overall reef fish diversity (Allen and Werner, 2002). Based on Allen and Werner (2002), the development of the CFDI was to respond to the requirement of a convenient method for assessing and comparing coral reef fish diversity among regions in the Indo-Pacific. They also has compiled a scoring system based on the number of species present in the following six families: Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae, and Acanthuridae. CFDI as the predictor variable (x) for estimating the independent variable (island) or total coral reef fishes fauna wherein areas less than 2000 km². A theoretical of Relative Biodiversity (RB) is then generated using the equation RB= 3.39 (CFDI) – 20.595 (Table 1.). For more comprehensive analysis, marine fish assemblages in each smalls island location (Liki, Bepondi and Miossu) was compared using some biodiversity indices including, Shannon-Wiener indices (*H'*) (Shannon, 1948), Evenness indices (*J*), Simpson's Dominance indices (*D*) and the Effective number of species (ENS) by (Jost *et al*., 2010).

Result and Discussion

General fish community composition

A total of 435 recorded species belong to 147 genera and 50 families of reef fish were found during the expedition in the Liki, Bepondi, and Miossu

Islands. Based on family ranking, most of the Islands show an almost similar pattern, with Labridae (wrasse), Pomacentridae (damselfishes), Acanthuridae (surgeonfishes), Chaetodontidae (butterflyfishes) and Scaridae (parrotfishes) was a top-five family of reef fish (Figure 2.). The Liki, Bepondi and Miossu are the locations nearly close to the equator with low latitudes gradient in heart of the world's Coral Triangle (Figure 1). The geographical location of these islands were also close to Raja Ampat Islands in West Papua with the famous highest marine biodiversity distribution. Therefore it provided a considerable influence on the reef fishes biodiversity in the Liki, Bepondi and Miossu. This result were similar with study by Mumby (2001) in which the biodiversity varied with biogeographic scale and with longitude and latitude gradients (Bellwood *et al*., 2014). Previous research showed that species richness was increased by decreasing latitude (Chabanet *et al*., 2016) and influence the abundance and biomass of reef fishes. The influence of latitudes and longitudes on the diversity of fish were shown by the water quality and environmental conditions. Cummings *et al*. (2011), showed that the higher latitude has impact on the water quality, including higher rates of ocean acidification, lower temperatures (Roberts *et al*., 2002), higher variation of sea surface temperature

and wave-generated turbulence (Choat and Bellwood, 1991). So the location of Liki, Bepondi and Miossu in Lower Latitude has a positive influence on the growth of the coral skeleton and reef fishes diversity.

In present works, the three outer islands showed a similar dominant fish family, i.e. Labridae, Pomacentridae, Acanthuridae, Scaridae, Chaetodontidae, and Serranidae (Figure 2.), those islands have low anthropogenic pressure. Labridae and Pomacentridae are the most abundant fish families in terms of the diversity (Pratchett *et al*., 2013). They have higher phylogenetic relation in Indo-Pacific locations (Cowman, 2014). Previous studies of Nunez-Lara *et al*. (2016) explained that Pomacentridae and Labridae were dominant in terms of the relative diversity and abundance. They also comprise more than 50 percent of the fishes on the reef, the rests were Gobiidae, Apogonidae, Serranidae, Chaetodontidae, and Acanthuridae (Allen, 2000). This is contrary with our findings in pristine location that shows Pomacentridae and Labridae were almost in the same number as Gobiidae, Apogonidae, Serranidae, Chaetodontidae, and Acanthuridae. This composition shows that the Liki, Bepondi, and Miossu still have undisturbed natural habitat.

Table 1. Interpretation of CFDI values in terms of relative categories by Allen and Werner (2002)

Relative Biodiversity (RB)	Single Site	Restricted Area	Country-Region
Extraordinary	> 150	> 330	> 400
Excellent	130 - 149	260 - 329	330 - 399
Good	100 - 129	200 - 259	220 - 329
Moderate	70 - 99	140 - 199	160 - 219
Poor	40 - 69	50 - 139	80 - 159
Very poor	< 40	< 50	< 80

Figure 2. The Family ranking of Reef Fishes in three Small Outer Islands - Papua; A) Liki Islands, B) Bepondi Island, and C) Miossu Islands)

IUCN Red List categories of reef fish species

Out of one hundred and twenty individuals of 15 species reef fishes in present study were belong to several status according to IUCN Red List, i.e. 9 species were Near Threatened (NT) categories, four species were Vulnerable (VU) categories, and one species was Endangered (EN) categories (Figure 3.). The highest reef fishes density which were in the Red list species was observed in MIOC.25 (Miossu Islands) with the total individual (*n*) of 21 individuals in the area of 350m², and species richness (SR) was seven. Furthermore, in MIOC.25 (Miossu Islands) there is the highest population of Endanger Species (EN) of *C. undulatus*. The higher density of Vulnerable (VU) species observed in Liki Island (LIKC.026 and LIKC.21), both of sites location had density and species richness (n= 26, SR= 6) and (n= 15, SR= 4), respectively. In addition, the higher density of Near Threatened species was observed in Bepondi Islands (BEPC.04) with density (n) 12 individuals in the area of 350m² and species richness (SR) was 2 species.

The outer islands do not only show the high fish diversity but also the places of some endangered species. The low level of exploitation and the environment in good condition provides the species to grow. Our result found 15 species marine fishes from Near Threatened (NT) to Endangered Species (EN) categories in the IUCN Red List Status, including several shark species, Parrotfishes species, Butterflyfishes species, Grouper species, Ray, mackerel species, Filefish species and Wrasse species. Five species identified as vulnerable categories, including *Mobula tarapacana*, *M. alfredi*, *Bolbometopon muricatum*, *Oxymonacanthus*

longirostris, and *Plectropomus areolatus*. Two out of five vulnerable species were Manta rays which are pelagic elasmobranchs (*Mobula tarapacana* and *M. alfredi*). Another vulnerable fish species found in SOI West Papua was *B. muricatum* and known as the bumphead parrotfish. *B. muricatum* may serve as a keystone species in the Indo-Pacific coral reefs due to their role as a large excavator in the coral reef ecosystem (Obura and Grimsditch, 2009) and control the benthic algae (Knowlton and Jackson, 2017). The results show that the population of *B. muricatum* in Liki and Miossu is not as high as the population of other Scaridae species, but their presence in both locations show good habitat complexity in the coral ecosystem and signify that the several giant reef fishes were not threatened.

From all the threatened fish species, *C. undulatus* was categorized as Endanger species but could be found in almost all observation sites on the islands of Liki and Miossu. *Cheilinus undulatus* (The humphead wrasse), commonly known as the Maori or Napoleon wrasse, was the most significant member of Labridae family with enormous size among reef fishes with more than two meters in length and could reach up to 100 kg in weight (Sadovy *et al.*, 2007). It is believe that the high number of endangered species in Liki Bepondi and Miossu is partly due to local cultural customs known as *sasi*. *Sasi* plays an essential role in protecting ecosystems by preventing overexploitation of marine resources. *Sasi* has economic beneficial for the community and provides opportunities for all communities to be able to manage and utilize marine resources. The region that still maintains *Sasi* practices have a better condition of aquatic resources
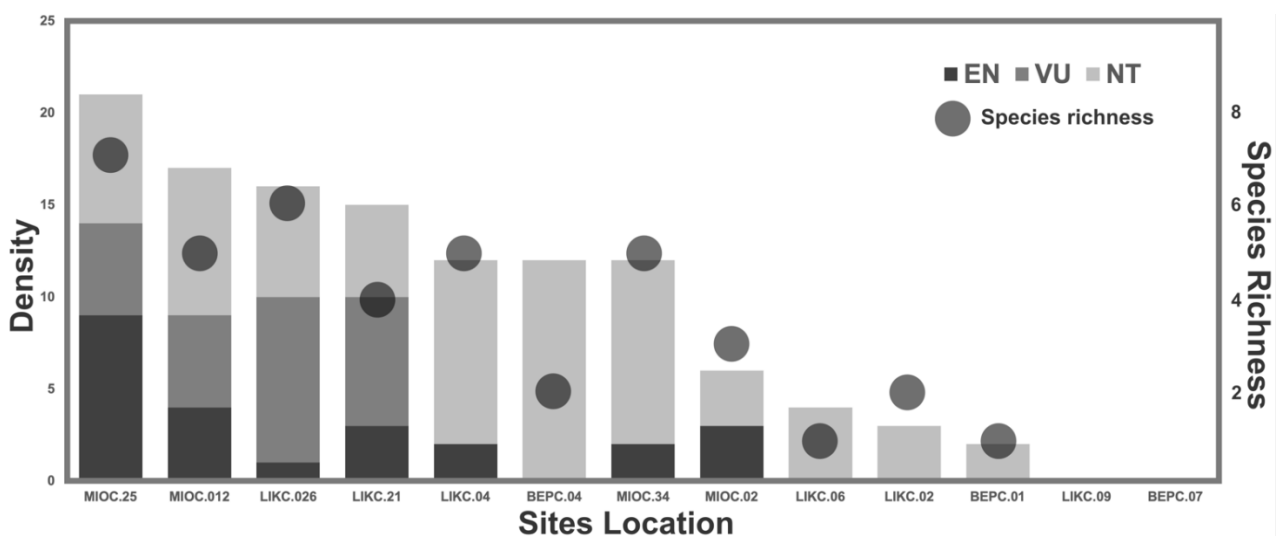

Figure 3. The density and Species Richness of coral reef fishes in Red List IUCN status (Near Threatened to Endanger Species categories) in each sites Small Outer Islands location.

compared to the area that have abandoned the practice (Boli *et al*., 2014). *Sasi* provides a culture habit for the local community which can conserve and use marine resources wisely and sustainable without exploiting over-utilization (Persada et al., 2018). The traditional Community Law of *Sasi* management model can be utilized as a useful tool for preventing over-harvesting of fish resources in Liki, Bepondi, and Miossu.

Coral Reef Fish Diversity Index (CFDI)

From three of outers small islands in Papua, Liki and Miossu had extraordinary categories of CFDI regression formula with the value of CFDI was 218 and 198, respectively. The component of regression model of CFDI in Liki Islands were Acanthuridae (33), Chaetodontidae (29), Labridae (59), Pomacanthidae (10), Pomacentridae (59), and Scaridae (28). While the component of CFDI model in Miossu were Acanthuridae (26), Chaetodontidae (28), Labridae (54), Pomacanthidae (11), Pomacentridae (51), and Scaridae (27). Bepondi Islands had excellent categories of CFDI with the following component, Acanthuridae (26), Chaetodontidae (28), Labridae (54), Pomacanthidae (11), Pomacentridae (51), and

Scaridae (27). Two site location studies had extraordinary categories of CFDI, i.e. LIKC.04 (CFDI =159) and MIOC.12 (CFDI =152). Most study sites in Bepondi Island (BEPC.01, BEPC.04, BEPC.07) had moderate categories of CFDI, and the value of CFDI were 84, 93, and 97, respectively. Most of the sites located in Liki and Miossu had a relative high of marine fish diversity with range CFDI value from 111

(LIKC.06) to 159 (LIKC.04). This was shown that the Relative Biodiversity based on CFDI value in Liki and Miossu categorize as Extraordinary and in Bepondi as Excellent Relative Biodiversity (Table 2.).

However, the diversity of reef fish in his present study sites was lower compared to Raja Ampat of Papua - with a CFDI value of 326 (McKenna *et al*., 2002). The total CFDI for the coral reef species in Raja Ampat Islands was as follows, Labridae (108), Pomacentridae (100), Chaetodontidae (42), Acanthuridae (34), Scaridae (28), and Pomacanthidae (25). According to (Donnelly *et al*., 2003) almost every sites location in Raja Ampat has an extraordinary category of CFDI value, including in Kofiau, Kri Island, Miosba, Misool, Keruo Island and Batanta. Two other regional locations that are ranked higher than Raja Ampat are Milne Bay in Papua New Guinea and Maumere Bay on the island of Flores of Indonesia with the value CFDI of 337 and 333, respectively (Donnelly *et al*., 2003). The world's leading country for reef fish diversity, based on CFDI values is Indonesia (McKenna *et al*., 2002). Previous studies by Allen and Adrim (2003) listed that Indonesia has the world's highest total Pomacentridae species (138), with the totals recorded for other areas Papua New Guinea (109), northern Australia (95), W. Thailand (60), Fiji Islands (60), Maldives (43), Red Sea (34), Society Islands (30), and Hawaiian Islands (15) (McKenna *et al*., 2002). From our results, it is believed that the value of the CFDI is influenced by biogeographic conditions that are very close to Raja Ampat and all research locations have unique characteristic because it directly faced the western equatorial Pacific Ocean and has varied oceanographic

Table 2. The Coral Fish Diversity Index (CFDI) in Small Outer Island Indonesia Papua (Liki Island, Bepondi Island and Miossu Island)

Sites	CFDI	Observed species	Estimated Species	Categorized
LIKC.02	121	177	390	Good
LIKC.04	159	242	518	Extraordinary
LIKC.06	111	181	356	Good
LIKC.09	123	194	396	Good
LIKC.21	118	175	379	Good
LIKC.26	139	216	451	Excellent
BEPC.01	84	128	264	Moderate
BEPC.04	93	156	297	Moderate
BEPC.07	97	140	308	Moderate
MIOC.02	141	215	457	Excellent
MIOC.12	152	234	495	Extraordinary
MIOC.25	140	211	454	Excellent
MIOC.34	127	180	410	Good
Liki Islands	218	371	715	Extraordinary
Bepondi Island	139	228	451	Excellent
Miossu Islands	197	333	651	Extraordinary

conditions, including deep water, clear visibility, dynamic wave, and currents conditions (Surinati and Corvianawatie, 2019). High CFDI values in Miossu Island was because it is in the western equatorial Pacific and characterized by the presence of warm sea surface temperatures (SST) and commonly known as "warm pools" (Nicol *et al*., 2014). The higher SST within the Indo-Pacific warm pool enhances diversity and species evolution, as mentioned by Sanciangco *et al*. (2013). That the warm SST in western equatorial pacific correlated significantly with species richness. Another environmental characteristic in Liki, Bepondi, and Miossu that caused high CFDI values were excellent clear water conditions in which several of sites had more than 20 meters visibility. The excellent visibility indicates less suspended sediment. The suspended sediments reduce water quality and may led to biodiversity loss and fundamental changes in fish assemblages on coral reefs (Hess *et al*., 2017).

Other ecological index of reef fish

Coral reef fish in small outer Islands location of Papua showed high biodiversity indices (Shannon-Wiener) with the *H'* value more than 4.0 (high categories). The coral fishes in Miossu Islands were generally more diverse than Liki and Bepondi with the mean of diversity index Shannon-Wiener in Miossu (*H'*) was (4.57±0.11 se; n= 4), followed by Shannon-Wiener diversity index in Liki, and Bepondi was (*H'*) (4.45±0.25 se, n= 6) and (4.30±0.13 se, n= 3), respectively. The Kruskal-Wallis test for diversity indices (Kruskal-Wallis chi-squared = 3.12, df=2, *P* = 0.21) showed that there was no significantly different of diversity in each location. In terms of species richness (*SR*) analysis showed that Liki and Miossu were significantly higher than Bepondi (Kruskal-Wallis chi-squared = 6.68, df=2, *P* = 0.036). Based on

Simpson dominance (*D*) index analysis, there was no dominated species in all location. The true diversities analysis with an Effective Number of Species (ENS) showed that Liki Islands had a similar mean diversity as a community of 88 equally common species. In comparison, both of Bepondi and Miossu had mean ENS value were 74 and 97 equally common species, respectively (Figure 4.).

The Liki, Bepondi, and Miossu is close to the center of world marine diversity, especially the Miossu Islands which is located on the head of a Bird's Head Papua (Figure 1.). Previous studies of Allen and Erdmann (2009) showed that reef fishes in the Bird's Head Peninsula are the most diverse in the CT. The high diversity of coral reefs supports the diversity of fish in Liki, Bepondi, and Miossu. Studies showed that there was a strong positive correlation between coral reef habitat (coral cover) with the abundance and diversity of reef fish (Komyakova *et al*., 2013). Based on present results, for islands with similar characteristics, the value of fish diversity decreased from the center (Miossu) - West to East Papua location (Liki) (Figure 2.), except for Bepondi which has different characteristics. Previous studies of Allen (2008) revealed that the diversity of reef fish is also slowly decreased from the central North Sulawesi (Indonesia) heading west across the Indian Ocean and the lowest diversity of fish and coral reefs found in the Caribbean (Pratchett *et al*., 2011). The studies from McKenna *et al*. (2002) also reported that the species richness (SR) generally decreases with further distance from the Coral Triangle. Sanciangco *et al*. (2013) explained that beside the latitude, the species richness was also significantly influenced by longitudinal, and the peak of species richness was found along the 130–150° east, in which Liki, Bepondi and Miossu are located.
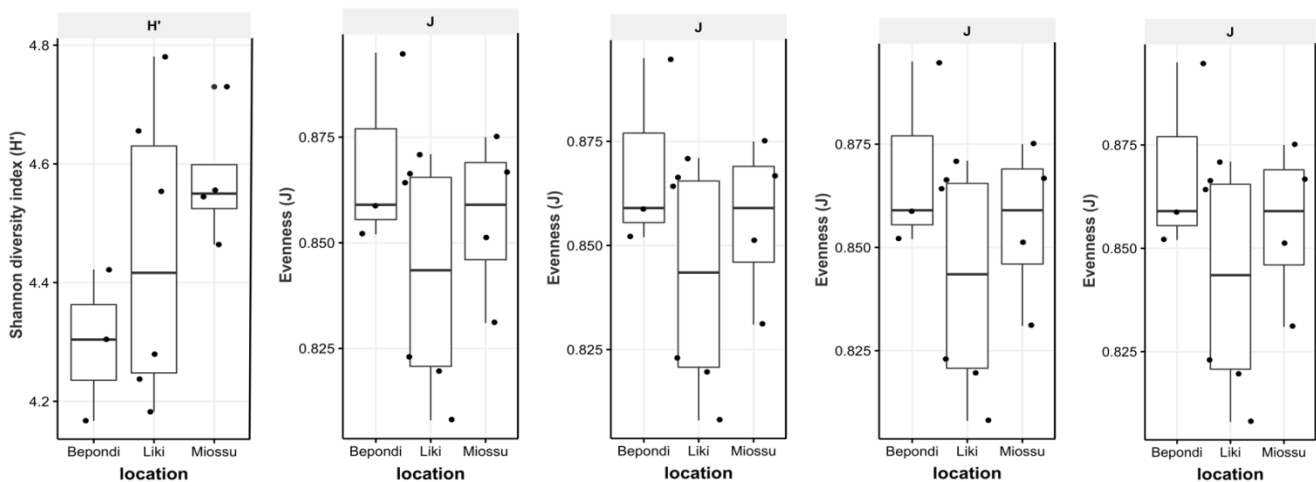

Figure 4. Marine Biodiversity Indices (*H'* = Shannon-Weaver Index, Evenness Equitability (J), D = Simpson Dominance, SR = Species Richness, ENS = Effective Number Species) between three locations of SOI- Papua (Liki, Bepondi and Miossu
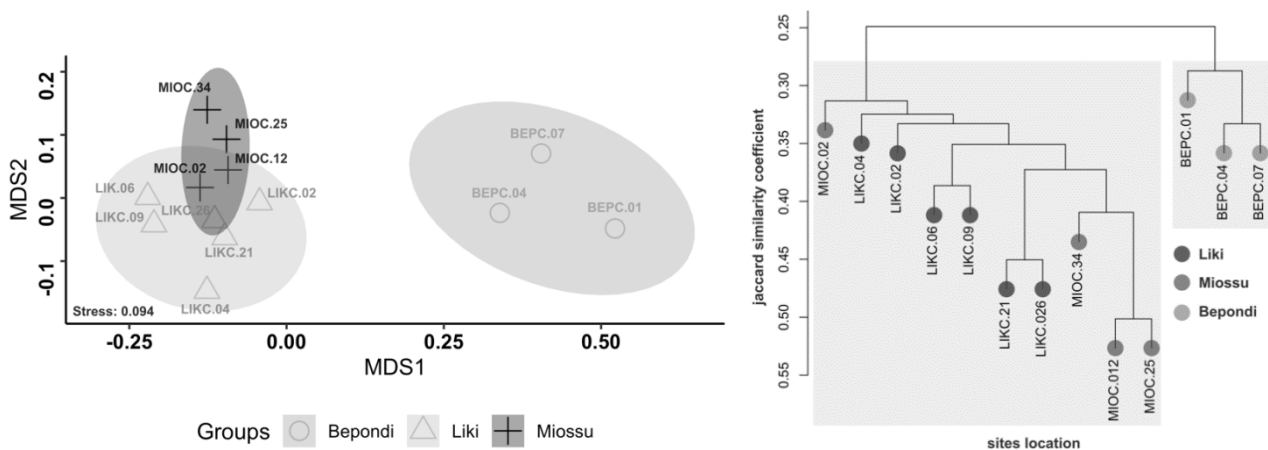
Figure 5. Non-metric multidimensional scaling (nMDS) analysis of Bray-Curtis dissimilarity index. Each sample is labelled by sites location and reef fishes composition. The ellipses represent 95% confidence intervals for samples collected at the same sites location (left). Dendrogram showing the hierarchical cluster analysis from Jaccard similarity coefficient of sites location (right)

The multivariate non-metric multidimensional scaling ordination (nMDS)

The nMDS showed clear differences in marine fish composition among sites, although Liki and Miossu were clustered and had an overlapping pattern, and based on the ANOSIM test, Bepondi Island had different fish composition (R= 0.494, *P*< 0.05). The final data set of reef fish composition in three locations of outer Islands Papua by Hierarchal Cluster Analysis (HCA) using dendrogram resulted two differential cluster (Liki-Miossu group) and (Bepondi Group). Liki and Miossu islands have almost the similar coral reef habitat conditions with steep reef slope (Figure 5). Most of the research sites location have more than 50% coral cover with live corals found up to a depth of 20 meters. The Bepondi Island has different habitat characteristics from Miossu and Liki with reef flat. The habitat condition in Bepondi Island has differed from Liki and Miossu with extensive reef flat condition and had the fair categories with around 20-40% coral cover. The coral in Bepondi is more diverse than Liki and Miossu, but strong currents cause low coral cover. Interesting fact that in Bepondi, *Halimeda spp.* growth is quite massive. This present study shows that there are differences in the composition of reef fish amon islands. The number of species and abundance of Gobiidae of Bepondi is significantly higher than Liki and Miossu. It is concluded that Halimeda influences the abundance of Gobiidae, as previous research of Langston and Spalding (2017) in the Main Hawaiian Islands (MHI).

Conclusion

Coral reef ecosystems in the small outer Islands have high productivity and fish species diversity of due to support of good environment condition, varied habitat complexity and less anthropogenic pressure. There is a unique pattern of reef fishes composition in pristine island in which the Pomacentridae and Labridae were almost in the same number as the Gobiidae, Apogonidae, Serranidae, Chaetodontidae, and Acanthuridae. This composition shows that Liki, Bepondi, and Miossu still have undisturbed and natural habitat. The coral ecosystems in those islands provide important habitat to breed, nurse, and grow various fish species and include those in Red List of IUCN status (Vulnerable and Endanger categories). This study also proved that local wisdom in Papua called *Sasi* provided full protection to the ecosystem and supported high diversity of reef fishes.

Acknowledgment

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