Change in Reef Fish Assemblages along Depth Gradient at Gili Rakit and Gili Lipan Marine Protected Areas (MPAs)

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Abstract. Since 2010, Marine Protected Areas (MPAs) have been established in Indonesia to ensure the sustainable management of coral reef ecosystems. This study examines fish assemblages across varying depths and MPAs management areas, specifically assessing the suitability of Gili Rakit and Gili Lipan MPAs. The study concludes that deeper coral reefs have higher reef fish abundance, with a majority of carnivores, planktivores, and omnivores. Gili Taekebo has the lowest abundance and species richness, while Pulau Lipan has the highest. The target reef fish are primarily found in the core zone, rehabilitation, and open access management types. Based on the findings, MPAs should prioritize sites with gradient depth coral reefs and complex habitats to enhance reef fish biodiversity richness. Takad Tabampang and Pulau Bedil are recommended as sustainable fisheries management types, while Gili Taekebo could benefit from rehabilitation or open access management. Pulau Lipan and Labajo may benefit from target fish re-stocking programs.

1 Introduction

A significant increase in population in Indonesia, in line with anthropogenic pressure escalation from the mainland on coastal ecosystems, threatens the resilience of coastal ecosystem services to humans [1–3]. As before, Marine Protected Areas (MPAs) became essential tools for managing and preserving coastal ecosystem biodiversity [4]. MPAs utilized a regulatory and exclusion approach of extractive or destructive activities to maintain and enhance biodiversity, or mitigate the degradation of coastal ecosystem conditions, especially coral reef ecosystems [4–6]. However, several studies have indicated the saturation of MPAs with fisheries sustainability zone around them [7–10], so an MPAs needs to be reviewed with the latest research/method approaches that provide different perspectives on the effectiveness of MPAs.

The perspective of depth gradient could significantly impact the reef fish diversity [11–13]. There are migration corridors for several types of target reef fish functional groups and spawning aggregations for certain types of high commercial reef fish in deeper habitats, especially parrotfish (*Scaridae*) [14], groupers (*Epinephelidae*) [15], snappers (*Lutjanidae*)

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[16], and emperors (*Lethrinidae*) [17]. On the other hand, fishing activities are increasingly heading to deeper waters with the escalation of advanced fishing technology trends [18]. In some cases, it is also triggered by the degradation of reef fish-bodied size in shallower habitats. Moreover, selective fishing gear have a significant role to maintain reef fish assemblages, yet in Indonesia mostly used multi-gear and multi-species fishing gear [19]. Multi-species fishing gear was shape of advanced technology to exploited marine resources on deeper waters, while on shallow habitat, was utilizing mono-gear with multi-species fishing gear [20]. An MPAs has its carrying capacity for sustaining fisheries activities around it, and it could reach saturation limit if there is no control from mainlands to fisheries based on the quotation. Spillover effects from no-take/core zone management type in MPAs take time to recover biodiversity and reef fish assemblages other management types inside MPAs [21].

Gili Rakit and Gili Lipan MPAs located in the waters of Saleh Bay to the northwest side of Sumbawa. Local characteristics of coral reef habitat around these MPAs surround with "Takad/Terumbu Karang Dangkal" or shallow coral reef habitat. Most coral reef habitats in Gili Rakit and Gili Lipan MPAs biodiversity are shallow coral habitats lower than 7 meters; deeper habitats mostly changed from coral reef to sand substrate. Those characteristics of reef habitats could have different biodiversity and ecological processes built until now, coinciding with anthropogenic pressure throughout the year. This study aims to indicate the influence of depth changes on reef fish assemblages and diversity; then, it could re-evaluate Gili Rakit and Gili Lipan MPA site management type effectiveness.

2 Materials and methods

2.1 Study sites

There are various coral reefs on Sumbawa Island, including combinations of fringing reefs with a declivous or steep slope [22]. The condition of the waters on Sumbawa Island, influenced by the Indonesian waves cross and the Flores Sea, causes an abundant influx of larvae, nutrients, and circulation of different mass waters [23]. The areas with the widest distribution of coral reefs are found in the Gili Rakit and Gili Lipan MPAs [24]. The coral reef ecosystem in this location is spread along the coast and includes the small islands around it (Figure 1). The coral reefs in the Gili Rakit and Gili Lipan MPAs consist of fringing reef types. The frequent fishing activities and the high dependence of coastal communities on fish resources around Gili Rakit and Gili Lipan MPAs result in degraded targeted reef fish-bodied size yearly [24-26].

Gili Rakit and Gili Lipan MPAs encompass 15 sites representing five management types (Table 1). The core zone is a gear and fishing restricted area; sustainable fisheries zone are utilized for fishing activities for coastal communities around Saleh Bay mostly; tourism utilization zone is the area most affected by coastal tourism activity; and the rehabilitation zone is a degraded coral reef ecosystem around MPAs that intervented with a rehabilitation program to re-stocking or recover the defective habitat; and open access is an area without any restriction rules outside MPAs management type. Seven sites represent depth gradients in the coral reef habitat. The coral reef ecosystem in the vicinity of Gili Rakit and Gili Lipan is predominantly found in shallow habitats, generally at depths of less than 7 meters, which is characteristic of these MPAs. However, there are also instances where deeper coral reef ecosystems, exceeding 7 meters in depth, exist at various sites in the region (Table 1)

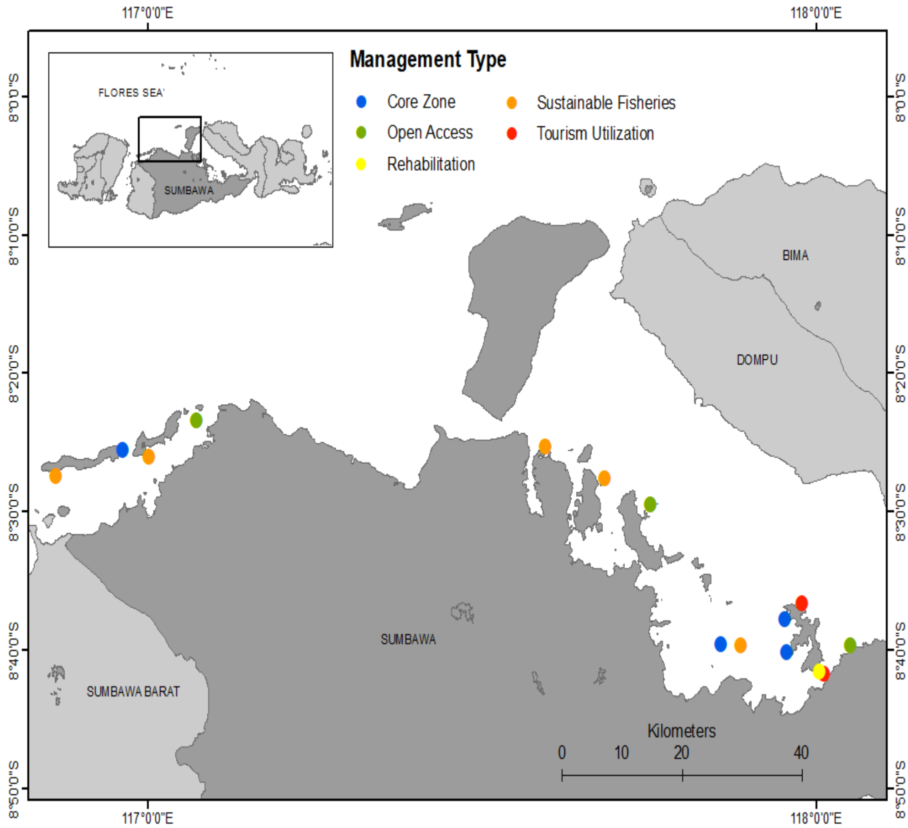

Fig. 1. The coral reef ecosystem sampling locations around Gili Rakit and Gili Lipan MPAs, inside and outside Saleh Bay.

2.2 Reef fish assemblages

All reef fish data were collected using Underwater Visual Census (UVCs) along a 50-meter transect with three repetitions [27, 28]. Transect was laid above the substrate and gave a waiting phase to normalized reef fish around the transect after the laydown process. UVCs assessment parallel with coastal line and separated depth categorized by shallow coral reef habitat (0-7 meters depth) and deep (> 7-meter depth). Reef fish recorded data avoiding daily feeding anomaly hours before 09:00 and after 16.30 [29]. Reef fish was identified to species level and then categorized by functional and trophic level.

2.3 Ecological analyses

Reef fish structure characteristics along depth gradient and among MPAs management types were compared using Analysis of Similarity (ANOSIM). Multivariate ecological analyses (nonmetric multidimensional scalling) were built as an ordination of the UVCs' repetition of each site to reconstruct univariate analysis. Similarity percentages (SIMPER) was conducted to determine species and family contribution on different depth and management type [30]. All analyses used a significant level of $P \leq 0.001$ and square root transformation for multivariate ecological analyses to down weighting abundant data.

Table 1. Coordinate, depth, and management type each observation location.

Sites	Status	Latitude	Longitude	Depth Gradient
Pulau Lipan	Core Zone	8° 39' 31.87"	117° 51' 26.36"	Shallow
West Pulau Panjang	Core Zone	8° 25' 33.14"	116° 57' 41.99"	Deep & Shallow
Labajo	Core Zone	8° 40' 7.69"	117° 57' 17.52"	Shallow
Tanjung Sentigi	Core Zone	8° 37' 46.31"	117° 57' 10.90"	Deep & Shallow
Gili Taekebo	Sustainable Fisheries	8° 39' 37.81"	117° 53' 13.95"	Shallow
East Pulau Panjang	Sustainable Fisheries	8° 27' 23.42"	116° 51' 44.20"	Shallow
Tanjung Bila	Sustainable Fisheries	8° 27' 34.12"	117° 41' 01.03"	Deep & Shallow
Tanjung Padang	Sustainable Fisheries	8° 26' 01.31"	117° 0' 02.07"	Shallow
Tanjung Tengah	Sustainable Fisheries	8° 25' 15.86"	117° 35' 37.97"	Shallow
Pulau Bakau	Tourism Utilization	8° 41' 41.11"	118° 0' 40.01"	Deep & Shallow
Tanjung Batu	Tourism Utilization	8° 36' 36.05"	117° 58' 43.93"	Shallow
Tanjung Lepe Tambora	Rehabilitation	8° 41' 29.86"	118° 0' 16.77"	Deep & Shallow
Gili Dewa	Open Access	8° 39' 37.11"	118° 3' 06.41"	Deep & Shallow
Kampung Pecak	Open Access	8° 23' 23.87"	117° 4' 21.78"	Shallow
Takad Tabampang	Open Access	8° 29' 28.98"	117° 45' 5.93"	Deep & Shallow

3 Results

3.1 Reef fish communities characteristics on different depth

Total 160 reef fish species were identified in deep habitats, and 155 species were recorded on shallow coral reefs on Gili Rakit and Gili Lipan MPAs. On average, reef fish communities dynamic along a depth gradient at Gili Rakit and Gili Lipan MPAs are more abundant in deeper habitats (243 individuals/250 m² and 26 species/250 m²) (Figure 2). Gili Lipan with 273 individuals/250 m² (±16 SE) in 33 species, and Labajo, with 246 individuals/250 m² (±26 SE) in 31 species, represented the highest abundance of reef fish and species diversity on shallow coral reef ecosystems. On the other hand, Tanjung Sentigi and Pulau Bakau are the most diverse and abundant reef fish community structures in deeper coral reef habitats. There are significant differences between shallow and deep reef fish communities in East Pulau Panjang, Tanjung Bila, and Tanjung Lepe Tambora. While another site that has two depth habitat indicated conformity and diversity contiguous value.

Planktivores and omnivores were observed to be dominant trophic levels in Gili Rakit and Gili Lipan MPAs. Tanjung Sentigi and Pulau Bakau on deeper coral reef habitats have a dominant composition of planktivores above 139 individuals/250 m² (Figure 3). These two sites have a low abundance of predator trophic level (carnivore), affecting the reef fish community's stability. In contrast, carnivore trophic levels tend to incline by depth shifting.

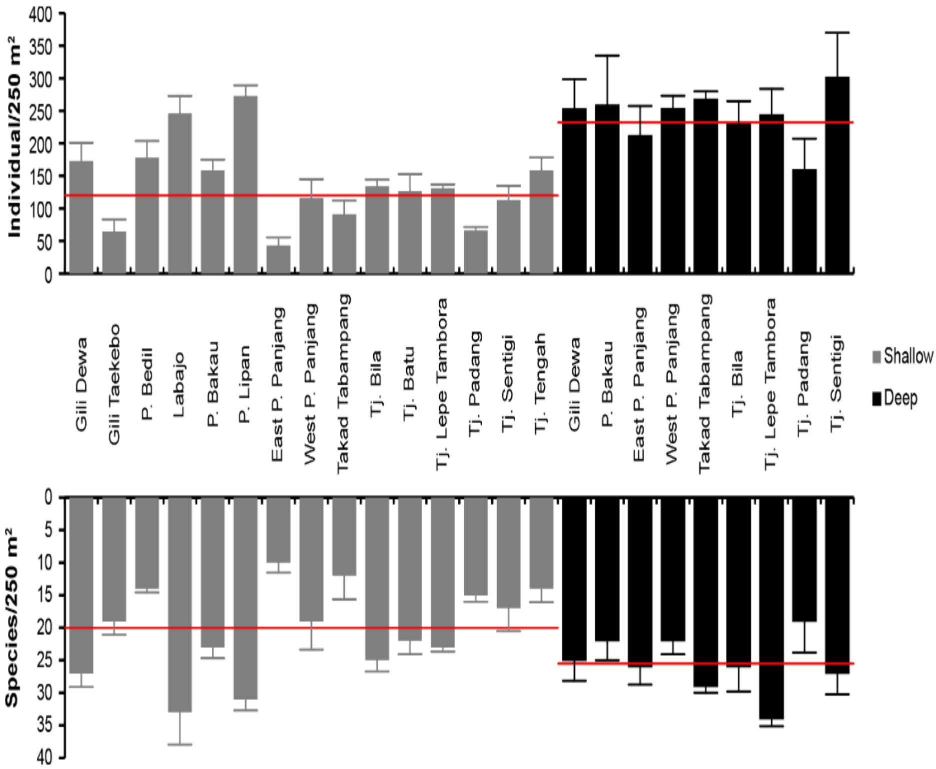

Fig. 2. Reef fish abundance and species diversity on Gili Rakit and Gili Lipan MPAs on shallow and deep coral reef habitat.

In shallower coral reef habitats, omnivores have to tend more contributed trophic levels, such as Pulau Lipan at 114 individuals/250 m² (±16 SE), Labajo at 85 individuals/250 m² (±21 SE), and Gili Dewa at 59 individuals/250 m² (±6 SE). There is a shifting in trophic structure level composition parallel with its abundance. Herbivore, detritivore, and corallivore indicated not prominent throughout Gili Rakit and Gili Lipan MPAs.

The depth variable showed no intersection between shallow and deep coral reef habitats (Figure 4). Shallow and deep reef habitats consist of different reef fish species and abundance. Vector indicated target reef fish family (Haemulidae, Carangidae, Lutjanidae, and Caesionidae) most formed deep reef fish habitat. Pomacentridae and Labridae, found to have the highest reef fish abundance, directed several shallow transect verge with deep transect. Acanthuridae, Balistidae, Nemipteridae, and Scaridae are migratory and tend to be found around shallow habitats Gili Rakit and Gili Lipan MPAs.

Mayor reef fish detected contributed the most to shallow habitats. Chaetodon octofasciatus and Chaetodon baronessa form the Indicator group fish found related on shallower depth gradient. Scarus prasiognathos represent deep coral reefs and Scarus rivulatus in the shallow underwater ecosystem, even though those came from the same family group. Key species from highest abundance reef fish separate deep and shallow coral reefs are *Pomacentrus simsiang* and *Neopomacentrus nemurus* (shallow), with *Pomacentrus alexanderae* and *Neopomacentrus filamentosus* (deep). Thalassoma lunare contributed evenly on two different depth categories. Target reef fish sheltered on deep coral reef habitat and form niches based on Table 2 are Scarus prasiognathos, Caesio cuning, Scarus rivulatus, and Lutjanus Biguttatus. Different reef fish contribute to the depth gradient around Gili Rakit and Gili Lipan MPAs up to the lowest taxon level.

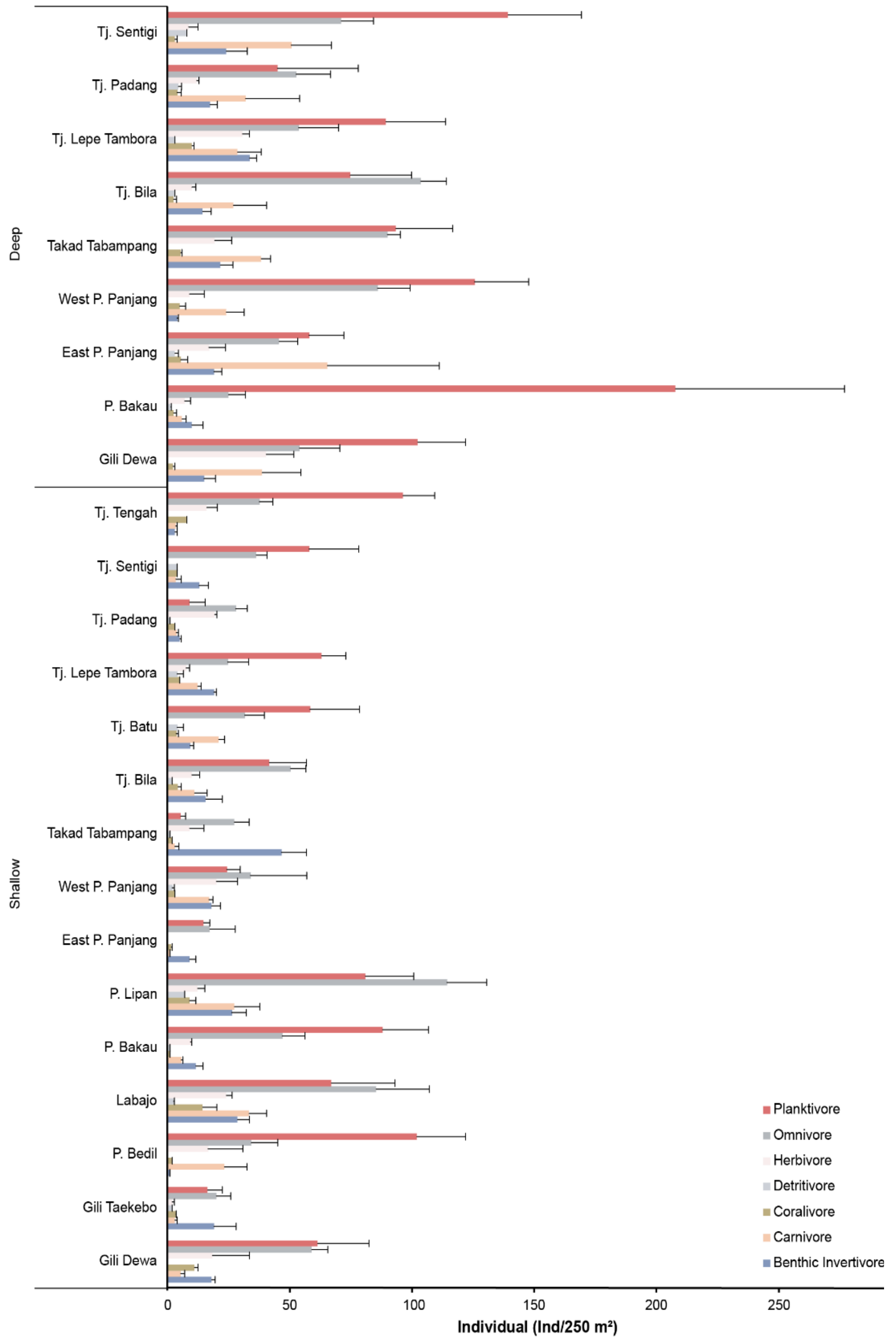

Fig. 3. The reef fish trophic level along depth gradient on Gili Rakit and Gili Lipan MPAs.

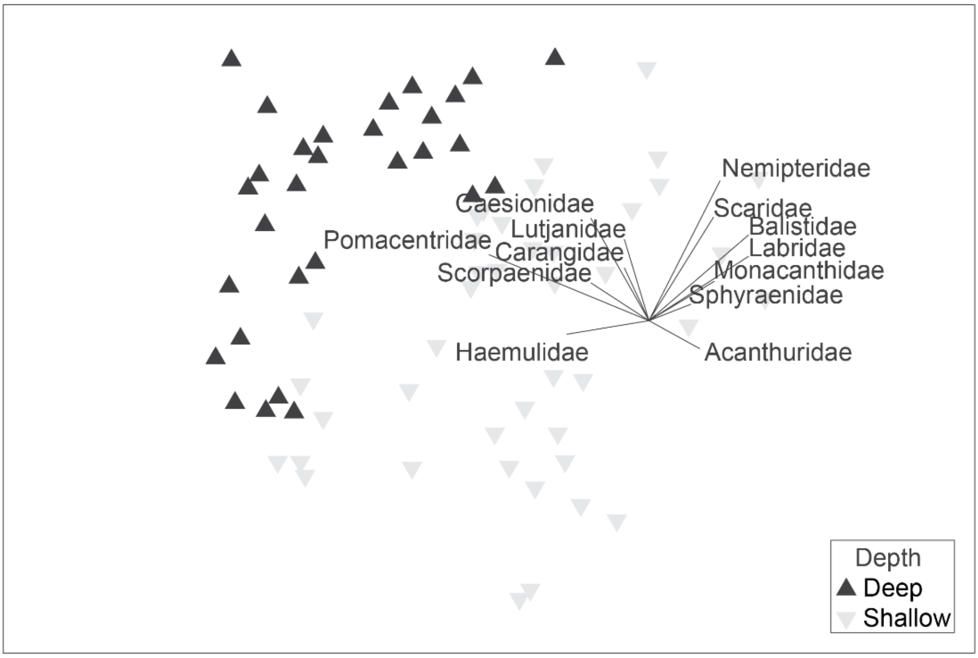

Fig. 4. Non-Metric multidimensional scalling ordination from UVCs of 69 transects on two type depth.

Table 2. Composition of 80% species contribution cumulative within depth gradient.

Species per depth	**Av. Abundance**	**Av. Similarity**	**%Contribution**	**%Cumulative**
Shallow				
average similarity: 24,50				
Pomacentrus simsiang	2.38	2.59	10.56	10.56
Thalassoma lunare	2.10	2.57	10.47	21.03
Pomecentrus moluccensis	2.42	2.52	10.27	31.30
Neopomacentrus nemurus	2.22	1.40	5.72	37.02
Scarus rivulatus	1.06	1.08	4.40	41.42
Pomacentrus coelestis	1.35	1.07	4.35	45.77
Dischistodus melanotus	0.96	0.98	3.99	49.76
Amblyglyphidodon curacao	1.41	0.95	3.88	53.64
Pomacentrus adelus	0.89	0.88	3.60	57.24
Neopomacentrus filamentosus	1.47	0.64	2.60	59.84
Dischistodus perspicillatus	0.79	0.56	2.29	62.13
Chrysiptera parasema	0.56	0.53	2.15	64.28
Chaetodontoplus mesoleucus	0.74	0.50	2.02	66.30
Halichoeres leucurus	0.91	0.45	1.83	68.13

Species per depth	Av. Abundance	Av. Similarity	%Contribution	%Cumulative
Chrysiptera cyanea	0.83	0.45	1.83	69.96
Pentapodus trivittatus	0.73	0.45	1.83	71.79
Chaetodon octofasciatus	0.81	0.42	1.71	73.50
Pomacentrus grammorhynchus	0.42	0.38	1.54	75.04
Chromis ternatensis	1.08	0.36	1.49	76.53
Halichoeres chloropterus	0.34	0.35	1.44	77.97
Chaetodon baronessa	0.63	0.33	1.33	79.30
Scolopsis margaritifer	0.80	0.32	1.31	80.61
Deep				
average similarity: 37,03				
Pomacentrus alexanderae	5.44	8.43	22.77	22.77
Neopomacentrus filamentosus	3.07	2.62	7.08	29.85
Thalassoma lunare	1.82	1.67	4.50	34.35
Chrysiptera rollandi	1.00	1.33	3.59	37.94
Cheilodipterus quinquelineatus	1.84	1.17	3.15	41.09
Neopomacentrus nemurus	2.23	1.15	3.11	44.20
Amblyglyphidodon curacao	1.82	1.13	3.04	47.24
Scolopsis ciliata	1.09	1.11	3.01	50.25
Chaetodon octofasciatus	1.06	1.10	2.97	53.22
Scarus prasiognathos	0.88	1.09	2.96	56.18
Caesio cuning	2.18	1.01	2.73	58.91
Pomacentrus simsiang	1.28	0.96	2.58	61.49
Dischistodus perspicillatus	0.97	0.95	2.58	64.07
Pomacentrus burroughi	0.97	0.91	2.45	66.52
Chrysiptera parasema	1.27	0.90	2.44	68.96
Chromis scotochiloptera	0.97	0.70	1.90	70.86
Chaetodontoplus mesoleucus	0.92	0.65	1.74	72.60
Cheilinus fasciatus	0.78	0.58	1.56	74.16
Upeneus tragula	0.66	0.44	1.20	75.36
Scarus rivulatus	0.78	0.43	1.16	76.52
Lutjanus biguttatus	0.96	0.42	1.15	77.67
Halichoeres chloropterus	0.52	0.41	1.10	78.77
Pomacentrus coelestis	1.09	0.41	1.10	79.87
Halichoeres leucurus	0.60	0.40	1.09	80.96

3.2 Reef fish composition of Gili Rakit and Gili Lipan MPA management type

205 species in 31 families recorded in this study sheltered or migrated across Gili Rakit and Gili Lipan MPAs. Gili Rakit and Gili Lipan MPAs' core zone indicated sustainable biodiversity by preserving reef fish assemblages (Figure 5). Pulau Lipan maintains the highest abundance with 273 individuals/250 m² (±16 SE), and Labajo for the highest species richness (33 species/250 m² (±5 SE)). The lowest reef fish biodiversity is in between sustainable fisheries management types. Moreover, it is lower than open access functionally outside the MPAs corridor. Gili Taekebo comprises 64 individuals/250 m² (±20 SE), and Tanjung Padang with 113 individuals/250 m² (±20 SE). The lowest species richness found on Pulau Bedil (open access) and Tanjung Tengah (sustainable fisheries zone) contains 14 species/250 m².

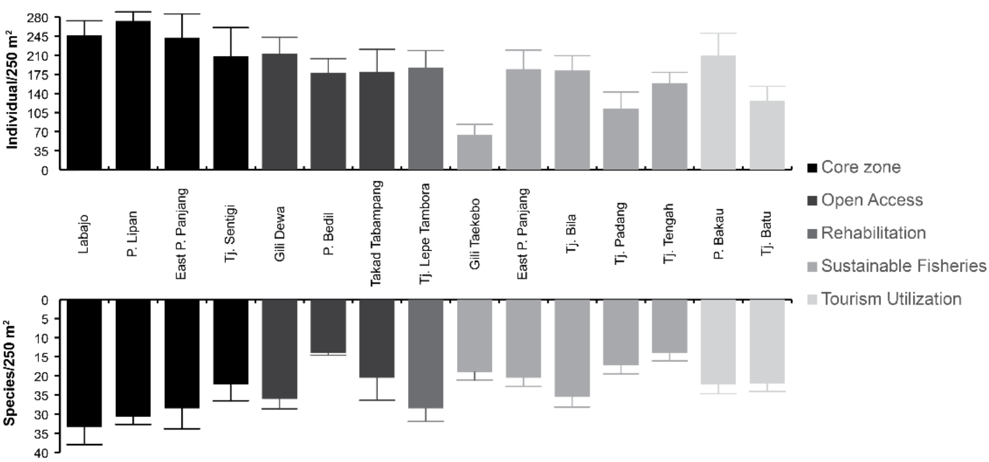

Fig. 5. Reef fish abundance and species diversity on Gili Rakit and Gili Lipan MPAs on different Gili Rakit and Gili Lipan MPAs management types.

Based on the functional reef fish group, the major category held the highest on each site. Functionally major reef fish only fit out food web in coral reef ecosystems. They consist of small- to medium-sized reef fish from the *Pomacentridae* and *Labridae* family groups. Major reef fish generally represent reef fish composition along Gili Rakit and Gili Lipan MPAs, so the abundance of reef fish and the major reef fish group are similar (Figure 5 and Figure 6). Target and indicator groups tend to fluctuate more lucratively differently with the abundance of reef fish. The highest target reef fish is not on sustainable fisheries but on rehabilitation and open access area. East Pulau Panjang, with 49 individuals/250 m² (±27 SE) as the core zone highest target reef fish abundance, Pulau Bedil with 45 individuals/250 m² (±1 SE) for open access, and Tanjung Lepe Tambora as the rehabilitation area (33 individuals/250 m² (±9 SE)). Indicator reef fish in all sites fluctuated from 1 (Tanjung Padang-Sustainable fisheries) to 19 (Labajo-Core zone) individuals/250 m².

Management type nMDS ordination based on UVCs transect indicated intersection among different management types. The core zone was grouped by similarity reef fish composition and attracted other management-type transects with similar composition. The underside of nMDS showed a group of degraded sites/transects which grouped based on the lowest composition of reef fish (Figure 7). The left side group consisted of various species of reef fish that only occurred among those groups, such as *Aeoliscus strigatus*, *Diploprion bifasciatum*, *Sphyraena barracuda*, and *Pterois volitans*.

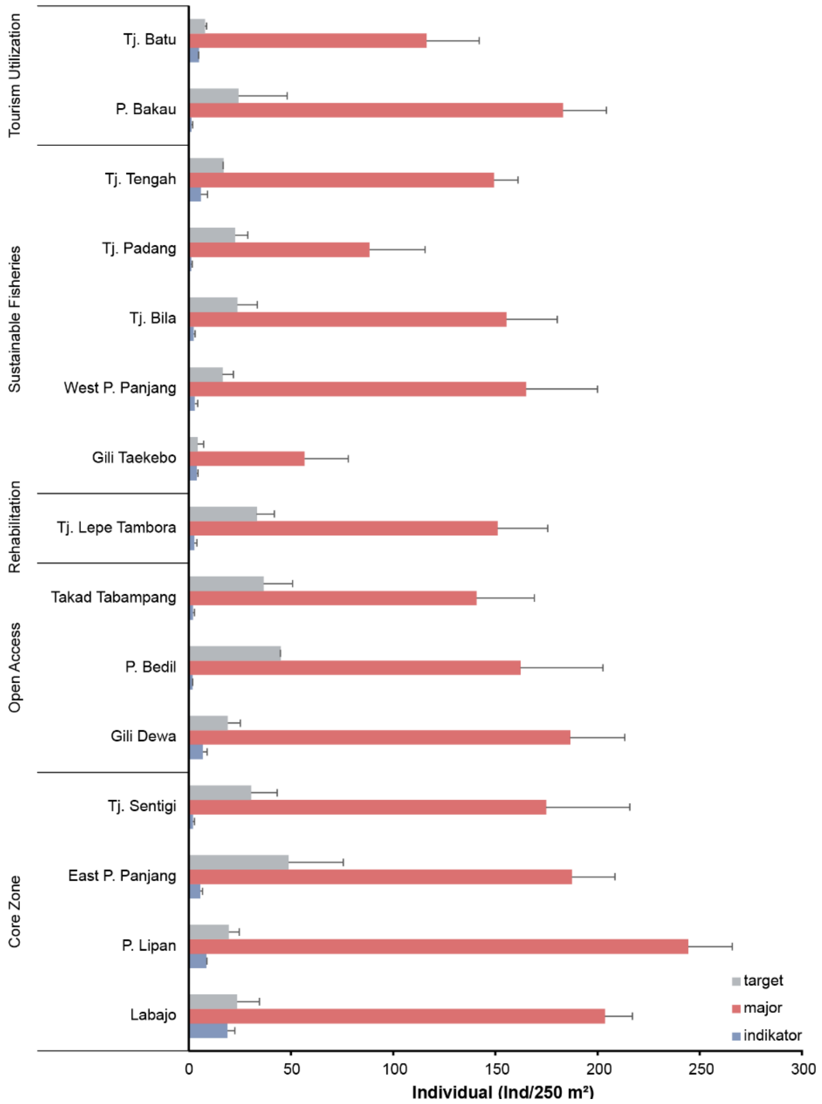

Fig. 6. The reef fish functional group on each management type on Gili Rakit and Gili Lipan MPAs.

Similarity percentage on different management types mostly consisting of *Pomacentridae* and *Labridae*, which have high abundance and diverse species. The core zone should represent a robust coral reef with species contribution from *Chaetodontidae*. The target fish family (*Serranidae*) was found around the rehabilitation zone, while sustainability fisheries zone consisted of the non-target reef fish family (*Nemipteridae*). Tourism utilization has a strong composition of *Pomacentridae* than other management types inside MPAs. *Scaridae* as a secondary target reef fish option by Saleh Bay fishers occurred in open access, rehabilitation, and sustainable fisheries zone.

Fig. 7. Non-Metric multidimensional scalling ordination from UVCs of 69 transects on each MPAs management type.

4 Discussion

4.1 Depth gradient affect to reef fish assemblages

Depth is one of the factors that influence life below water. The derivative effect of depth alteration is normally related to light dispersion [31], water mass movement [32], and physical oceanography [33]. The depth shifting could shape zones that cause biota diversity to vary or be different. Therefore the depth influence possibly affects the vertical distribution of coral reef habitat. The diversity of marine biota is indirectly related to certain biotic and abiotic factors which influence water conditions with a change in depth. Reef fish species are one of the coral reef inhabitants distributed unevenly along environmental shifting linked to either change in physical oceanography or gradient on coral reef ecosystem structure.

Gili Rakit and Gili Lipan MPAs have several sites that encounter species enrichment for possessing vertical shifting cavity broader. The composition of reef fish species contribution even changes parallel with the depth alteration. Depending on the coral reef-type habitat, various factors could influence reef fish distribution by depth alteration. Most Gili Rakit and Gili Lipan MPAs coral reefs have a typical shallow coral reef habitat (Takad) after 7 meters of depth shifting to sand coverage. Ecologically, high biodiversity reef fish would occur in a habitat with complex rugosity [34], various substrates or food items [30], and water-unique phenomena [35]. Results indicated planktivores and omnivores to be the highest contributed reef fish across depth (Table 3). Both primary food items came from phytoplankton and zooplankton. Exhibited Gili Rakit and Gili Lipan MPAs column water conditions accommodate phytoplankton and zooplankton to be enriched around these MPAs. The abundance of planktivores and omnivores is related to the recovery condition of the habitat, as known both are early/low trophic levels of reef fish. Most top predators from the carnivore trophic level only occurred in ecologically healthy habitats on Gili Lipan and Labajo shallow water; moreover, those found migrated around deeper habitats.

Table 3. Composition of 80% family contribution cumulative within MPAs management type.

Species per depth	Av. Abundance	Av. Similarity	%Contribution	%Cumulative
Core Zone				
average similarity: 58,53				
Pomacentridae	10.12	29.58	50.54	50.54
Labridae	4.38	13.05	22.29	72.83
Nemipteridae	2.68	3.49	5.96	78.79
Chaetodontidae	1.96	3.33	5.69	84.48
Open Access				
average similarity: 61,12				
Pomacentridae	10.72	33.94	55.54	55.54
Labridae	4.26	11.42	18.69	74.23
Scaridae	2.07	3.87	6.33	80.56
Rehabilitation				
average similarity: 74,60				
Pomacentridae	9.68	26.34	35.31	35.31
Labridae	5.71	15.38	20.62	55.93
Scaridae	3.87	9.98	13.37	69.30
Nemipteridae	2.71	6.72	9.01	9.01
Serranidae	2.06	5.10	6.84	15.85
Sustainable Fisheries				
average similarity: 60,86				
Pomacentridae	9.33	30.73	50.50	50.50
Labridae	3.11	9.38	15.41	65.91
Nemipteridae	2.05	6.29	10.34	76.25
Scaridae	2.32	5.78	9.49	9.49
Tourism Utilization				
average similarity: 72,04				
Pomacentridae	11.58	44.86	62.27	62.27
Labridae	2.92	9.95	13.81	76.08
Nemipteridae	2.11	6.84	9.50	85.58

Coral reef habitats with broader vertical distribution would have various diversity and rugosity based on sunlight penetration and water environment condition. Thus, altering coral reefs between depths would provide different niches for various biota [36, 37]. The broader depth gradient of coral reef habitat than various niches could provide for more species. Gili Rakit and Gili Lipan MPAs sites with depth gradients are most likely more sustainable than sites with shallow habitats only. The coral richness at different depths would also affect the reef fish density and biodiversity. The live coral occurrence in shallower coral reef habitats strongly directs reef fish distribution. Reef fish composition and interaction in deeper habitats would indirectly influence the re-stocking of shallower habitats [38]. Most Spawning Aggregations (SPAGs) of certain reef fish occur in deeper habitats. SPAGs are a phenomenon of reef fish spawning that could spill over the abundance of those certain reef fish to the area around the exact SPAGs location.

A shallow coral reef surrounds Teluk Saleh, most likely influencing small-scale fisheries' selected gears such as pole and line or speargun. This type of fisheries tools directly affected the territorial or migration of reef fish on shallow coral reefs. On average, data showed lower density in shallower habitats caused directly by small-scale fisheries throughout the MPAs established. MPAs should reconsider the depth gradient effect on the reef fish community structures, as those locations inhabited by depth gradient coral reefs should be managed properly as core zone (with other MPAs minimum criteria), distinctive for Gili Rakit and Gili Lipan MPAs.

4.2 Gili Rakit and Gili Lipan MPA management type term establishment causing reef fish biodiversity shifting

Ecological shifting occurred the most on the Indonesian coral reefs through natural phenomena and massive/yearly anthropogenic pressure [39, 40]. Gili Rakit and Gili Lipan MPAs are one of the MPAs affected yearly by destructive fishing before it was established. These MPAs were established afterward, and destructive fishing is completely prohibited, causing the side effects of degradation of target reef fish quality and sizing. Gili Rakit and Gili Lipan MPAs are developed under the unhealthy coral reef habitat. Otherwise, management development by the MPAs enacts centralized fisheries activities in sustainable fisheries management areas.

Based on monitoring results, Gili Rakit and Gili Lipan sustainable fisheries zone are experiencing a depletion of target reef fish. Centralizing gear impact on those areas can only be one of several direct impacts on the depletion of reef fish assemblage inside sustainable fisheries. Tourism utilization is manageable with more major functional group reef fish as exotic biota embellished the coral reef habitat for tourism attraction. Underwater tourism activities generally require reef fish with unique bodied-color patterns and schooling of various reef fish species. On the other hand, rehabilitation and open access zones indicated more abundant target reef fish than sustainable fisheries. Both areas are gear-allowed because rehabilitation areas are inhabited by degraded coral reef ecosystems at the establishment of MPAs, then rehabilitated to recover the coral reef habitat. In comparison, open access is areas outside the MPAs management area and are not restricted by any law. This condition indicated the opportunity for re-managing the area management on Gili Rakit and Gili Lipan MPAs.

Shifting of reef fish structure became clear for several sites under Gili Rakit and Gili Lipan MPAs management since 2017. Shifting has most occurred in sustainable fisheries zone, yet it is still linear that centralized fisheries are applied decently by Saleh Bay coastal communities. Still, those negative shiftings are influenced by the sustainability of fisheries under MPAs management. Those negative shifting by degraded reef fish biodiversity should be managed because it could become a multiplier effect on its habitat's carrying capacity and resilience. Re-stocking of target reef fish ecologically will take more periods and phases. On Gili Rakit and Gili Lipan MPAs, ecological re-stocking could not follow the inclination trends of fisheries needs by Saleh Bay coastal community. Biodiversity shifting that occurred on those MPAs, indicated by reef fish biodiversity and target reef fish abundance deflation, could be anticipated by government aspect intervention to recover its effectiveness.

4.3 MPAs effectivity suggestion for sustainable development

The essence of Marine Protected Areas (MPAs) is a management effort that is considered effective in achieving the ecological goals of a water area through regulation and limitation of human activities [41]. In its development, MPA is aimed at responding to various needs in terms of ecology, biodiversity, fish structure and populations, increasing local income and improving fisheries systems, and creating jobs [42]. When drawn on the 2030 Sustainable Development Goals, measuring the effectiveness of an MPA will be faced with evaluating the achievements of various indicators, especially SDG 14 which will be related to human food security, poverty, the health of the aquatic environment, law enforcement at the water, access for small-scale fisheries, utilization of science in water utilization and opening opportunities for multi-stakeholder coordination [43]. Looking at the range of MPA objectives, the effectiveness of an MPA management must at least include measurements of biophysical, socio-economic, and governance conditions.

Research on Gili Lipan and Gili Rakit's MPA indicates that there is a biophysical factor that influences the status of reef fish resources: water depth gradient. [41] divided the biophysical conditions as measured in the effectiveness of an MPA into ten: an abundance of key species, the population structure of key species, distribution, and complexity of habitat, composition and structure of the community, success of the community recruitment process, integration of food web, type of fishing effort, water quality, indication of ease of recovery, and level of threat from human activities. Of the ten parameters, depth variations indicate that if there are variations in the depth of water, the ten parameters can be answered. So the depth variation factor can be a parameter to determine whether a location becomes an MPA or not to pursue it in a sustainable and long-term manner.

Human activities are the greatest pressure on marine ecosystems and human activities are indicated to have contributed greatly to the effectiveness of MPA on Gili Lipan and Gili Rakit. From a study of the communities' perceptions, the people around the coast of Saleh Bay are currently working on capture fisheries (small scale), vannamei shrimp culture, and corn farming on the coast. All three put great pressure on the form of low target fish as well as waste contamination which reduces water quality, especially at shallow depths. According to the community, as long as there is an MPA, fishing communities are not part of the decision-makers and do not know how to differentiate between practices in open access zones, tourism zones, and sustainable fisheries zones, while only knowing that it is prohibited to catch fish in the core zone. The implication is, because the sustainable fisheries zone is a shallow area that can be easily accessed for small-scale fishing, almost all types of fishing are conducted in this zone, resulting in fish depletion. This condition is the same as what happened in Malaysia when fishers were not part of the decision-making regarding MPA, fishers tended to extract as much as possible in one location [44]. In studies on community perceptions, the establishment of MPAs often creates opposition and conflictual narratives, but the community is rarely asked to determine the success measures of the management of an MPA or the determination of zones and models of adaptation and regulation [45].

So in the context of the findings of this study, two important issues are suggested to improve the quality of the Gili Lapan and Gili Rakit MPAs. The first suggestion, because the target fish resources in the sustainable fisheries zone are already low, it is better if the sustainable fisheries zone is rearranged to an open access zone that is outside the MPA [24-26]. The condition of Sumbawa waters which are rich in shallow coral reef habitats without variations in depth gradient should be protected from capture because this area can become a target fish restocking location. The second suggestion, in determining MPA zoning should be built based on consensus in an integrated coastal management framework consisting of polycentric relationships between many parties. The role of fishers and local coastal communities is a key factor in determining the zoning and the form of mitigation that must be taken in each zone because the aspect of the sustainability of fishers's livelihoods is a determining factor in predicting whether an MPA is effective or not.

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