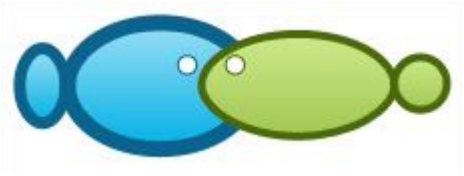

Fish condition in the artificial reef reef ball™ in Ratatotok Peninsula, North Sulawesi, Indonesia

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Abstract. The objective of the study is to describe the recent conditions of reef fishes in Ratatotok Peninsula, Southeast Minahasa, North Sulawesi, after the artificial reef (reef ball™) deployment in 1999. Coral fish colonization has been observed since 2000 in six localities of the reef ball™ deployment. Sixteen years after the deployment, those sites were studied to observe the community structure of the coral fishes. The fish observations were focused in Sicod, Teluk Buyat, Tanjung Buyat, St. III, Segara, and Selat Besar and used SCUBA survey. Coral fishes observed are target fish, major fish, and indicator fish. This study found that all localities showed high diversity of fish genera, and nearly all sites showed low evenness. No genera have dominated the area with high richness in genera. The coral fish community structure in the reef ball has resulted in a new fish community after 16 years of the deployment with increasing coral fish population. Therefore, the use of the artificial reef in the form of reef ball could be a positive way to improve the reef fish condition, particularly in Ratatotok Peninsula.
Key Words: colonization, diversity, dominance, evenness, richness.

Introduction. Coral reef condition degradations in Ratatotok peninsula and Teluk Buyat are caused by uncontrolled exploitation under various unrecommended ways, such as poisoning, bomb fishing, and gill net operations in the coral reefs (Lalamentik 1996, 1997, 1998), besides natural phenomena, such as coral bleaching, that occurs in many regions worldwide (Gordon et al 2018; Keith et al 2018; Norin et al 2018; Kline et al 2019; Muñiz-Castilo et al 2019; Robinson et al 2019; Rossi 2019; Claar et al 2020; de Barros Marangoni et al 2020). Coral reef degradations from destructive activities or global warming-induced natural cause, such as bleaching, have also been reported in many scientific journals (Kularatne 2019; Hong 2019; Humphries et al 2019; Nieder et al 2019; Rossi 2019; Andradi-Brown et al 2020; Hall-Spencer & Kon 2019; Yunitawati & Clifton 2021). Cesar (2000) also reported that the coral damage was also caused by large-scaled fish poisoning fishing operations in the remote areas, around the inhabited islands, and other places in Indonesia. As a result, fish population in this area declines.

Artificial reef placement on the sea floor is an alternative to provide shelter and habitat for marine biota in the damaged coral reefs. In 1993, PT Newmont Minahasa Raya (PT. NMR) made artificial reef structures under a registered name "Reef ball™" whose design was set by Todd Barber, a construction designer, and his colleagues to help rehabilitate the damaged coral reef area in various places worldwide by building a better reef module. This reef ball™ has been utilized in 56 countries, some of them are the United States, Bahama Islands, Canada, Australia, New Zealandu, West Malaysia, Hong Kong, Qatar, Oman, France, and others (Barber 2000). In 1999, PT. NMR produced approximately 3,000 Reef balls™ which had been deployed in 5 localities of Ratatotok peninsula, Southeast Minahasa Regency, North Sulawesi.

Rondonuwu (2017) established 3 groups of reef fishes, i.e. target fish, indicator fish, and major fish. Target fish are an importantly economic fish group for human consumption in the families of Acanthuridae (surgeonfishes), Caesionidae (fusiliers), Haemulidae (grunts), Lethrinidae (emperor breams), Lutjanidae (snappers), Scaridae (parrotfishes), and Siganidae (rabbitfishes). Indicator fish are a fish group whose occurrence is related with coral reef ecosystem condition. They belong to family

Chaetodontidae (butterflyfishes) covering several genera, such as *Chaetodon*, *Heniochus*, *Hemithaurichthys*, *Chelmon*, *Coradion*, and *Forcipiger*. Major fish are small-sized fish groups, 5 to 25 cm body length in general, with various colors known as ornamental fish. This group is found to be abundant, either in number or species, and tends to be territorial in the coral reef area. They are represented by families Pomacentridae (damselfishes and clownfishes), Apogonidae (cardinalfishes), Labridae (wrasses), and Blenniidae (combtooth blennies).

This study is aimed to observe the recent condition of the fish communities around the reef ball^{TM} deployment in Ratatotok peninsula covering species composition, abundance, and diversity.

Material and Method

Study site. This observation was done along Ratatotok peninsula and around Teluk Buyat, Northeast Minahasa, North Sulawesi, Indonesia (Figure 1). Data were collected in 2014 for one-week using SCUBA dive team. Six observation points were selected in this study, Sikod Bay, Teluk Buyat, Tanjung Buyat, ST.III, Segara, and Selat Besar, where the reefballs had been deployed at different depths.

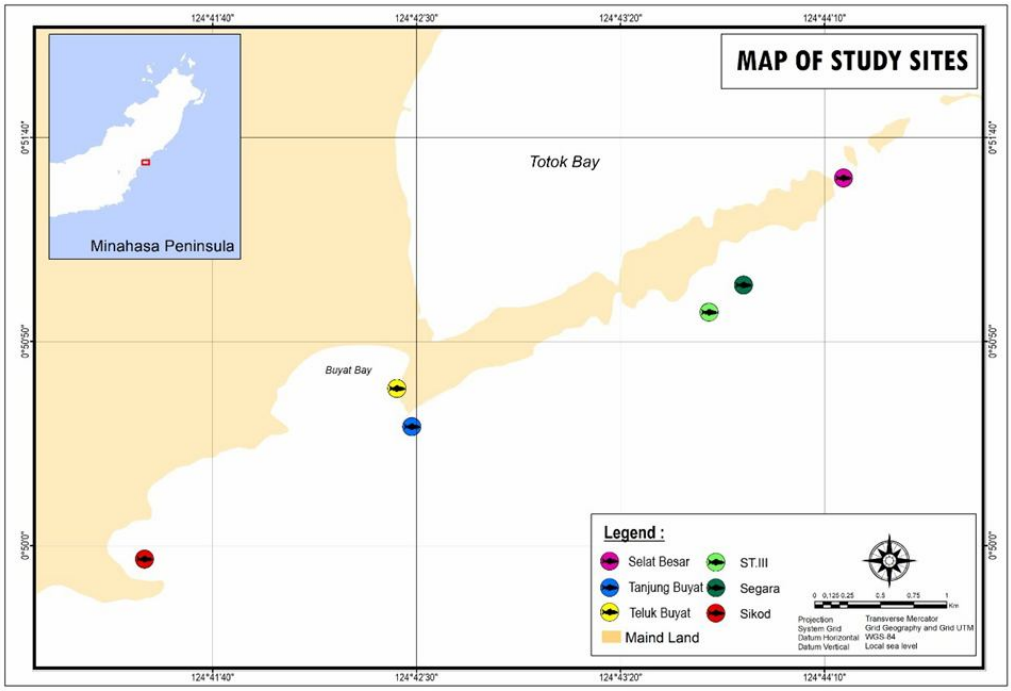

Figure 1. Study sites: Sikod, Teluk Buyat, Tanjung Buyat, ST. III, Segara, Selat Besar.

Data collection. Coral fish observations were carried out using visual census method (English et al 1997), and the fish survey around the reef ball^{TM} used Point Center Visual Census. In early 2020, quick census visual method was also carried out to see qualitatively the fish community condition in the area of reef ball^{TM} deployment.

Species determination was based on the external morphological characteristics observed in the dive. The fish unidentified underwater were photographed and detected using several fish identification guides (Myers 1991; Kuiter 1992; Randall et al 1997; Kuiter & Tonozuka 2004; Allen et al 2005). Number of individuals was also recorded with genera. The study sites were revisited in 2020 using SCUBA survey of quick census visual method to see the fish population development in the reef ball^{TM} areas.

Data analyses

Species diversity. This parameter was estimated using Shannon-Wiener formula (Krebs 2014):

$$H' = -\sum_{i=1}^{s} pi \ln pi \quad ; \; pi = ni/N$$

where: H' = diversity index;
s = number of species;
pi = proportion of number of individual of species-*i* to number of individuals of all species (s);
n_i = number of individual in species-*i*;
N = number of individual of all species (s).

H' < 1.5 indicates low diversity, 1.5-3.5 as moderate diversity, and H' > 3.5 as high diversity.

Species evenness. This parameter estimation used Sorensen index (Odum 1971):

$$IS\ (\%) = 2C / A + B \times 100$$

where: IS = evenness index;
C = number of the same species in both communities;
A = number of species in the community a;
B = number of species in the community b.

Decision criteria: two communities are not different if IS > 50%.

Species dominance. Coral fish species dominance was estimated using Simpson index (Krebs 2014):

$$D = \sum pi^2$$

where: D = dominance index;
pi = relative density of species *i* or ni/N.

Species richness. Species richness was calculated using Margalef index (Ludwig & Reynolds 1988):

$$R1 = (S - 1) / \ln (N)$$

where: R1 = Margalef richness index;
S = number of species;
N = total number of individuals.

R1 < 3 indicates as low species richness, R1 = 3-5 as moderate richness, and R1 > 5 as high richness.

Species density. Coral fish density is expressed as number of individuals of coral fish recorded in areal unit (Giyanto et al 2014):

$$Di = ni / A$$

where: Di = coral fish density of species *i* per areal unit;
ni = number of individuals of species *I*;
A = observation area (ha).

In this study, the observation area was limited to 40 reefballs in each study site, in which a reefball is assumed to be 1 m^2 so that total amount of the reefballs had an observation area of 40 m^2.

Results and Discussion

Species composition. The highest number of target fish species for all study sites was found in ST. III with 58 species but the highest total of individuals was in Tanjung Buyat, 962 individuals (Table 1). The highest number of major species group and number of individuals were recorded in Tanjung Buyat, 54 species and 1,476 individuals, respectively (Table 2). The highest number of indicator species was recorded in Segara, 12 species and 83 individuals, respectively (Table 3). The highest total number of species for all study sites was found in ST. III, 121 species, while the highest number of

individuals was in Tanjung Buyat, 2,519 individuals (Table 4). The present study also recorded 24 fish families in all study sites. Other previous similar studies recorded different number of families, such as 27 families and 51 species (Lowry et al 2010) in 6 sites of artificial reef ball in coastal saltwater lagoon, the Lake Macquarie, NSW, Australia, 17 families and 27 species (Folpp et al 2011) in the estuary with artificial reefs, 53 species and 6,853 individuals in the estuarine area, NSW (Folpp et al 2013).

Table 1

Target species composition in the 6 sites

No.	*Species*	*Study sites*					
		Sikod	*T. Buyat*	*Tg. Buyat*	*ST. III*	*Segara*	*S. Besar*
	Family Acanthuridae						
1	*Acanthurus pyroferus*	21	7	37	28	39	16
2	*Acanthurus nigricans*		6	8	5	3	
3	*Acanthurus nigrofuscus*	22			24	34	23
4	*Acanthurus thompsoni*	16		25	10	8	11
5	*Acanthurus xanthopterus*	27		56	14	12	37
6	*Ctenochaetus binotatus*		5		4	6	3
7	*Ctenochaetus striatus*	15	5	22	36	20	34
8	*Naso lituratus*	2	1	4		3	2
9	*Zebrasoma scopas*	16	33	27	15	20	12
	Family Zanclidae						
10	*Zanclus cornutus*	32	8	12	10	15	10
	Family Caesionidae						
11	*Caesio cuning*	23	34	82	89	44	
12	*Caesio teres*	55		72	56	65	52
13	*Pterocaesio tile*	110	25	110	130	197	160
	Family Haemulidae						
14	*Plectorhinchus chaetodonoides*				3		
15	*Plectorhinchus flavomaculatus*	26		7	2		
16	*Plectorhinchus lineatus*					1	2
17	*Plectorhinchus lessonii*	2		3	2	1	2
18	*Plectorhinchus vittatus*	2					2
	Family Holocentridae						
19	*Myripristis adusta*	2	4		2	7	4
20	*Myripristis amaena*			4	4	5	
21	*Myripristis murdjan*		3	10	11	8	4
22	*Sargocentron caudimaculatum*	2	4	10	8		5
	Family Labridae						
23	*Cheilinus chlorourus*		5		6	8	
24	*Cheilinus fasciatus*	7		2	8	11	8
25	*Cheilinus trilobatus*				12	8	4
26	*Hemigymnus melapterus*	4	4	4	6	5	
	Family Lethrinidae						
27	*Lethrinus harak*	6		23	11	14	7
28	*Lethrinus lentjan*	5		8	6	22	
29	*Monotaxis grandoculis*	13	6	5	15		5
	Family Lutjanidae						
30	*Lutjanus decussatus*	4			5	6	
31	*Lutjanus fulviflamma*	20	6	15	9	6	
32	*Lutjanus fulvus*	40	4	30	23	10	8
33	*Lutjanus kasmira*	62	22	75	9	8	
34	*Macolor niger*	3		2		1	1
	Family Mullidae						
35	*Mulloidichthys flavolineatus*	9	6	61	62	11	
36	*Parupeneus barberinus*	2		12	14	5	7
37	*Parupeneus ciliatus*					2	2
38	*Parupeneus indicus*			2	1		

39	*Parupeneus multifasciatus*	26	33	30	29	30	19
40	*Parupeneus trifasciatus*	4	12	9	19	22	16
	Family Nemipteridae						
41	*Scolopsis bilineata*	4	4	5	6	6	5
42	*Scolopsis ciliata*	7	12	6	10	5	
43	*Scolopsis margaritifera*	3			4	6	4
	Family Scaridae						
44	*Chlorurus bleekeri*	5	6	33	15		9
45	*Chlorurus capistratoides*			3		4	2
46	*Chlorurus sordidus*	8			6	4	2
47	*Scarus chameleon*		1	1	4		
48	*Scarus dimidiatus*	9	2	42	27	12	3
49	*Scarus ghobban*	2			5	2	
50	*Scarus oviceps*				4		6
51	*Scarus tricolor*	4	2	11	9	1	
52	*Scarus xanthopleura*			2	2	4	
	Family Serranidae						
53	*Cephalopholis argus*	3	2		2	2	
54	*Cephalopholis cyanostigma*		2		1	2	3
55	*Epinephelus fasciatus*	1		2	1	2	
56	*Epinephelus hexagonatus*		1				3
57	*Epinephelus maculatus*	1	2		1	1	
58	*Epinephelus merra*	3	4	3	2	3	6
59	*Epinephelus sexfasciatus*	2		3		4	
60	*Epinephelus* sp.			2	2	3	2
61	*Plectropomus areolatus*			2	2		
	Family Siganidae						
62	*Siganus canaliculatus*	12		45	33	21	
63	*Siganus corallinus*		4	11	9		3
64	*Siganus doliatus*				4	3	
65	*Siganus puellus*	10	12	8	4	3	15
66	*Siganus vulpinus*	11		16	14	12	10
	Total species	46	34	47	58	54	41
	Total individuals	663	287	962	855	757	529

Table 2

Major species composition in the 6 sites

No.	*Species*	*Study sites*					
		Sikod	*T. Buyat*	*Tg. Buyat*	*ST. III*	*Segara*	*S. Besar*
	Family Apogonidae						
1	*Ostorhinchus apogonides*	6		20	28	10	
2	*Ostorhinchus compressus*			34	4	8	4
3	*Ceilodipterus intermedius*		3	2			2
	Family Aulostomidae						
4	*Aulostomus chinensis*		2	1	4	4	5
	Family Balistidae						
5	*Balistapus undulatus*	9	7	14	19	12	28
6	*Balistoides viridescens*			2		2	3
7	*Odonus niger*	4		5		16	56
8	*Sufflamen albicaudatum*		4		2	1	
9	*Sufflamen bursa*	4	4	2	2		3
10	*Sufflamen chrysopterum*	2	2		3		
	Family Ephippidae						
11	*Platax teira*	2		4		3	
	Family Labridae						
12	*Anampses* sp.	2			2	2	
13	*Bodianus mesothorax*			2		4	2
14	*Coris gaimard*		2	3	16	28	59
15	*Gomphosus varius*	2		2		2	8
16	*Halichoeres hortulanus*	4	4	12	16	10	12
17	*Halichoeres prosopeion*				5	2	6
18	*Halichoeres* sp.	4	2	4	2	3	7

19	*Labroides bicolor*	3		7	6		2
20	*Labroides dimidiatus*		2	4	6	3	3
21	*Labroides pectoralis*	4		4	2	4	5
22	*Novaculichthys taeniourus*		2	2		2	2
23	*Pseudocheilinus hexataenia*		2	2		4	
24	*Pseudocheilinus octotaenia*	2		2	3		
25	*Stethojulis* sp.			2	2		
26	*Thalassoma jansenii*	4		3	7	4	
27	*Thalassoma lunare*		3	2	4	6	6
	Family Muraenidae						
28	*Gymnothorax javanicus*		4	2		2	3
	Family Ostraciidae						
29	*Lactoria cornuta*	2	2		2		
30	*Lactoria* sp.				2	4	
31	*Ostracion* sp.		4		2		2
	Family Pomacanthidae						
32	*Centropyge bicolor*	4		12	15	22	20
33	*Centropyge tibicen*	12		16	17	23	15
34	*Pomacanthus imperator*			1			
35	*Pomacanthus navarchus*	2			2	1	1
36	*Pygoplites diacanthus*			4	3	4	6
	Family Pomacentridae						
37	*Acanthochromis polyacanthus*			110	85	110	75
38	*Amblyglyphidodon aureus*			26	76	10	15
39	*Amblyglyphidodon curacao*	6	4	87	128	96	110
40	*Amblyglyphidodon leucogaster*	8	15	53	36	70	12
41	*Chromis analis*	20	14	75	110	60	45
42	*Chromis margaritifer*		2	6	8	30	6
43	*Chromis ternatensis*			187	183	110	116
44	*Chromis viridis*			24	76	107	42
45	*Chromis weberi*	26		4	30	9	12
46	*Chromis xanthura*		4	8	8		
47	*Chrysiptera* sp.	10		4	11	16	30
48	*Chrysiptera* sp.			10			
49	*Dascyllus aruanus*	36	10	38	30	40	8
50	*Dascyllus reticulatus*	28		57	78	41	15
51	*Dascyllus trimaculatus*	78	11	198	57	120	69
52	*Neoglyphidodon melas*	4		2	4	2	
53	*Neoglyphidodon nigroris*	44		37	30	19	27
54	*Neopomacentrus* sp.			4			2
55	*Parma* sp.			19	36		12
56	*Plectroglyphidodon lacrymatus*	4		4	16	22	9
57	*Pomacentrus* sp.			18	37	20	
	Family Scorpaenidae						
58	*Dendrochirus* sp.	2		3	2		
59	*Dendrochirus zebra*		2		2	3	
60	*Pterois antennata*		3			2	
61	*Pterois* sp.	1			2	2	1
	Family Serranidae						
62	*Pseudanthias huchtii*			182	78	35	56
63	*Pseudanthias tuka*			34		42	
64	*Pseudanthias squamipinnis*	26		113	64		
	Family Tetraodontidae						
65	*Canthigaster papua*	3	2		2	3	2
66	*Canthigaster valentini*	4	1	3	2		
	Total species	34	27	54	52	50	44
	Total individuals	372	117	1476	1367	1155	924

Table 3

Indicator species composition in the 6 sites

No.	Species	Study sites					
		Sikod	T. Buyat	Tg. Buyat	ST. III	Segara	S. Besar
	Family Chaetodontidae						
1	*Chaetodon baronessa*				5		3
2	*Chaetodon citrinellus*	2		2			2
3	*Chaetodon kleinii*	19	6	29	12	15	20
4	*Chaetodon lunulatus*	8		14	11	18	9
5	*Chaetodon oxycephalus*				2	2	
6	*Chaetodon punctatofasciatus*	2		4	6		4
7	*Chaetodon rafflesii*			2	2	2	4
8	*Chaetodon trifascialis*					6	4
9	*Chaetodon ulietensis*					2	
10	*Chaetodon unimaculatus*			4		2	
11	*Chaetodon vagabundus*	2		4	4	6	2
12	*Coradion melanopus*		1	2		2	
13	*Forcipiger flavissimus*		3		12	9	2
14	*Forcipiger longirostris*		4	8	16	12	
15	*Heniochus acuminatus*	34		8			
16	*Heniochus chrysostomus*				2		3
17	*Heniochus varius*			4	6	7	2
	Total species	6	4	11	11	12	11
	Total individuals	67	14	81	78	83	55

Table 4

Total number of species and individuals for the 6 sites

Total	Study sites					
	Sikod	Teluk Buyat	Tanjung Buyat	ST. III	Segara	Selat Besar
Total species	86	65	112	121	116	96
Total individuals	1,102	418	2,519	2,300	1,995	1,508

Species diversity. The index value ranged from 3.72 to 4.02, with the lowest diversity in Teluk Buyat and the highest in ST. III (Figure 2). This finding indicates high species diversity in all study sites. The higher the index (H'), the more diverse the species composition (Odum 1971). All study sites showed H' > 3.5, meaning that the fish diversity in the reef ball™ is generally high and has formed separate community, particularly in Ratatotok Peninsula.

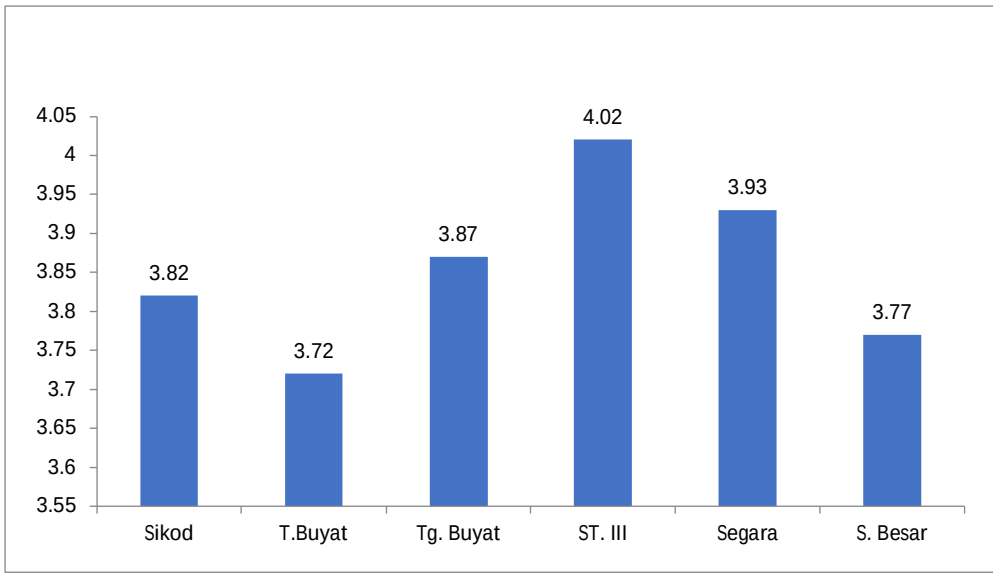

Figure 2. Values of diversity index at the 6 study sites.

Species evenness. Evenness index ranged from 47.68 to 81.01% (Table 5). It indicates that fish communities in all study sites are nearly similar, and only Teluk Buyat and Sikod are different. This finding is in line with Odum (1971) that stable community has evenness index ranging from 0.6 to 0.8. It indicates that after 16 years of reef ball deployment, the fish communities in all study sites, but Teluk Buyat and Sikod, are in stable condition.

Table 5

Evenness index values between study sites

Site	*Sikod*	*Teluk Buyat*	*Tanjung Buyat*	*ST. III*	*Segara*	*Selat Besar*
Sikod	-	47.68	70.71	73.71	68.32	63.74
T. Buyat		-	55.37	61.29	57.46	52.17
Tg. Buyat			-	78.97	77.19	71.15
ST. III				-	81.01	73.73
Segara					-	74.53
S. Besar						-

Species dominance. The highest species dominance was recorded in Selat Besar, 0.039, and the lowest in ST III, 0.029 (Figure 3). This range is categorized as low dominance indicating that all study sites have no dominant species.

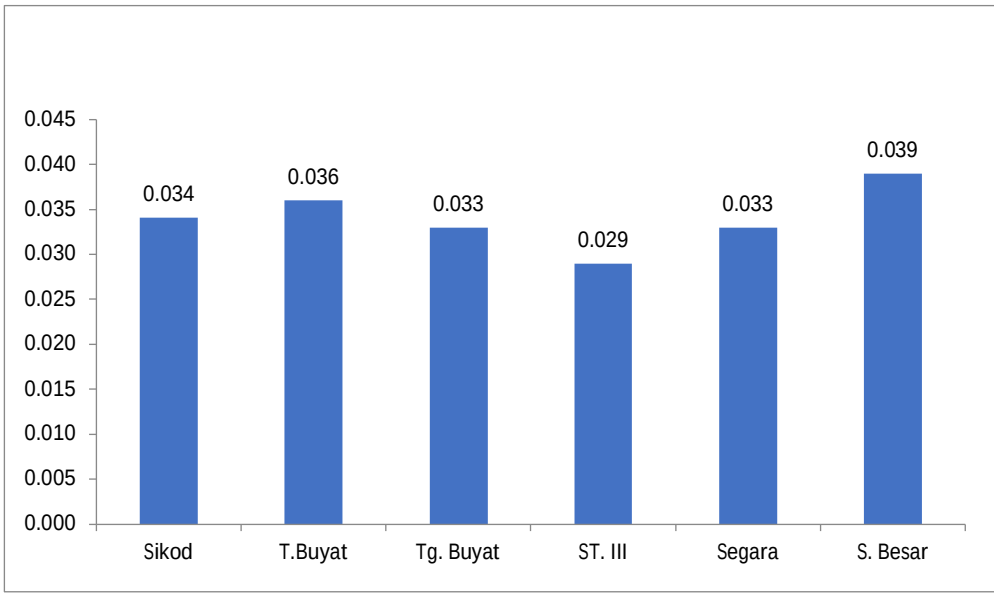

Figure 3. Dominance index values at the 6 study sites.

Richness index. The present study found the highest species richness in ST. III, 15.63, and the lowest in Teluk Buyat, 10.60 (Figure 4). These values are higher than 5 which reflects high species richness in all study sites after 16 years of the deployment. This finding also indicates that each reef ball™ locality has particular species richness with specific characteristics with site.

Folpp et al (2020) found that in the river mouth with low number of natural coral reef, artificial reef positively influences fish abundance. Number of reef balls™ and its position setting in the field also affect the fish abundance. Jones et al (2020) found that larger artificial reef area can support species diversity and give good benefit in habitat utilization, and according to Lowry et al (2017), it could reduce mortality rate from fishing activities.

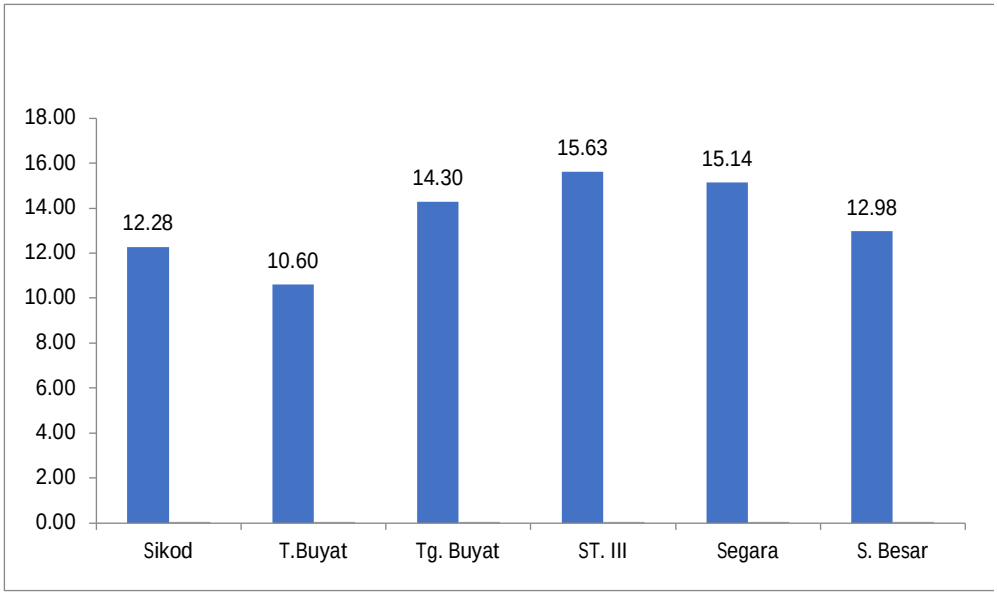

Figure 4. Richness index values at the 6 study sites.

Species density. Fish species density ranged from 10.45 to 62.98 ind m^{-3}. The highest density was recorded in Tanjung Buyat and the lowest in Teluk Buyat (Figure 5).

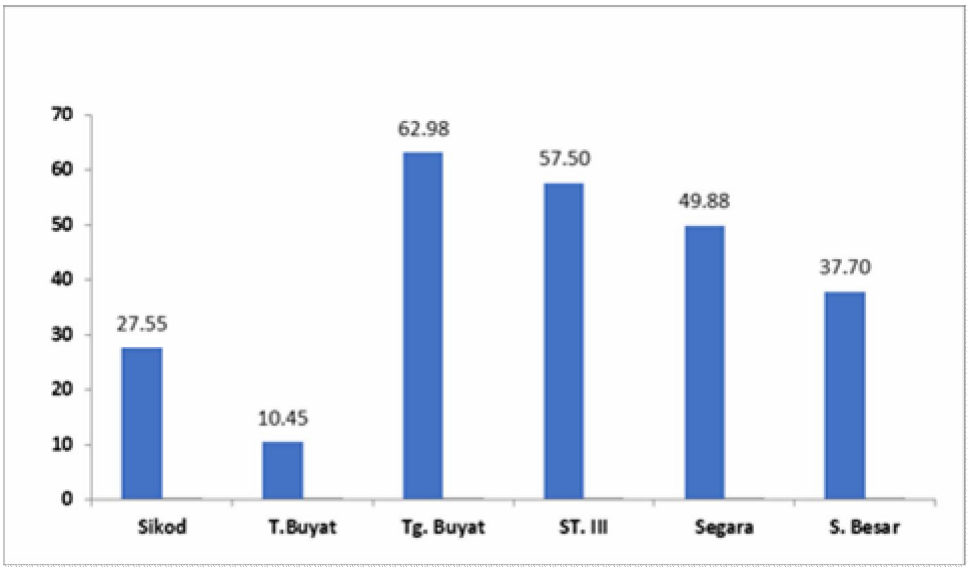

Figure 5. Species density values at the 6 study sites.

Dascyllus trimaculatus had the highest density, 4.95 ind m^{-3}, found in Tanjung Buyat, while *Zebrasoma scopas* was the species with the lowest density, 0.83 ind m^{-3} (Figure 6). Distance between Teluk Buyat and Tanjung Buyat is relatively close, but both localities look very different. *Z. scopas* belongs to target species group, while *D. trimaculatus* belongs to major species group. It could result from that both sites have different conditions. Teluk Buyat waters is relatively calm, semi-protected, and has rock face area, whereas Tanjung Buyat is opened to Molucca Sea. *Z. scopas* prefers more the algae-rich reef slope (Kuiter & Tonozuka 2004), whereas *D. trimaculatus* prefers the hole parts of the reef ball™ to avoid water currents and predators. The juvenile fish are often found in high density of anemone (Randall et al 1997; Kuiter & Tonozuka 2004), while the larger fish are often seen in the branching corals (Thamrongnawasawat & Saisaeng 2006). High species density was also recorded in ST. III and Segara, 4.58 ind m^{-3} for *C. ternatensis* and 4.93 ind m^{-3} for *P. tile* (Figure 6).

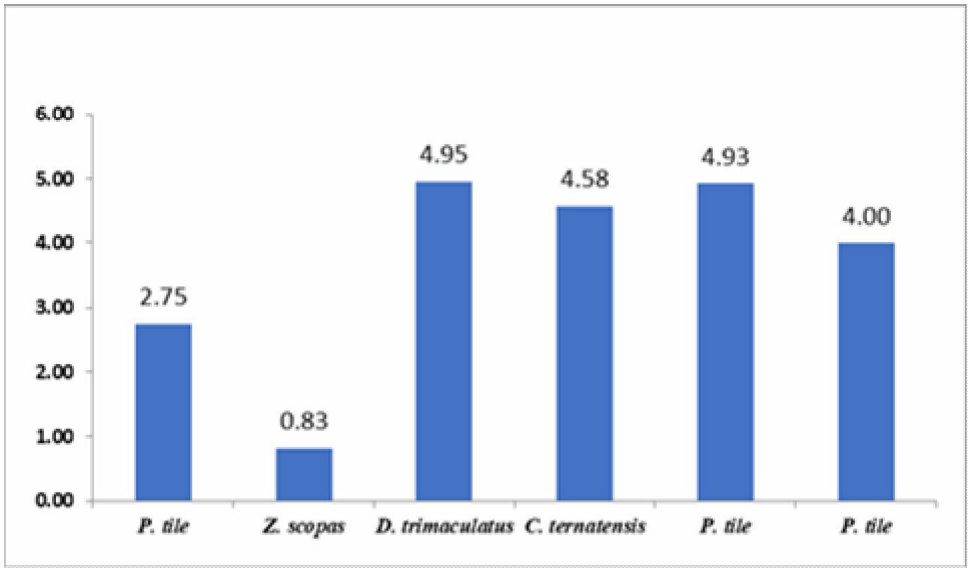

Figure 6. Specific species density values at each sites.

The evenness index in both localities is very high, 81.01%, but the species density of the dominant species is quite different, in which ST. III is dominated by major species, while Segara is dominated by target species. In fact, although both sites are close to each other, they have different characteristics so that the species density around the reef ball™ is different as well. This difference could result from the topographic condition, in which ST.III is slightly slant, whereas Segara has slopes with small bay that forms valley-like area. Members of *P. tile* make the reef ball™ in Segara as feeding area. This is in line with Kuiter & Tonozuka (2004) that this species prefers to feed on zooplankton at the reef edge.

Study site revisit in 2020 using quick census visual showed that several fish species increased in number of individuals, such as Sikod, ST.III and Tanjung Buyat. Sikod area showed very high number of individuals of family Acanthuridae dominated by *Z. cornutus* occurring in nearly all reef balls™. Similarly, *L. kasmira* and *L. fulvus* of family Lutjanidae were found in this site. Members of family Pomancentridae, *D. trimaculatus*, were commonly found around the reef balls™ covered with hard or soft corals.

In Tanjung Buyat, high number of individuals was shown by families Acanthuridae and Lutjanidae, such as *A. xanthopterus* and *A. pyroferus. L. kasmira* schooled in over 50 individuals. Individuals from family Mullidae, especially *M. flavolineatus* were also many in this site. In ST. III, the fish occurrence consisted of family Acanthuridae, such as small to medium-sized *A. pyroferus*, *A. striatus*, and *C. striatus*, and family Mullidae, such as *M. flavolineatus.* Family Pomacentridae has lived and hidden inside the reef ball™. *C. ternatensis* was found to live in the reef ball™ grown with high density of corals on the reef ball™. In Teluk Buyat, several fish species tended to be in the same number of individuals, they are in bigger individual size, such as *L. kasmira* and *Z. scopas.* These species are taken by local communities as target fish. There were recorded also large-sized Mullidae, *P. multifasciatus*, and small group of Caesionidaae, *C. cuning*, swimming around the reef ball™. According to local fishermen, they often came to the reef ball™ sites in certain months for fishing. Segara is also a fishing ground where local fishermen's boats operate their net to catch *Caesio* sp. school in this area. This location has small bay that enables the fishermen to use this species. Similar to ST. III, many fish of Acanthuridae, Mullidae, and Pomacentridae were observed. Selat Besar was recorded the fish group of Acanthuridae, such as *C. striatus* and *A. pyroferus*, grazing on the surface of reef ball™. Labridae, *C. gaimard*, and Balistidae, *O. niger*, and Pomacenthridae, were also abundant in the reef ball™ area. This site is highly influenced by tidal currents that make it become feeding route for certain fish species.

Members of family Pomancentridae, such as *D. trimaculatus*, *A. curacao*, and *C. ternatensis* were commonly found around the reef balls™ covered with hard or soft

corals. They inhabited reef ball™ associated with high density of hard corals and soft corals around the reef ball™, where numerous boulder corals occur, such as genus *Acanthochromis*, *Chromis* and *Dascyllus*. In some reef balls™ were found members of subfamily Anthiinae in high abundance, such as *Pseudanthias squamipinnis* and *P. huchtii.* Their occurrence is related with the availability of new shelter and habitat used to support the fish survival and development in the reef ball area. This finding is in agreement with Folpp et al (2020) that artificial reefs could give positive influence on total fish abundance development and with Lowry et al (2010) that species diversity increases over time following the deployment of artificial reefs.

Fish conditions have changed with time due to various environmental factors. Our revisit in early 2020 indicated that several fish species increased their individual numbers. Number of individuals of family Acanthuridae was very high and dominated by *Z. cornutus* in nearly each reef ball™. *L. kasmira* and *L. fulvus* of Lutjanidae were also found in high number, whereas *D. trimaculatus* of family Pomancentridae was abundant around the reef ball™ covered with hard corals or soft corals. However, the target fish *P. flavomaculatus* was found in low number and small size.

In Tanjung Buyat, there is high abundance of families Acanthuridae and Lutjanidae. The former was represented by *A. xanthopterus* and *A. pyroferus,* whereas the latter was represented by *L. kasmira.* This species was schooling in groups of above 50 small individuals. This site, according to the rental boat operator, was the fishing ground for *L. kasmira*. Other abundant fish species in this site were *M. flavolineatus* (Mullidae) and species from genera *Acanthochromis*, *Chromis* and *Dascyllus* (Pomacentridae). The most interesting fact in this site was the occurrence of members of subfamily Anthiinae, such as *P. squamipinnis* and *P. huchtii*, in high abundance in several reef balls™.

ST.III was dominated by members of small and medium-sized family Acanthuridae, *A. pyroferus*, *A. striatus*, and *C. striatus*, but in lower individual numbers, less than 50 individuals. It could result from high fishing pressures of local fishermen that utilize this area as fishing ground. Fishes of family Mullidae, such as *M. flavolineatus*, and Pomacentridae, such as *C. ternatensis*, and Seranidae, such as *P. squamipinnis* and *P. huchtii* were also abundant in this area. They benefited the reef ball™ fully covered with hard corals in this area. Boulder corals around the reef ball™ were also used by members of family Pomacentridae as habitat.

In Teluk Buyat, several species seemed not to grow in number of individuals, but they occurred as large-sized individuals, such as *L. kasmira* and *Z. scopas.* These species are often fishing target of the local community. Big-sized *P. multifasciatus* (Mullidae) was also recorded in this area, and small school of *C. cuning* (Caesionidaae) looked circling the reef ball™.

Segara becomes fishing ground for local fishermen. In this survey, it was apparent that a fishermen's boat was setting a fishing net to catch *Caesio* sp. (Caesionidae) school. Fish of family Acanthuridae, Mullidae, and Pomacentridae, such as *A. polyacanthus*, *Parupeneus ciliata*, *P. indicus*, and *D. trimaculatus*, were abundant near the hard corals growing on reef ball™. Members of subfamily Anthiinae, such as *P. squamipinnis* and *P. huchtii*, were abundant as well.

In Selat Besar, we found fishes of family Acanthuridae, such as *C. striatus* and *A. pyroferus*, then fish from family Labridae, such as *C. gaimard*, from family Balistidae, such as *O. niger*, and from family Pomacentridae, such as *A. curacao* and *C. ternatensis*, that were abundant near the reef ball™. This site is highly affected by tidal currents that make the area become feeding ground for certain fish. When the current condition is not strong, many fish are grazing near the reef ball™.

Overall surveys found *P. tile* schooling above 50 individuals in each study site. According to Kuiter & Tonozuka (2004), this species schools along the reef edge in various water depths to prey on zooplankton. This long period of reef ball™ deployment along Ratatotok peninsular waters has highly contributed to reef fish habitat rehabilitation and fish stock recovery in the area. Therefore, reef balls could be benefitted to help providing fish habitats in the degraded coral reefs.

Conclusions. The present study recorded 149 reef fish species of 24 families around six reefball locations with a total of 9,842 individuals. The fish community structure in the artificial reef-reef ball™ looks stable with high fish diversity, evenness, and richness and relatively very low dominance. Moreover, five study sites had high species density, and only Teluk Buyat had low species density. As a whole, all six study sites had high species richness. Fish population in Ratatotok peninsula has developed well, both in numbers and species, as a result of reef ball™ placement and supported the availability of fish habitats.

References

Allen G., Steene R., Humann P., Deloach N., 2005 Reef fish identification: Tropical Pacific. New World Publications, Inc. Fl, USA, 470 pp.

Andradi-Brown D. A., Beer A. J. E., Colin L., Hastuti, Head C. E. I., Hidayat N. I., Lindfield S. J., Mitchell C. R., Pada D. N., Piesinger N. M., Purwanto, Ahmadia G. N., 2020 Highly diverse mesophotic reef fish communities in Raja Ampat, West Papua. Coral Reefs 40:111-130.

Barber T. R., 2000 Reef balls™: an advanced technique to mimic natural reef systems using designed artificial reefs. *Reef ball* Development Group, Ltd., Florida, USA. Available at: www.reefball.com, www.reefball.org, 26 pp.

Cesar H. S. J., 2000 Coral reefs: their functions, threats and economic value. In: Collected essays on the economics of coral reefs. Cesar H. S. J. (ed), CORDIO, Kalmar University, Sweden, pp. 14-39.

Claar D. C., McDevitt-Irwin J. M., Garren M., Thurber R. V., Gates R. D., Baum J. K., 2020 Increased diversity and concordant shifts in community structure of coral-associated Symbiodiniaceae and bacteria subjected to chronic human disturbance. Molecular Ecology 29(13):2477-2491.

de Barros Marangoni L. F., Ferrier-Pagès C., Rottier C., Bianchini A., Grover R., 2020 Unravelling the different causes of nitrate and ammonium effects on coral bleaching. Scientific Reports 10:11975.

English S., Wilkinson C., Baker V., 1997 Survey manual for tropical marine resources. 2nd edition, Australian Institute of Marine Science, Townsville, 390 pp.

Folpp H., Lowry M., Gregson M., Suthers I. M., 2011 Colonization and community development of fish assemblages associated with estuarine artificial reefs. Brazilian Journal of Oceanography 59:55-67.

Folpp H., Lowry M., Gregson M., Suthers I. M., 2013 Fish assemblages on estuarine artificial reefs: natural rocky-reef mimics or discrete assemblages? PLoS ONE 8(6):e63505.

Folpp H. R., Schilling H. T., Clark G. F., Lowry M. B., Maslen B., Gregson M., Suthers I. M., 2020 Artificial reefs increase fish abundance in habitat-limited estuaries. Journal of Applied Ecology 57(9):1752-1761.

Giyanto, Manuputty A. E. W., Abrar M., Siringoringo R. M., Suharti S. R., Wibowo K., Edrus I. N., Arbi U. Y, Cappenberg H. A. W., Sihaloho H. F., Tuti Y., Zulfianita D., 2014 [Guide to coral reef health, reef fish, and megabenthos monitoring]. Coral Reef Information and Training Center (CRITC), Coral Reef Rehabilitation and Management Program (COREMAP), Lembaga Ilmu Pengetahuan Indonesia (LIPI), 77 pp. [in Indonesian]

Gordon T. A. C., Harding H. R., Wong K. E., Merchant N. D., Meekan M. G., McCormick M. I., Radford A. N., Simpson S. D., 2018 Habitat degradation negatively affects auditory settlement behavior of coral reef fishes. Proceedings of the National Academy of Sciences of the USA 115(20):5193-5198.

Hall-Spencer J. M., Kon K., 2019 Human impact. In: Japanese marine life: a practical training guide in marine biology. Inaba K., Hall-Spencer J. M. (eds), Springer Singapore, pp. 297-305.

Hong N., 2019 Area-based management approach in the South China Sea: current efforts and future prospects. Asia-Pacific Journal of Ocean Law and Policy 4(2):221-244.

Humphries A. T., Gorospe K. D., Carvalho P. G., Yulianto I., Kartawijaya T., Campbell S. J., 2019 Catch composition and selectivity of fishing gears in a multi-species Indonesian coral reef fishery. Frontiers in Marine Science 6:378.
Jones S. T., Asher J. M., Boland R. C., Kanenaka B. K., Weng K. C., 2020 Fish biodiversity patterns of a mesophotic-to-subphotic artificial reef complex and comparisons with natural substrates. PLoS One 15(4):e0231668.
Keith S. A., Baird A. H., Hobbs J. P. A., Woolsey E. S., Hoey A. S., Fadli N., Sanders N. J., 2018 Synchronous behavioural shifts in reef fishes linked to mass coral bleaching. Nature Climate Change 8:986-991.
Kline D. I., Teneva L., Okamoto D. K., Schneider K., Caldeira K., Miard T., Chai A., Marker M., Dunbar R. B., Mitchell B. G., Dove S., Hoegh-Guldberg O., 2019 Living coral tissue slows skeletal dissolution related to ocean acidification. Nature Ecology and Evolution 3:1438-1444.
Krebs C. J., 2014 Ecological methodology. Harper & Row, New York, 654 pp.
Kuiter R. H., 1992 Tropical reef fishes of Western Pacific: Indonesia and adjacent waters. PT. Gramedia Pustaka Utama, Jakarta, 314 pp.
Kuiter R. H., Tonozuka T., 2004 Pictorial guide to Indonesian reef fishes. Part 2. Fusilier – Dragonets, Caesionidae – Callionymidae. Indonesia: PT. Dive and Dive's, 318 pp.
Kularatne R. K. A., 2019 Unregulated and illegal fishing by foreign fishing boats in Sri Lankan waters with special reference to bottom trawling in northern Sri Lanka: a critical analysis of the Sri Lankan legislation. Ocean and Coastal Management 185:105012.
Lalamentik L. T. X., 1996 Coral reef conditions around the gold mining area of PT. Newmont Minahasa Raya: a monitoring study in Ratatotok and adjacent waters, the District of Minahasa North Sulawesi. Survey dated February, 1996, 54 pp.
Lalamentik L. T. X., 1997 Coral reef conditions around the Gold Mining Area of PT. Newmont Minahasa Raya: a monitoring study in Ratatotok and adjacent waters, the District of Minahasa North Sulawesi. Survey dated October, 1997, 51 pp.
Lalamentik L. T. X., 1998 Coral reef conditions around the gold mining Area of PT. Newmont Minahasa Raya: a monitoring study in Ratatotok and adjacent waters, the District of Minahasa North Sulawesi. Survey dated May, 1998, 48 pp.
Lowry M., Folpp H., Gregson M., McKenzie R., 2010 Assessment of artificial reefs in Lake Macquarie NSW. Port Stephens Fisheries Institute, Industry & Investment NSW Report no. 125, 47 pp.
Lowry M., Becker A., Folpp H., McLeod J., Taylor M. D., 2017 Residency and movement patterns of yellowfin bream (*Acanthopagrus australis*) released at natural and artificial reef sites. Marine and Freshwater Research 68(8):1479-1488.
Ludwig J. A., Reynolds J. F., 1988 Statistical ecology: a primer on methods and computing. John Willey & Sons, New York, 337 pp.
Muñiz-Castillo A. I., Rivera-Sosa A., Chollett I., Eakin C. M., Andrade-Gómez L., McField M., Arias-González J. E., 2019 Three decades of heat stress exposure in Caribbean coral reefs: a new regional delineation to enhance conservation. Scientific Reports 9:11013.
Myers F. R., 1991 Micronesian reef fishes. A practical guide to the identification of the coral reef fishes of the tropical central and western Pacific. A Coral Graphics Production, 298 pp.
Nieder C., Liao C. P, Chen C. A., Liu S. L., 2019 Filamentous calcareous alga provides substrate for coral-competitive macroalgae in the degraded lagoon of Dongsha Atoll, Taiwan. PLoS ONE 14(5):e0200864.
Norin T., Mills S. C., Crespel A., Cortese D., Killen S. S., Beldade R., 2018 Anemone bleaching increases the metabolic demands of symbiont anemonefish. Proceedings of the Royal Society B 285:20180282.
Odum E. P., 1971 Fundamentals of ecology. Third Edition, W. B. Saunders Co., Philadelphia, 574 pp.
PT.NMR. 1994 [Environmental impact analysis of gold mining activities in Minahasa and Bolaang Mongondow, North Sulawesi]. Report of PT. Newmont Minahasa Raya Atria Square Lt. 14 J. Jend. Sudirman Kav. 33-A Jakarta 10220, 514 pp. [in Indonesian]

Randall J. E., Allen G. R., Steene R. C., 1997 Fishes of the Great Barrier Reef and coral sea. Crawford House Press, Bathurst, 557 pp.
Robinson J. P. W., Wilson S. K., Jennings S., Graham N. A. J., 2019 Thermal stress induces persistently altered coral reef fish assemblages. Global Change Biology 25(8):2739-2750.
Rondonuwu A. B., 2017 [Coral fish community North Salawati, South Batanta, Raja Ampat regency, West Papua]. MSc Thesis, Universitas Sam Ratulangi, Manado, 86 pp. [in Indonesian]
Rossi S., 2019 Oceans in decline. Copernicus, 352 pp.
Thamrongnawasawat T., Saisaeng A., 2006 Coral fish of Thailand. Agricultural Research Development Agency and Faculty of Fisheries, Kasesart University, Bangkok, 298 pp.
Yunitawati D., Clifton J., 2021 Governance in the early stages of marine protected area development: a case study of Nusa Penida District Marine Conservation Area, Indonesia. Marine Policy 127:103653.

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