A preliminary analysis of coral cover and fish abundance in the regional marine conservation area of Biluhu Timur, Gorontalo, Indonesia

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Abstract. The waters of Gorontalo Province come with coral resources which continue to decline, making the government expand the regional marine conservation area (RMCA) to control this phenomenon. This preliminary analysis explores coral cover in KKPD Biluhu Timur and affords recommended basics of management. Data on corals were collected using the Line Intercept Transect method in four observation stations with two depths, namely 3 and 10 m. Coral conditions were examined using the UNEP analysis, and live coral cover conditions were classified by the Standard Criteria of Coral Damage in Minister of Living Environment Decree Number 4/2004. Results showed that coral conditions at four observation stations at a 3 m depth were categorized as good to excellent. The average live coral cover had a percentage of 82.8%. Coral conditions in the limited-use zone of KKPD Biluhu Timur at a 3 m depth were categorized as excellent (75-100%). Coral conditions at a 10 m depth were categorized as moderate to excellent. The average live coral cover had a percentage of 69.35%. The live coral conditions had percentages of 90.2% and 89.2%, and the dead ones had percentages of 1% and 2.8%. The total number of individuals found was 5265, composed of 144 species and 27 families. 2752 coral fish individuals were found at a 3 m depth, while 2514 were found at a 10 m depth. The highest number of coral fish found at a 3 m depth, namely 1032, consisting of 62 species and 17 families, was found at station 2. The second highest one, which was 865, made up of 63 species and 18 families, was found at station 1, and 521 individuals, from 41 species and 14 families, were found at station 4. The lowest one, with 333 individuals, composed of 45 species and 15 families, was found at station 3. Coral fish at a 10 m depth at station 1 had a number of 854, consisting of 49 species and 15 families. The number was followed by station 4, with 595 individuals, 41 species, and 12 families. At station 3, there were 559 individuals, 59 species, and 16 families, while station 2 contained the lowest number of individuals, species, and families, i.e., 506, 36, and 12, respectively.
Key Words: coral condition, coral fish diversity, live coral, marine conservation.

Introduction. A coastal area is represented by an intersection between land and sea, where the land is affected by the sea’s characters, namely tides, sea breezes, and salt intrusions, whereas the sea area has the influence of natural processes typically occurring on land, e.g., sedimentation and freshwater flows. In addition, human activities on land are carried out in coastal areas (Nontji 2002). Geographically, Gorontalo Province is located at the coordinates of 121^{0}23’-125^{0}14’ East Longitude and 0^{0}19’-0^{0}57’ North Latitude. It has 131 coastal villages, 123 small islands, and a coastal line of 903.7 km. The waters of Gorontalo Province are located in two marine areas, which are the sea areas of the Gulf of Tomini and the Sulawesi Sea (Gorontalo Province 2018).

The waters of Gorontalo Province located in the two sea areas have high potential coastal resources, which are enlisted as follows: coral ecosystem resources on 24084.04 ha, seagrass ecosystem resources on 7750.86 ha, and mangrove forest ecosystem resources on 16603.73 ha (Gorontalo Marine and Fisheries Service 2021). The data demonstrate how worrisome the coastal resource ecosystem conditions of Gorontalo Province are. Additionally, 53% of the coral ecosystem is in a bad condition, 79.88% of the seagrass ecosystem is in a deprived condition, and 48.17% of the mangrove forest ecosystem is in a sparse condition. This coastal ecosystem damage is mostly produced by anthropogenic factors or human actions (Gorontalo Marine and Fisheries Service 2021).

The coastal ecosystem damage can be ameliorated using a policy instrument, such as the building of a marine conservation area. A marine conservation area is promulgated through regulations to maintain sustainable biodiversity, resources, and ecosystem services (Ochieng et al 2024). Minister of Marine Affairs and Fisheries Decree Number 127/2023 states that the conservation area in the waters of Gorontalo Bay is managed as water parks, at a total area of 76580.48 ha. One of the regional marine conservation areas (KKPD) in Gorontalo Bay is Biluhu Timur KKPD in Biluhu Timur, Batudaa Pantai, Gorontalo Regency.

KKPD Biluhu Timur is composed of core and limited-use zones (Gorontalo Province 2018). The limited-use zone is, by this point, tapped for carrying out marine tourism activities, i.e., swimming, snorkeling, and diving. To underpin tourism activities in KKPD Biluhu Timur now, facilities and infrastructures, namely cottages (Tilalohe Beach and Itoduti Beach) and a diving center (Global Dive) are available. However, the development of marine tourism in Indonesia hurts the condition of coral reefs. Approximately 95% of coral reefs in Indonesia are currently threatened, with 35% in the high or extreme threat category (Burke et al 2012). The greatest threat to coral reefs comes from tourism and fishing activities, which account for more than 60% (Kunzuman 2004). In addition, of the 324 coral species observed in Indonesia, 43% are damaged and endangered (Adrim et al 2012). Based on a survey conducted by the Oceanographic Research Center of LIPI in 2008 at 985 stations, only 6.48% of coral reefs were in good condition, and only 5.48% were in excellent status (LIPI 2022).

High economic and ecological values of corals bring on serious damage to the coral ecosystem due to anthropogenic causes, e.g., pollution contaminating the waters, fish catching exceeding the capacity, eutrophication, fish catching practices using non-ecofriendly or deleterious fishing substances and coral bleaching phenomena in light of climate changes (Razak et al 2022). This study aims to assess the condition of coral cover and fish abundance in the East Biluhu Marine Protected Area (MPA), Gorontalo, Indonesia. Furthermore, it is expected that the results of this research will contribute to formulating strategies to conserve biodiversity, maintain ecological balance, and promote sustainable utilization of marine resources of the East Biluhu MPA.

Material and Method

Description of the study sites. The research was conducted 5 months, from November 2023 to April 2024, in the Regional Marine Conservation Area (KKPD) of Biluhu Timur, Biluhu, Gorontalo Regency, Gorontalo Province (Figure 1).

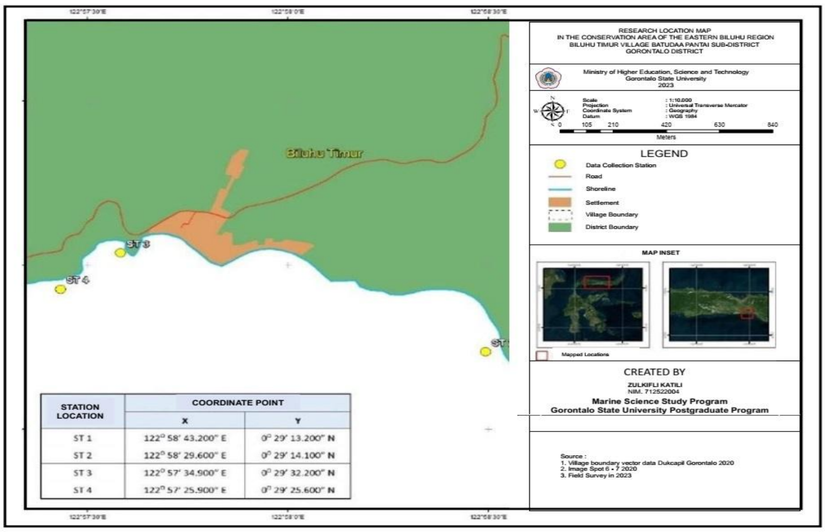

Figure 1. Research area in the Regional Marine Conservation Area of Biluhu Timur.

Procedures. Data collected in this research were data on coral community cover, coral growth forms, and physical factors of the waters. Tools used were SCUBA equipment, a rolling meter, underwater stationery, an underwater camera, GPS, a flow kite, a Secchi disc, and a dive computer. There were four stations, which were chosen because they are dive point locations for snorkeling and diving tourism activities in Biluhu Timur. Two stations represented locations far from the settlement area, and the other two represented locations close to the settlement area. The coordinate points of the four stations were as follows: station 1 at a coordinate point of 00°29'13.2" North Latitude and 122°58'43.2" East Longitude, station 2 at a coordinate point of 00°29'14.1" North Latitude and 122°58'29.6" East Longitude, station 3 at a coordinate point of 00°29'32.2" North Latitude and 122°57'34.9" East Longitude, and station 4 at a coordinate point of 00°29'25.6" North Latitude and 122°57'25.9" East Longitude.

Data on corals were collected using the Line Intercept Transect (LIT) method at four observation stations and two depths, i.e., 3 m and 10 m. The 3 m depth represented shallow waters (snorkeling tourism activities), while the 10 m one represented deep waters (diving tourism activities). The length of the roll transect line was 50 m (English et al 1997).

The number of coral fish species and the coral fish abundance were identified using the visual census method, namely observation-based coral fish identification (English et al 1997), which, technically, was conducted using the Belt Transect method. Data on fish and corals were collected sequentially. Fish abundance by type was measured at observation distance limits of 2.5 m on the left and 50 m on the right of the transect (5x50 m), and the coral fish abundance was stated in ind 250 m^{-2}. As for corals, data on the number of fish species and the fish abundance were also documented using an underwater camera. It enabled us to conduct quantification and identification of coral fish species more efficiently. Coral fish were identified directly in the field at family level (for fish species recognized during the observation) and in a laboratory.

Data analysis. To identify coral conditions at the research sites, a coral cover percentage analysis as suggested by UNEP (1993) was undertaken.

$$Ni = Li/L \times 100$$

Where: Ni - the cover percentage (%); Li - the total length of the category (cm); L - the length of the line transects (5000 cm).

Data on living coral cover conditions gained from the above equation were categorized based on Standard Criteria for Coral Damage as stated in Minister of Living Environment Decree Number 4/2001, as follows: 0-24.9% - damaged; 25-49.9% - moderate; 50-74.9% - good; 75-100% - excellent.

Analysis of coral fish abundance. Coral fish abundance in the research sites was analyzed using the following formula (Odum 1993):

$$N = \sum \frac{ni}{A}$$

Where: N - coral abundance; ni - the number of individuals of the species 1; A - the size of the data collection area.

Results and Discussion

Coral condition. Coral condition observation in the limited-use zone of KKPD Biluhu Timur was carried out at four stations at 3 and 10 m depths. In general, corals in the limited-use zone of KKPD Biluhu Timur were classified as fringing reef types. The lifeform cover at a 3 m depth is presented in Table 1.

Table 1

Percentage of lifeform cover at a 3 m depth

Station	*Biota and substrate cover (%)*						*Condition*
	Live coral	*Dead coral*	*Algae*	*Soft coral*	*Other*	*Abiotic*	
Station 1	89.2	2.8	5	0.8	0	2.2	Excellent
Station 2	90.2	1	0	0.2	1	7.6	Excellent
Station 3	82.6	8.6	0.6	0	0	8.2	Excellent
Station 4	69.2	14.6	3.4	1	2.4	9.4	Good
Mean	82.8	6.75	2.25	0.5	0.85	6.85	Excellent

Table 1 shows that coral conditions at four observation stations at a 3 m depth were good to excellent. The mean percentage of live coral cover was 82.8%. According to the Minister of the Living Environment Decree Number 4/2001 Concerning Standard Criteria for Coral Damage, coral conditions in the limited-use zone of KKPD Biluhu Timur at a 3 m depth were excellent (75-100%). This is because the area was located in a regional water conservation area and in the world's coral triangle area. This is aligned with Ginting (2023), noting that, in general, the eastern part of Indonesia, covering Sulawesi, Maluku, Halmahera, West Papua, Bali, West Nusa Tenggara, and East Nusa Tenggara, consists of the most coral genera in the country. The area is known as the world's coral triangle area, which constitutes the world's center for the highest stone coral biodiversity. Additionally, Burke et al (2002) explain that corals in Indonesia are diverse, and almost all of their types in the water area of Indonesia and their biodiversity are ever-increasing in number and degree to the east. Out of 75 genera found in 2002, 480 stone coral species, or 60% of overall stone coral species, have been recorded in Indonesia.

At a 3 m depth in the limited-use zone of Biluhu Timur KKPD, there were branching corals, massive corals, and algae-covered corals. Coral types found at the four stations were branching *Acropora*, tabulate *Acropora*, digitate *Acropora*, submassive *Acropora*, massive, branching, and submassive corals.

The results of substrate and biota cover recording for each category were live corals, dead corals, algae, soft corals, other biotas, and abiotic at a 10 m depth (Table 2).

Table 2

Percentage of lifeform cover at a 10 m depth

Station	*Biota and substrate cover (%)*						*Condition*
	Live coral	*Dead coral*	*Algae*	*Soft coral*	*Other*	*Abiotic*	
Station 1	77	6.4	0	2.4	4.2	10	Excellent
Station 2	45	2.4	0	9	32.8	10.8	Moderate
Station 3	76	6.2	1.8	2.6	1.4	12	Excellent
Station 4	79.4	7.6	1.6	0.6	4.6	6.2	Excellent
Mean	69.35	5.65	0.85	3.65	10.75	9.75	Good

Table 2 indicates that coral conditions at the four observation stations at a 10 m depth were moderate to excellent, and the mean percentage of live coral cover was the highest at 69.35%. Based on Minister of the Living Environment Decree Number 4/2001 concerning Standard Criteria for Coral Damage, coral conditions in the limited-use zone of KKPD Biluhu Timur at a 10 m depth were good (50-74.9%). Grounded on data collected from LIPI Center for Oceanographic Research (2018), out of 1067 coral sites in total, 386 (36.18%) were in bad condition, 366 (34.3%) were in moderate condition, 245 (22.96%) were in good condition, and 70 (6.56%) were in excellent condition.

The highest percentage of live coral cover, i.e., 79.4%, was found at station 4, whereas the lowest, i.e., 45%, was found at station 2. Furthermore, the highest percentage of dead coral cover, i.e., 7.6%, was found at station 4, while the lowest, i.e., 2.4%, was at station 2. In the limited-use zone of KPPD Biluhu Timur at a 10 m depth, there were three coral cover categories, namely branching corals, massive corals, and dead corals covered with algae.

Coral types found at the four stations were branching *Acropora*, tabulate *Acropora*, digitate *Acropora*, submassive *Acropora*, massive, branching, submassive, encrusting, and milepore corals. There were also abiotic components found, such as sand and rock. The percentages of live coral growth at each research station at 3 and 10 m depths are presented in Figure 2.

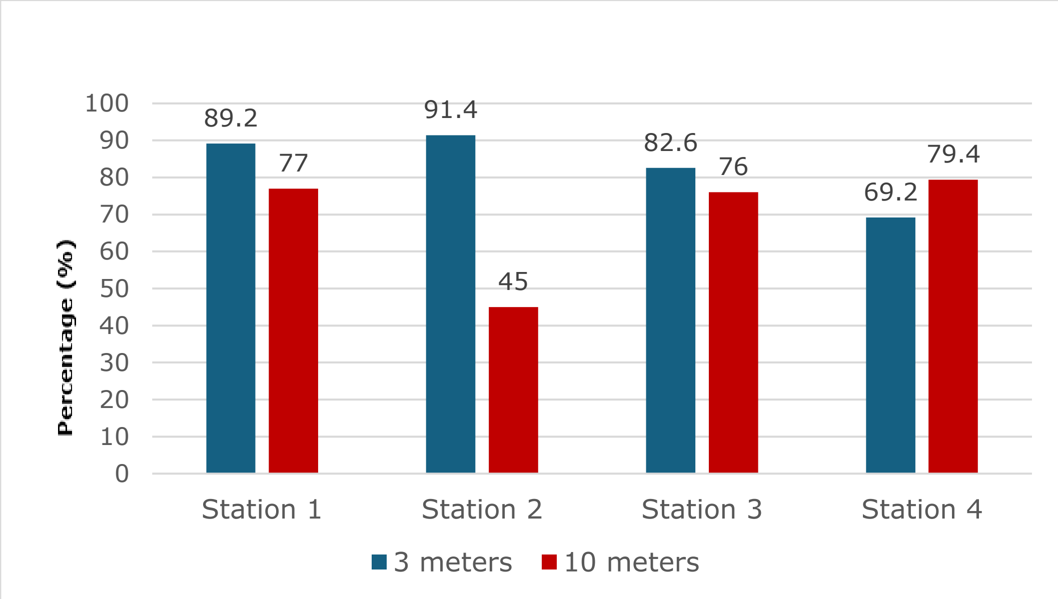

Figure 2. Live coral cover at each station at 3 and 10 m depths.

Figure 2 presents live coral conditions at stations 2 and 1, which showed the highest cover percentages at 91.4 and 89.2%, respectively, and at stations 3 and 4 with the lowest cover percentages at 82.6 and 69.2%, respectively. The coral cover conditions in this research were better compared to those observed by Puspitasari et al (2016), who obtained mean percentages of hard coral cover at TWP Anambas of 5.10-63.33%, observed at 34 stations. The highest percentage of coral fragments was found on Bawah Island (31.24%), followed by Kiabu Island (19.85%) and Telaga Island (17.74%). Accordingly, in our study, coral conditions in the regional marine conservation area of Biluhu were well maintained. At the four observation stations, coral death was mostly a result of algae growth on corals, evidenced by data as the results of an observation at station 4, which had the highest percentages of dead corals with algae (DCA) and macroalgae (MA) of 14.6 and 3.4%, respectively. The second highest percentages were at station 3, i.e., 8.6% of DCA and MA of 0.6%. We found the third highest percentages at station 3, namely 2.8% of DCA and 5% of MA, and the lowest at station 2, namely 1% of DCA and no MA. DCA existence at stations 1-4 was allegedly because of the competition between corals and algae, which could harm coral tissues, bringing on coral colony deaths. Puspitasari et al (2016) suggested that algae act as coral competitors, in terms of either space or light. One of the growth factors of algae is the influx of excessive nutrients and phosphorous into the waters, which could increase water nutrition (eutrophication).

Figure 3 shows live coral conditions at stations 2 and 1, suggesting the highest cover percentages of 90.2 and 89.2%, respectively. Dead coral conditions had the lowest cover percentages of 1% and 2.8%, respectively. Live coral conditions at stations 3 and 4 had the lowest cover percentages of 82.6% and 69.2%, respectively, and the highest dead coral cover percentages of 8.6% and 14.6%, respectively.

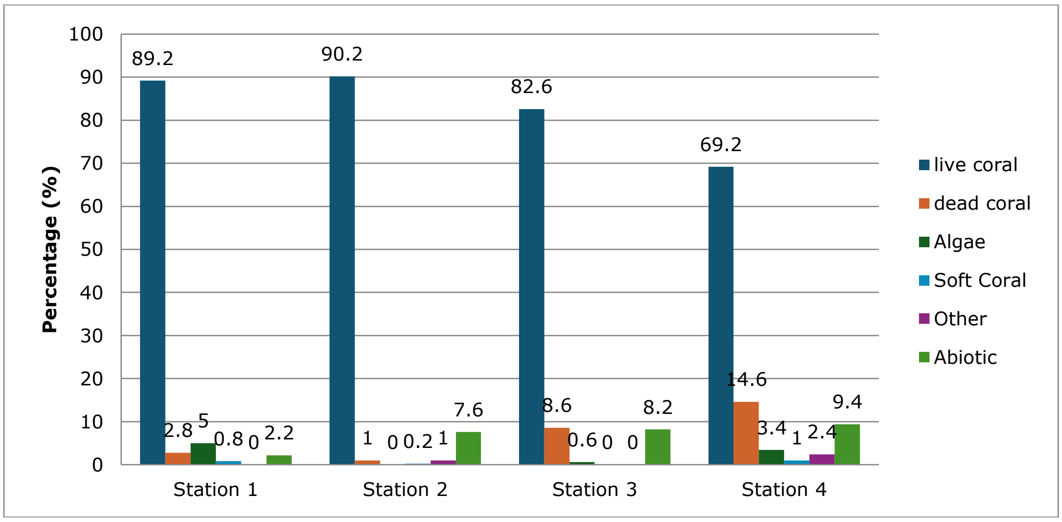

Figure 3. Lifeform cover at a 3 m depth.

As observed at the four stations, coral deaths were mostly a result of algae growth on corals, evidenced by data at station 4, with the highest percentages of DCA and MA, of 14.6 and 3.4%, respectively. The second highest percentages were found at station 3, i.e., 8.6% for DCA and 0.6% MA. We found the third highest percentages at station 3, namely 2.8% for DCA and 5% for MA, and the lowest at station 2, namely 1% for DCA and no MA. Yap et al (2011) and Dianastuty et al (2016) argued that algae acted as coral competitors, in terms of either space or light. One of the growth factors of algae is the influx of excessive nutrients into the waters, which could increase eutrophication.

As suggested in Figure 4, the highest percentage of live coral conditions, namely 79.4%, was found at station 4, followed by station 1, i.e., 77%, and station 3, i.e.,76%, all categorized as excellent. Station 2 had the lowest percentage, 45%. The live coral conditions there were categorized as moderate. At the four observation stations, coral deaths were by algae growth on corals. Our observation results demonstrated that station 4 had DCA at the highest percentage of 7.6% yet no MA, and the second highest DCA of 6.4% without MA was present in station 1. Station 3 had the third highest DCA of 6.2% and MA of 1.8%, while station 2 had the lowest DCA of 2.4% and no MA. Abiotic components often found at a 10 m depth included rock (RCK) or volcanic rock cover (6.6%) and sand cover (3.4%) at station 1. At station 2, the abiotic component of cover was RCK (7%), and there was a coral gap which protruded deeply. Among abiotic components found at station 3, RCK had a cover of 4.8%, sand (S) had a cover of 4.6%, and rubble (R) or coral fractures had a cover of 2.6%. Coral rubble at station 3 could have formed because of tourist access, tourists stepping on corals or using fins pedaling for snorkeling or diving. At station 3, a group of 20 tourists carried out free-diving activities.

According to Chabanet (2005), the tourists can accidentally or intentionally touch the corals, and the sediment stirred up could cover and bury them. At station 4, the covering abiotic component was RCK at a cover percentage of 6.2%. Station 2 had the lowest live coral cover percentage, with an 'Others' cover percentage of 32.8%. The 'Others' group constituted benthos biota associated with corals, such as mollusks, echinoderms, crustaceans, tunicates, bryozoans, and anemones.

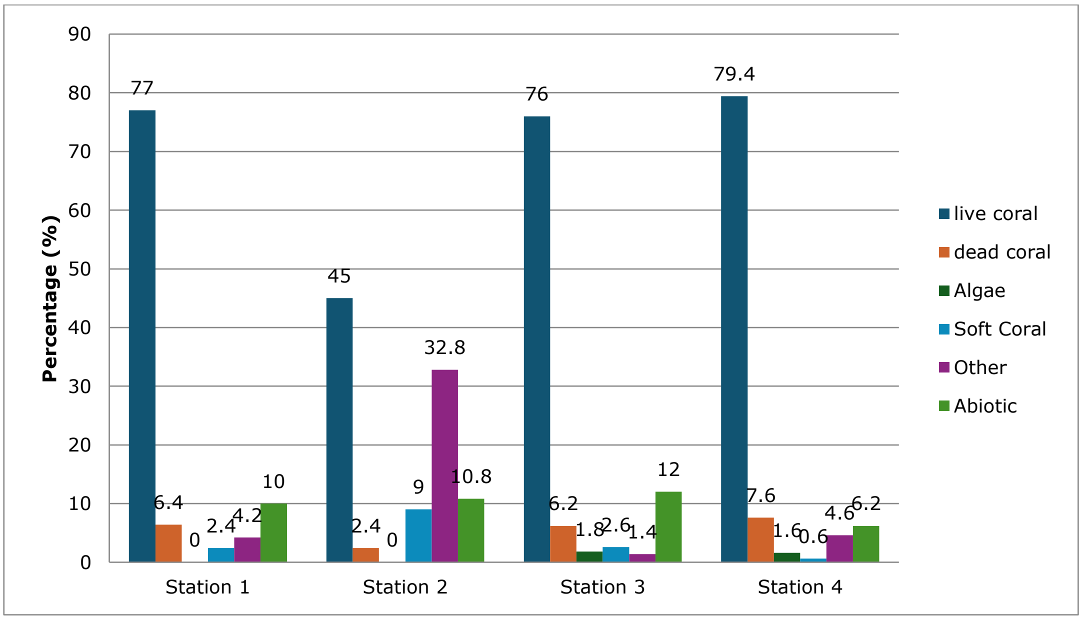

Figure 4. Lifeform cover at a 10 m depth.

Several factors that generate damage to coral ecosystems in Indonesia are fishing practices using non-ecofriendly or harmful fishing substances, e.g., poisons, non-ecofriendly marine tourism activities, pollution on account of economic or developmental activities conducted on land or sea, mountain and agricultural activities which do not put much concern on environmental protection principles inducing sedimentation and turbidity, and natural factors, e.g., global warming, which led to coral bleaching (Schulz et al 2019; Dewi et al 2021; Turisno et al 2024). In addition to degrading coral quantity and quality, a damaged ecosystem can also cut the number of other organisms around corals. Moreover, degraded coral quantity and quality likely affect fishers, who are the beneficiaries of resources around the corals, such as fish and other benthic organisms. The extant resources have to be protected and managed to avoid more severe damage by building a protected area through a marine nature reserve establishment (Triwibowo 2023).

Conditions and types of coral lifeform in the limited-use zone of KPPD Biluhu Timur, associated with ecotourism suitability feasibility, are suitable for snorkeling and diving tourism (Supriharyono 2000).

Similar research was performed in some sea waters of Indonesia, which nowadays have become famed tourism areas. Results conveyed that live coral cover in the limited-use zone of KKPD Biluhu Timur was higher in percentage compared to that in tourism objectives. As reported by Vina et al (2021), the mean percentage of live coral cover in the waters in Olele was 61.25%. Fajar et al (2019) proposed that the mean percentage of coral cover in harbor coasts in Bangka was between 46.6-71.04%. Laapo (2021) posited that the mean percentage of coral cover in all tourism spots of Kepulauan Togean National Park was 57.9%. Kambey (2014) proposed that stone coral cover in Bunaken at the spot of Lounds was 53.16%, while that at the spots of Fukui and Mandolin it was 36.3% and 59.9%, respectively. Current speed is a physical factor with a direct impact on coral growth forms. A strong current which flows regularly influences the coral growth form (Supriharyono 2000). Furthermore, current speed was also correlated with tourist convenience and safety while snorkeling and diving (Yulianda 2019).

Coral fish abundance. There were 5236 individuals found, from 140 species and 27 families. At a 3 m depth, there were 2724 coral fish individuals found, whereas at a 10 m depth, 2512 individuals were found. Coral fish distribution at 3 m and 10 m depths is presented in Tables 3, 4 and 5.

Table 3

Coral fish distribution at a 3 m depth

Station	*Number of individuals*	*Number of species*	*Number of families*
Station 1	865	77	19
Station 2	1032	60	17
Station 3	318	45	16
Station 4	509	36	13
Total	2724		

Table 3 presents that at a 3 m depth in the limited-use zone of KPPD Biluhu Timur, stations 1 and 2 had the highest number of individuals, species, and families, while stations 3 and 4 had the lowest.

Table 4

Coral fish distribution at a 10 m depth

Station	*Number of individuals*	*Number of species*	*Number of families*
Station 1	864	46	16
Station 2	499	35	13
Station 3	560	60	17
Station 4	589	35	10
Total	2512		

Table 5

Coral fish at 3 and 10 m depth

No	*Family*	*Species*	*Amount*
1	Acanthuridae	*Zebrasoma scopas*	50
2		*Acanthurus pyroferus*	51
3		*Acanthurus thompsoni*	32
4		*Acanthurus nigrofuscus*	100
5		*Acanthurus nigricans*	2
6		*Naso lituratus*	6
7		*Acanthurus lineatus*	1
8		*Zebrasoma veliferum*	1
9		*Ctenochaetus tominiensis*	4
10		*Acanthurus striatus*	30
11		*Acanthurus triotegus*	5
12		*Acanthurus tominiensis*	1
13		*Ctenochaetus striatus*	15
14		*Naso thynnoides*	1
15	Apogonidae	*Cheilodipterus heptazona*	2
16		*Apogon compressus*	4
17	Aulostomidae	*Aulostomus chinensis*	7
18	Balistidae	*Balistipus undulatus*	5
19		*Melichthys vidua*	3
20		*Sufflamen bursa*	1
21	Caesionidae	*Pterocaesio tessellatus*	150
22		*Pterocaesio randali*	250
23		*Pterocaesio digramma*	90
24		*Pterocaesio pisang*	100
25	Chaetodontidae	*Chaetodon punctatofasciatus*	16
26		*Chaetodon lunulatus*	10
27		*Chaetodon lunula*	1
28		*Chaetodon vagabundus*	8
29		*Chaetodon baronessa*	10
30		*Chaetodon kleinii*	10
31		*Chaetodon ornatissimus*	8
32		*Chaetodon longirostris*	10
33		*Hemictaurichthys polylepis*	25
34		*Forcipiger longirostris*	4

35		*Heniochus varius*	6
36		*Chaetodon oxycephalum*	2
37		*Chaetodon trifascialis*	2
38		*Chaetodon rafflesii*	4
39		*Chaetodon ephippium*	2
40		*Heniochus chrysostomus*	2
41		*Chaetodon orbatissimus*	2
42		*Heniochus singularius*	2
43	Cirrhitidae	*Paracirrhites forsteri*	8
44	Cirrhitidae	*Cirrhitichthys falcao*	2
45	Ephippidae	*Platax teira*	2
46	Fistulariidae	*fistularia commersonii*	6
47	Haemulidae	*Plectorhinchus vittatus*	4
48	Holocentridae	*Sargocentron cardimaculatum*	7
49	Holocentridae	*Neoniphon sammara*	1
50	Holocentridae	*Myripristis vittata*	5
51	Labridae	*Thalossoma hardwicke*	9
52	Labridae	*Labroides dimidiatus*	33
53	Labridae	*Thalossoma amblycephalum*	45
54	Labridae	*Cirrhilabrus solorensis*	5
55	Labridae	*Thalossoma lunare*	2
56	Labridae	*Halichoeres hortulanus*	5
57	Labridae	*Thalassoma hardwicke*	14
58	Labridae	*Pseudocheilinus hexataenia*	3
59	Labridae	*Cheilinus trilobatus*	1
60	Labridae	*Labrichtys unilineatus*	1
61	Labridae	*Cheilinus digramma*	2
62	Labridae	*Halichoeres prosopeion*	2
63	Labridae	*Halichoeres leucoxanthus*	1
64	Labridae	*Thalassoma cf jansenii*	1
65	Labridae	*Pseudodax moluccanus*	2
66	Labridae	*Cheilinus sp 1*	1
67	Labridae	*Cheilinus celebicus*	2
68	Labridae	*Pseudocheilinus hexataenia*	2
69	Labridae	*Cheilinus fasciatus*	4
70	Labridae	*Labrichthys unilineatus*	1
71	Letherinidae	*Macolor macularis*	2
72	Lutjanidae	*Lutjanus ehrenbergii*	10
73	Mullidae	*Parupeneus bifasciatus*	7
74	Nemipteridae	*Scolopsis bilineata*	6
75	Nemipteridae	*Scolopsis lineata*	16
76	Pomacentridae	*Amphiprion ocellaris*	2
77	Pomacentridae	*Neoglyphidodon thoracotaeniatus*	16
78	Pomacentridae	*Premnas biaculeatus*	6
79	Pomacentridae	*Neoglyphidodon nigroris*	80
80	Pomacentridae	*Plectroglyphidodon lacrymatus*	5
81	Pomacentridae	*Ablyglyphidodon curacao*	40
82	Pomacentridae	*Abudefduf vaigiensis*	240
83	Pomacentridae	*Dascyllus trimaculatus*	49
84	Pomacentridae	*Chromis margaritifer*	61
85	Pomacentridae	*Chrysiptera rollandi*	11
86	Pomacentridae	*Pomacentrus lepidogenys*	45
87	Pomacentridae	*Chrysiptera rex*	11
88	Pomacentridae	*Hemyglyphidodon plagiometopon*	4
89	Pomacentridae	*Pomacentrus taeniometopon*	7
90	Pomacentridae	*Pomacentrus moluccensis*	80
91	Pomacentridae	*Chromis amboinensis*	550
92	Pomacentridae	*Amphiprion clarkii*	13
93	Pomacentridae	*Chromis lineata*	170
94	Pomacentridae	*Amphiprion perideraion*	6
95	Pomacentridae	*Chromis viridis*	115
96	Pomacentridae	*Chromis cf caudalis*	10
97	Pomacentridae	*Chromis liniata*	60
98	Pomacentridae	*Pomacentrus smithi*	10
99	Pomacentridae	*Chrysiptera parasema*	2
100	Pomacentridae	*Chromis atripes*	10
101	Pomacentridae	*Chromis xanthura*	2
102	Pomacentridae	*Dischistodus prosotaenia*	1

103		*Dascyllus reticulatus*	22
104		*Chromis retrofasciata*	47
105		*Chromis leucogaster*	5
106		*Chromis analis*	70
107		*Neoglyphydodon nigroris*	51
108		*Ablyglyphidodon leucogaster*	65
109		*Chrysiptera sp 2*	45
110		*Amphiprion sandaracinos*	4
111		*Pomacentrus retrofasciatus*	10
112		*Plectroglyphidodon dickii*	9
113		*Neoglyphidodon crossi*	5
114		*Chromis opercularis*	2
115		*Premnas biaculeatus*	6
116	Pomacanthidae	*Pygoplites diachantus*	14
117		*Chaetodontoplus mesoleucus*	3
118	Pholidichthyidae	*Pholidichthys leucotaenia*	50
119	Phempherididae	*Pempheris vanicolensis*	4
120	Ptereleotrididae	*Ptereleotris evides*	4
121	Scaridae	*Scarus prasiognathos*	1
122		*Scarus psittacus*	1
123		*Scarus quoyi*	4
124		*Scarus tricolor*	2
125		*Scarus rivulatus*	4
126		*Chlorurus sordidus*	1
127		*Scarus niger*	2
128		*Chlorurus bleekeri*	4
129	Serranidae	*Cephalopholis leopardus*	1
130		*Cephalopholis boenak*	1
131		*Cephalopholis leoparda*	1
132		*Pseudanthias tuka*	1850
133	Siganidae	*Siganus vulpinus*	12
134		*Siganus spinus*	27
135		*Siganidae vulpinus*	2
136	Synodontidae	*Synodus ulae*	2
137	Tetraodontidae	*Arothron stellatus*	1
138		*Arothron nigropunctatus*	2
139		*Ostracion meleagris*	1
140	Zanclidae	*Zanclus cornutus*	48
Total	27	140	5236

In terms of coral fish distribution at a 10 m depth in the limited-use zone of KPPD Biluhu Timur, stations 1, 3, and 4 had the highest number of individuals, species, and families, whereas station 2 had the lowest. The distribution of reef fish at a depth of 3 m by station is presented in Figure 5.

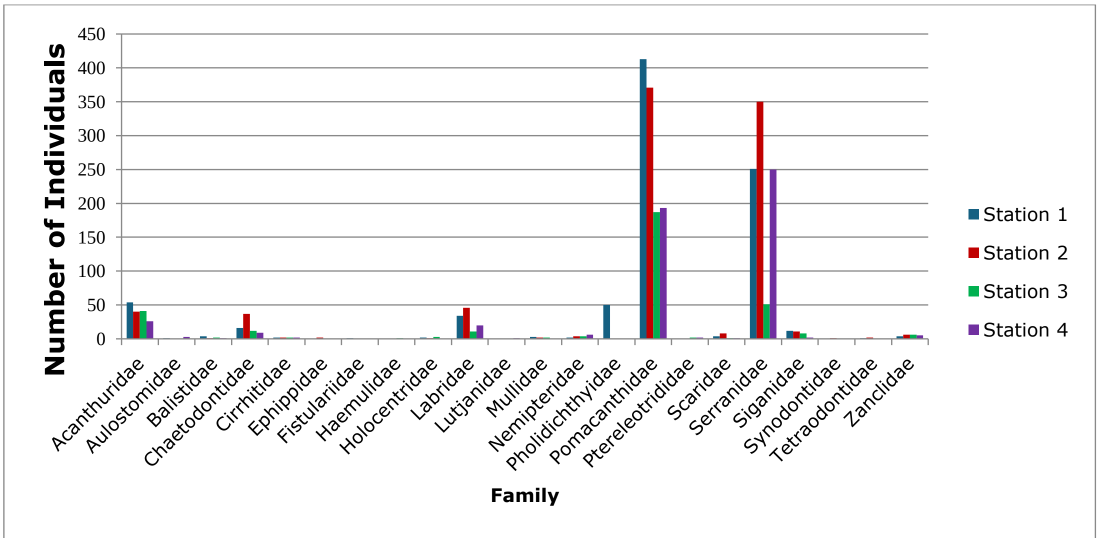

Figure 5. Coral fish individual distribution at a 3 m depth.

Our coral fish observation and identification at a 3 m depth in the limited-use zone of KPPD Biluhu Timur showed that station 2 had a coral fish distribution with the highest number of individuals (1032), species (60), and families (17). The second highest was apparent in station 1, with the number of individuals, species, and families of 865, 77, and 19, respectively. Meanwhile, the lowest one was found in station 4 (509 individuals, 36 species, and 13 families) and station 3 (318 individuals, 45 species, and 16 families). The gap in the number of individuals, species, and families is thought to be because the highest live coral cover was in stations 2 and 1, while the lowest was in stations 4 and 3.

Results showed that at a 3 m depth, the highest number of coral fish individuals was from the Pomacanthidae family. The Pomacentridae family was abundant, both in the number of species and of individuals, in tropical corals. The high number of the Pomacentridae family was also owing to their nature related to territorialism preference and group swimming. In addition, the fish can be found from the tidal area to a depth of 40 m (Hamzah et al 2020). The Pomacentridae family is comprised of tropical coral fish with attractive characteristics, i.e., bright color pattern, slightly flattened shape, the number, activities, and existence greatly influenced by the morphological characteristics of the substrates (Hamzah et al 2020). The distribution coral fish at a depth of 10 m by station is presented in Figure 6.

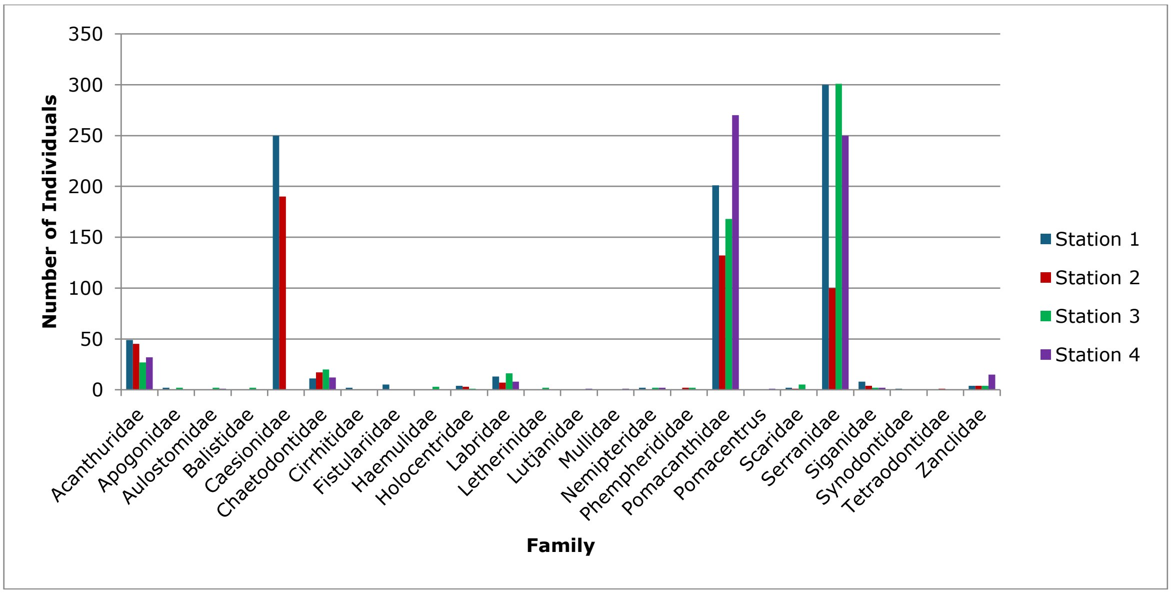

Figure 6. Coral fish individual distribution at a 10 m depth.

At a 10 m depth in the limited-use zone of KKPD Biluhu Timur, coral fish distribution with the highest number of individuals at 864, species at 46, and families at 16 was found in station 1. The second highest was in station 4, with 589 individuals, 35 species, and 10 families. Stations 3 and 2 had the lowest, with 560 individuals, 60 species, and 17 families and 499 individuals, 35 species, and 13 families, respectively. The discrepancy in the number of individuals, species, and families could have been because the highest live coral cover was in stations 1 and 4.

At a 10 m depth, coral fish individuals mostly encountered were from the Serranidae family. The Serranidae family (groupers) are carnivores living in coral areas and sheltered in large and massive coral crevices. Groupers are categorized into the main catch fish by fishers (Prasetya 2014).

Nearly all fish living in corals came with high dependence on corals, in terms of either their shelter or food. Syam et al (2023) stated that coral fish adaptation to water quality parameters vary, but the most influential parameters on their composition are live corals, nitrites, ammonia, larvae abundance, and temperature. Additionally, the research sites were placed into the Pacific Ocean area, where, according to Bachtiar et al (2022), coral fish diversity is considered highest in Indonesia, especially related to the three trophic levels, namely coral fish, herbivore fish, and carnivore fish. Research had attested to a positive correlation between the topographic complexity of corals and the distribution and abundance of fish living there. Research on corals proposed that coral fish held a strong association with corals and could be invoked as a coral health indicator (Adrim 2012).

Rani et al (2011) argued that coral fish settled and searched for food in coral areas (sedentary), and, accordingly, damaged and disintegrated corals would likely pose a habitat loss to the fish. To fish with a great reliance on corals, damaged or declined coral conditions affect diversity and abundance. 3 and 10 m depths presented an abundance of fish from the Chaetodontidae family, which ear algae, coral animals, and corals, and accordingly, the fish's existence was an indicator of coral conditions. The family was abundant in corals in good condition, high algae cover areas, and areas with abundant crustaceans, which were its food. The Chaetodontidae family could act as an indicator of a fertile coral ecosystem (English et al 1997).

Research on the same topic was carried out in several sea waters in Indonesia, which had become famous tourism objectives today. Results exhibited that the limited-use zone of KKPD Biluhu Timur maintained a higher number of individuals, species, and families than that in the tourism objectives. This was congruent with the results of Mahale et al (2018), who pointed out 36 coral fish species with 12993 individuals found in coastal areas. Coloay et al (2022) found 1869 individuals, 79 species, and 19 families in the waters of Lihaga Island. Mujiyanto & Sugianti (2013) found 1369 individuals, 58 species, and 10 families of coral fish found in the waters of Taman Nasional Karimun Jawa.

Conclusions. Coral conditions at station 4 at a 3 m depth were good to excellent. The mean average of live coral cover was 82.8%, which coral conditions in the limited-use zone of KKPD Biluhu Timur at a 3 m depth being excellent (75-100%). The highest percentage of live coral cover conditions was in station 2 (90.2%), whereas the lowest (69.2%) was in station 4. The highest percentage of dead coral cover was in station 4 (14.6%), while the lowest was in station 2 (1%). At a 3 m depth there were three coral cover categories, which were branching corals, massive corals, and algae. Types of corals found at the four stations were branching *Acropora*, tabulate *Acropora*, digitate *Acropora*, submassive Acropora, massive, branching and submassive corals. Corals at a 10 m depth were in moderate to excellent conditions, and the highest mean percentage of live coral cover of 69.35% was found at stations 2 (90.2%) and 1 (89.2%). Stations 2 and 1 also had the lowest mean percentage of dead coral cover of 1% and 2.8%, respectively. Meanwhile, in terms of live coral conditions, stations 3 and 4 presented the lowest cover percentage: 82.6% and 69.2%, respectively. Regarding dead coral conditions, stations 3 and 4 had the highest cover percentage at 8.6% and 14.6%, respectively. The total number of fish individuals found was 5265, consisting of 144 species and 27 families. 2751 coral fish individuals were found at a 3 m depth, whereas 2514 were found at a 10 m depth. The highest number of coral fish at a 3 m depth was found at station 2 (1032 individuals, 62 species, and 17 families). The second highest was noticeable at stations 1 (865 individuals, 63 species, and 18 families) and 4 (521 individuals, 41 species, and 14 families). Meanwhile, the lowest was identified at station 3, with 333 individuals, 45 species, and 15 families. At a 10 m depth, coral fish at station 1 came with the highest number of 854 individuals, 49 species, and 15 families, and the second highest was present at station 4 (595 individuals, 41 species, and 12 families). At station 3, there were 559 individuals, 59 species, and 16 families found. Finally, station 2 showed the lowest number of individuals, species, and families found at 506, 36, and 12, respectively.

Conflict of Interest. The authors declare that there is no conflict of interest.

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Received: 12 June 2024. Accepted: 04 September 2024. Published online: 22 January 2025.
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How to cite this article:
Hasim, Katili Z., Hamzah S. N., Musrifah F. S., Samatowa L., 2025 A preliminary analysis of coral cover and fish abundance in the regional marine conservation area of Biluhu Timur, Gorontalo, Indonesia. AACL Bioflux 18(1):148-162.