Coral health assessment of two marine national parks (takabonerate and wakatobi) in southern sulawesi

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Abstract. Coral reef ecosystems carry out a wide range of ecological functions and sustain the livelihoods of coastal communities through fisheries, coastal protection, and tourism. However, the coral condition has declined recently due to climate changes and anthropogenic activities. This study was undertaken in May 2019 to assess reef health status in Takabonerate and Wakatobi Marine National Park based on three components: live coral cover, resilience component (macroalgae and rubble cover), and fish biomass. The highest coral cover was 45.53% (Wanci), with an average cover of 24.6% and 29.48% in Takabonerate and Wakatobi. The average biomass of reef fish in Wakatobi was higher in Wakatobi (1.26 kg/ha) than in Takabonerate (0.70 kg/ha). For the resilience score, the average cover of macroalgae and rubble was 0.11% and 6.35% in Takabonerate and 1.64% and 0.51% in Wakatobi. Based on the coral, resilience, and biomass fish score, the Coral Health Index scored 5 (fair) and 9 (good) for Takabonerate and Wakatobi. The data suggested that reefs in both locations could recover from disturbance. However, the low biomass of targeted fish in the Takabonerate shows high fishing activities, which might lead to a direct/indirect impact on coral health.

1 Introduction

Coral reefs exhibit remarkable biodiversity and productivity despite occupying only 1% of the seafloor. [1,2]. Coral reef has several ecological functions related to the coastal communities and reef dwelling organism [3]. Overall, ecological services and goods provided by coral reefs reach 375 million dollars, consisting of tourism, fisheries and coastal protections [4,5]. Moreover, about a quarter of fisheries production in developing countries come from coral reef, and most of the coastal communities rely on food from the coral reef [6]. Threats to coral reefs have increased, which might decline the reef's function, services and goods.

The coral cover has experienced a 50% loss in the past decade as a result of changing climates, excessive fishing, habitat loss, and pollution. [7]. As a result, there has been a significant increase in studies focused on the condition and future prognosis of coral reefs.

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To accurately predict the future of coral reefs, it is important to assess the fluctuations in the structure of the reef. The utilization of hard coral cover has long been employed as an indicator to assess the state of coral reefs. [8]. The inclusion of other variables, which include conservation classes [9] and health indicators [10], contributes to the improved precision in assessing the condition of coral reefs. The assessment of coral health is crucial in facilitating the effective management of coral reefs and their associated ecosystems [11]. The evaluation of coral health status often involves the assessment of benthic community composition and fish abundance, which are widely recognized parameters [12, 13]. According to the findings of [8], the inclusion of hard coral cover, macroalgae, and fish community is crucial for accurately assessing the general state of a reef ecosystem.

In order to assess the overall health of coral reefs, the coral reef health index (RHI) was formulated by combining three parameters: fish biomass, resilience factor (comprising fleshy seaweed and rubble cover), and live coral cover [10]. Low coral cover and a decline in fish population were distinguishing features of the poor reef, as noted by [14]. Furthermore, the ability of coral to withstand and recover from environmental changes is contingent upon their adaptive capacities and the influx of larvae into the reef ecosystem, both of which are controlled by macroalgae and the presence of suitable substrate. Macroalgae is considered a potential competitor for the substrate utilized by coral juveniles. The post-settlement period of coral juveniles has a poor succession rate, resulting in a notable percentage of post-settlement mortality [16,17]. The first parameter referred to the hard (scleractinian) coral, fish biomass refers to the total biomass of targeted fish families (Serranidae, Lutjanidae, Lethrinidae, Haemulidae, Acanthuridae, Scaridae, and Siganidae), and the resilience factor was scored based on the macroalgae and rubble cover. In 2017 and 2018, the national status of coral reefs in Indonesia was evaluated using the coral reef health index (RHI) [10,17].

Takabonerate and Wakatobi Marine National Parks were located in the south of Sulawesi Island and included in the center of Coral Tri Angle. According to the SK Menteri Kehutanan Nomor 92/Kpts/2001, Takabonerate Marine National Park covered 530,765 ha and was the third largest atoll in the world with an area of 220,000 ha. Meanwhile, Wakatobi Marine National Park has 1.39 million ha and consists of three types of reefs: fringing reef, patch reef and atoll. Both MPAs were important to the surrounding fisheries industry, in which MPA plays an important role in the spillover process (emigration of adult, larva and juvenile from MPA) [18]. As mentioned by [19], Wakatobi is one of the hot spots of reef fish in Indonesia. Takabonerate has a limited diversity of coastal ecosystems (mostly consisting of reefs and seagrass), while Wakatobi offers a diverse seascape. This study aimed to assess the coral health of Takabonerate and Wakatobi Marine National Park following the method of [10]. In addition, information on coral morphological class, fish abundance and diversity are added.

2 Materials and Method

2.1 Study area

Located south of Sulawesi Island, Takabonerate Marine National Park is located near Selayar Island, while Wakatobi Marine National Park is located near Buton Island and south of Kendari Regency. TMNP is mostly an atoll with cover areas of about 530,765 ha, with a small portion of the island located in the north part of the national park. WNMP is an archipelago covering areas of about 1.39 million ha consisting of 4 main islands, Wangi-Wangi, Kaledupa, Tomia and Binongko (excluded in this research), also atoll located on the south of Kaledupa, and Tomia. A small portion of the population (13,623) in TMNP is concentrated in the northern part. Unlike TNMP, the WNMP population reached 96,111, located in all the islands. The MPAs have different types of the reefs; atolls dominate TNMP, while WMNP consists of fringing, patch and atoll reefs. Although the TNMP location is remote, fishing activities are plenty and use medium size boats. In WNMP, the fishermen were dominantly by inboard motorized boats, which allowed them to fish far from the village.

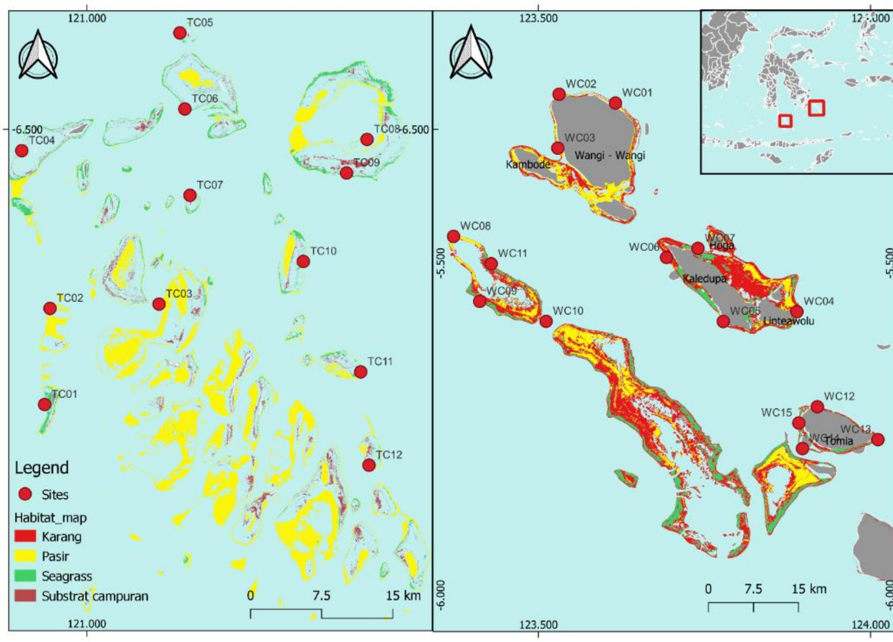

Fig 1. Map showing the samping sites of Takabonerate (left) and Wakatobi (right) Marine National Park.

2.2 Sampling protocols

Sampling was carried out in May 2019 (Wakatobi) and June 2019 (Takabonerate) at fifteen and twelve sites, respectively (Fig 1). The underwater photo transect (UPT) method by [16] was used for the benthic survey. A 50m line transect was laid parallel with the island and placed between 7-9m depth. The underwater visibility was more than 5m during samplings. The 58x44cm frame was placed at every meter, with the frame placed on the left of the transect line at the odd meter and right at the even meter. The photo transect was collected using Canon G-15, with the total photo for each transect was 50 photos.

Components of fish were assessed in addition to the benthos. The researcher performed an underwater visual census (UVC) in order to assess the composition of fish communities and estimate the sizes of reef fish populations. [21]. A total observation area of 350 m2 was established by documenting the reef fish species present along a 70x5m (2.5m on each side) reef. This area was augmented by 20m using benthic transect lines to account for the fish's movement throughout the transect. The identification of the fish following the field guide by [22] for functional group and estimation of biomass (a and b values) was followed by [23].

2.3 Data analysis

All the quadrant photos were then analyzed using CPCe 4.1 to estimate the benthic and substrate percent cover [24]. A total of thirty randomly selected points were distributed within each quadrant. Subsequently, each point was assigned to either the benthic lifeform or substrates category. It is worth noting that the lifeform of hard coral was specifically identified as the representative for live coral cover. The identification of the benthic and substrate components was thereafter conducted based on established classification criteria by [20].

The CHI was calculated based on a combination of three components: live coral cover (LCC), resilience component (FS and R cover) and fish biomass (total). The three components were then classified into three levels: low, medium and high, based on the result in Table 1. For the CHI calculation purposes, the fish biomass covert from gram/350m2 to Kg/Ha.

Table 1. Component score and the categories in coral health index (CHI)

Benthic component	Score	Category
Live coral cover (LC)	LCC < 19%	Low
	19 ≤ LCC ≤ 35%	Medium
	LCC >35%	High
Recovery ability (Resilience)	FS < 3% U (R ≤ 60% LC >5%)	High
	FS > 3% U (R ≥ 60% LC >5%)	Low
Fish Biomass (B)	B < 970 Kg/ha	Low
	970 Kg/ha ≤ B ≤ 1940 kg/ha	Medium
	B > 1940 Kg/ha	High

A combination of benthic components and the fish biomass score was then formulated to obtain the RHI values. The index value is then classified based on the weighting of the value of each component and then classified based on Table 2 below.

Table 2. CHI values and the categories

Coral Cover	Recovery ability	Score	Fish Biomass	Score	Total Score	CHI
High	High	6	High	6	12	10
High	High	6	Medium	4	10	8
High	High	6	Low	2	8	6
Medium	High	5	High	6	11	9
Medium	High	5	Medium	4	9	7
Medium	High	5	Low	2	7	5
High	Low	4	High	6	10	8
High	Low	4	Medium	4	8	6
High	Low	4	Low	2	6	4
Low	High	3	High	6	9	7
Low	High	3	Medium	4	7	5
Low	High	3	Low	2	5	3
Medium	Low	2	High	6	8	6

3 Result and discussion

3.1 Corals and benthic communities

According to the coral cover classification of [10], five sites (TC02, TC06, TC09, TC12, and WC10) exhibited compromised coral cover, composed primarily of Takabonerate. Most sites in both Taka and Waka had a majority of medium coverage, with 6 sites in Takabonerate and 11 sites in Wakatobi (Table 3). The following seven locations were classified as being in good condition: WC07, WC11, WC01, WC02, WC12, WC13, and WC14. The average coral coverage across both parks was 24.62% ± 2.17 in Takabonerate and 29.48% ± 2.47 in Wakatobi, ranging from 9.20% to 45.53%. (Fig 2). The highest coral cover was recorded at TC11 (37.07%) and WC02 (45.53%), while reefs at TC09 and WC10 had the lowest coverage (14.87% and 9.20%). The live coral cover of selected sites demonstrated low to high conditions. The low coral cover was exhibited in four sites (Takabonerate), and only one in Wakatobi; in medium condition were six sites in Taka and 9 in Waka. Lastly, reefs with high conditions were two in Taka and five sites in Waka. The average LCC of 24.62% (Taka) and 29.48% (Waka) was slightly lower compared to the Komodo Marine National Park (30.84%), located in Nusa Tenggara Timur [25]. Moreover, the LCC in both locations was lower than the latest cover in East Asian regions (36.8%) [26]. The LCC in Wakatobi was higher than in Spermonde, which recorded an average LCC of 27.83% [23]. The macroalgae cover in all sites was less than 3%. The highest cover was recorded at WC03 with 2.4%. Most sites had rubble cover less than 10%, especially in Wakatobi, where the average cover was 1.64%. In Takabonerate, rubble cover was slightly higher, where three sites had rubble cover more than 10%, namely WC02, WC07, and WC08. On these conditions, both reefs might bounce back to the initial condition after natural disturbance, fewer macroalgae cover, and the availability of consolidated substrate gives a high probability of coral juveniles settling and growing. In addition, the natural condition of both MPAs that are bordered by open sea, such as the Banda Sea, gives good water circulation and flushing to the reef that inhibits the macroalgae growth [28,29]. Moreover, it also enhances the recovery process after a bleaching event [30].

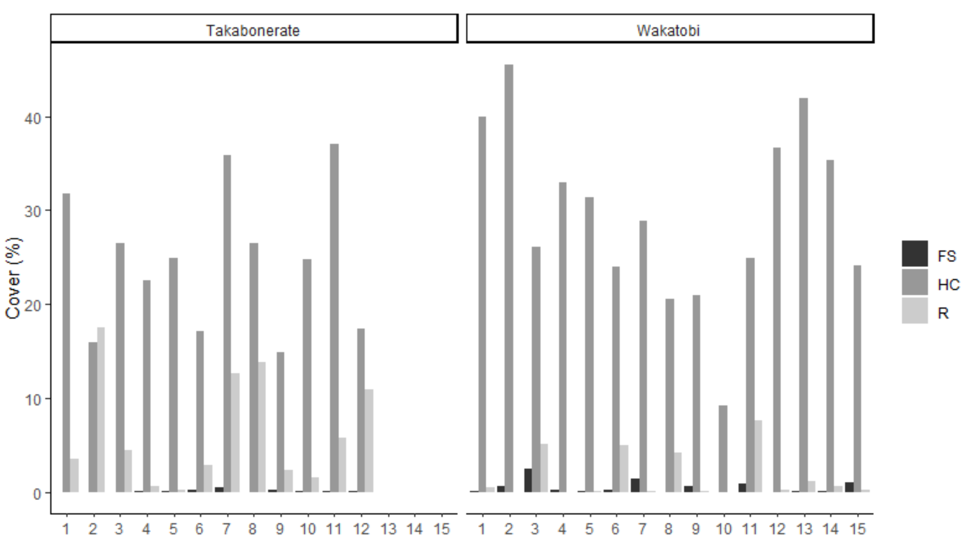

Fig 2. Percentage of coral cover (HC), macroalgae (FS) and rubble (R)

Table 3. Benthic cover and coral condition at all sites

Sites	HC	DCA	SC	SP	FS	OT	R	S	Coral cond.
TC01	31.73	49.87	6.73	1.00	0.00	6.53	3.53	0.60	M
TC02	15.93	47.60	2.33	1.67	0.00	7.73	17.53	7.20	L
TC03	26.53	57.47	0.53	1.87	0.00	2.40	4.47	6.73	M
TC04	22.53	47.73	9.07	4.60	0.07	13.80	0.60	1.60	M
TC05	24.93	33.13	11.07	13.07	0.13	17.07	0.20	0.40	M
TC06	17.13	38.20	6.67	8.60	0.27	23.80	2.87	2.47	L
TC07	35.93	37.53	0.20	1.40	0.40	4.73	12.67	7.13	H
TC08	26.53	20.80	0.93	2.67	0.00	5.27	13.87	29.93	M
TC09	14.87	24.07	22.67	3.87	0.27	28.73	2.27	3.27	L
TC10	24.80	46.33	5.33	1.07	0.07	13.60	1.53	7.27	M
TC11	37.07	30.47	13.07	2.07	0.07	10.93	5.73	0.60	H
TC12	17.40	27.47	3.67	3.00	0.07	2.93	10.93	34.53	L
WC01	40.00	24.73	0.20	13.13	0.07	21.47	0.40	0.00	H
WC02	45.53	10.67	11.47	17.53	0.53	13.87	0.00	0.40	H
WC03	26.13	33.67	0.00	12.27	2.40	5.13	5.13	15.27	M
WC04	33.00	26.27	19.07	9.00	0.20	12.47	0.00	0.00	M
WC05	31.33	30.73	7.87	12.80	0.07	16.60	0.07	0.53	M
WC06	24.00	19.27	16.07	22.53	0.27	11.07	4.93	1.87	M
WC07	28.80	29.67	10.47	15.40	1.40	12.87	0.13	1.27	M
WC08	20.47	23.00	14.67	5.67	0.00	29.33	4.20	2.67	M
WC09	20.93	21.13	32.93	10.73	0.60	12.87	0.07	0.73	M
WC10	9.20	32.47	36.27	6.00	0.00	11.40	0.00	4.67	L
WC11	24.87	29.67	10.20	6.73	0.80	11.27	7.53	8.93	M
WC12	36.67	29.47	11.60	8.40	0.00	12.80	0.20	0.87	H
WC13	41.93	35.13	3.27	8.53	0.13	9.13	1.07	0.80	H
WC14	35.27	26.60	8.93	13.00	0.13	13.47	0.60	2.00	H
WC15	24.07	24.60	5.53	5.13	1.00	39.33	0.20	0.13	M
Av. Tak	24.62 ± 2.17	38.39 ± 3.32	6.86 ± 1.87	3.74 ± 1.04	0.11 ± 0.04	11.46 ± 2.41	6.35 ± 1.69	8.48 ± 3.31	M
Av. Wak	29.48 ± 2.47	26.47 ± 1.63	12.57 ± 2.70	11.12 ± 1.26	0.51 ± 0.17	15.54 ± 2.22	1.64 ± 0.64	2.68 ± 1.08	M

* L= low, M= Medium, H= High

3.2 Fish communities

The marine national parks of Takabonerate (2114) and Wakatobi (7540) recorded a cumulative number of 9652 targeted reef fish. On average, the abundance of reef fish in Takabonerate and Wakatobi was 176 and 503, respectively. The highest and the lowest abundance was recorded at TC06 (122) and WC04 (976). In summary, a total of 132 species were discovered, belonging to 7 family and 32 genera (Table 5) Chaetodontidae was the subsequent most frequently observed fish family, after Acanthuridae. In both localities, only two species were observed at every site: *Siganus vulpinus* and *Ctenochaetus striatus*. In order to facilitate conservation and management, diversity and abundance of fish are crucial metrics. The disparity in reef fish abundance and diversity between Takabonerate and Wakatobi, as indicated by the data, could potentially be attributed to the seascapes of the respective locations. In the context of this investigation, the absence of mangroves in Takabonerate could potentially impact the composition of the fish. Multiple fish families utilize mangroves as nursery grounds, including Scaridae (parrotfish), Serranidae (grouper), and Lutjanidae (snappers) [31,32]. Consequentially, coral reef regions adjacent to mangroves exhibited a greater diversity of reef fish [33]. As an indicator of reef health, Chaetodontidae richness in both locations is higher than in Bintan (2 species) and Batam (3 species), which had turbid conditions [34], which is shown coral reef condtiton in both locations are in good.

Based on the visual census, reef fish in the marine national park were dominated by herbivores (106 and 265), followed by carnivores (39 and 126) and corallivores (31 and 111) (Fig 3a). The reef fish abundance and species richness were higher in the Wakatobi and Takabonerate. Similarly, the fish biomass was higher in Wakatobi than in Takabonerate, and herbivorous fish was higher than the carnivorous. Moreover, similar patterns were also seen in all sites, especially in Waktobi. However, few sites were dominated by the carnivore fish, such as TC01, TC04, TC10, TC12, WC12, and WC13. Overall, the highest and the lowest biomass was recorded at TC01 and WC04 (1044.34 Kg/Ha and 4258.29 KG/Ha) and TC06 and WC05 (637.26 Kg/Ha and 1018.21 Kg/Ha), respectively. The highest herbivore biomass was at TC05 and WC04, while carnivore was recorded at TC01 and WC13. On the other hand, TC06 and WC05 had the lowest biomass of herbivores, and TC02 and WC07 had the lowest carnivore biomass. On average, the fish biomass of Takabonerate and Wakatobi was 244.44±80.06Kg/ha and 1112.15±219.6 Kg/ha (Fig 3b). The fish biomass recorded in this study was high compared to PAD (167.6 Kg/ha) and Songsong Island (115.5 Kg/ha) [35]. However, the biomass is considered low (Takabonerate) compared to fish biomass in the Kei Kecil archipelago, with biomass ranging from 456.62-3,593.85 Kg/ha [36]. According to [37], the use of fish biomass ensures a holistic metric to determine the resilience of reefs against future stress. The high density of herbivores fish in most of the sites gives benefits to coral health. Herbivore fish play an important role as controllers of algae growth macroalgae, turf algae or algae that grow on dead coral [38]. Although Scaridae and Acanthuridae were high in both locations, both fish families are fishermen's targets [39,40]. The change in the population of those fish families might influence coral growth, as it has an ecological function as a controller of algae growth [41].

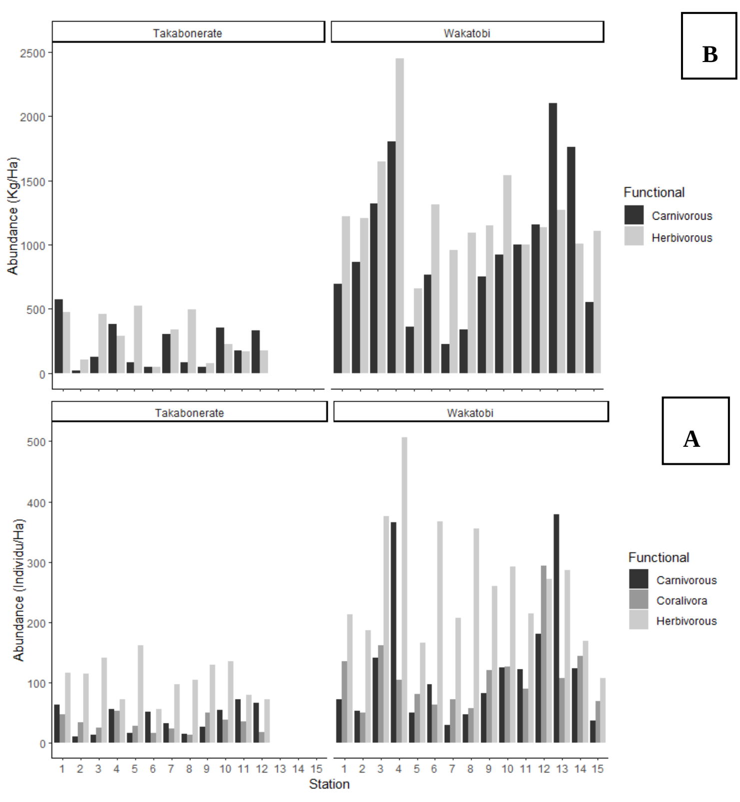

Fig 3. Abundance (A), and Biomass (B) of reef fishes based on the functional groups in Takabonerate and Wakatobi (left and right)

3.3 Coral reef health index

The coral health index represented three components: the recent condition of live coral, the resilience and the ecological function. The Coral health index consists of two components: benthic and fish component. The major components of the benthic were live coral cover (HC), fleshy seaweed cover (FS) and rubble (R). The live coral cover represented the recent condition, while FS and R illustrated the reef's resilience, which both categories influence the survival of coral juvenile settlements [8,16,42].

Based on the result, the CHI values of the coral reef in Takabonerate was 5 (range 3-7), while in Wakatobi was 9 (range 7-10). The distribution of the CHI in all sites is displayed in Fig 4. The fish component influenced the difference in the CHI value between Takabonerate and Wakatobi. On average, both locations had similar values on the coral component and the resilience factor, where the coral condition was in the medium condition. Both locations had similar values of resilience component and environment condition (good water circulation). The fish biomass in Wakatobi was five times higher than in Takabonerate (2224.30 Kg/Ha and 488.88 Kg/Ha). The highest score of CHI was recorded at TC01 (7), WC02, WC12, WC13 and WC14 (10), with live coral cover categorized at medium (Takabonerate) and High (Wakatobi) and fish component medium (Takabonerate) and high (Wakatobi). Meanwhile, the lowest CHI was 3 (Taka) and 7 (Waka), recorded at TC02, TC06, TC09 and TC12 and WC05, WC07, WC08, WC09, WC10 and WC15.

Table 4. The coral health index score

Station	HC(%)	FS(%)	R(%)	BIOM	CCC	CR	CS	RFC	FS	CHI
TC01	31.73	0.00	3.53	1044.35	M	1	5	M	4	7
TC02	15.93	0.00	17.53	121.42	L	1	3	L	2	3
TC03	26.53	0.00	4.47	583.33	M	1	5	L	2	5
TC04	22.53	0.07	0.60	663.14	M	1	5	L	2	5
TC05	24.93	0.13	0.20	600.10	M	1	5	L	2	5
TC06	17.13	0.27	2.87	92.15	L	1	3	L	2	3
TC07	35.93	0.40	12.67	637.25	H	1	6	L	2	6
TC08	26.53	0.00	13.87	579.51	M	1	5	L	2	5
TC09	14.87	0.27	2.27	124.97	L	1	3	L	2	3
TC10	24.80	0.07	1.53	580.81	M	1	5	L	2	5
TC11	37.07	0.07	5.73	339.73	H	1	6	L	2	6
TC12	17.40	0.07	10.93	499.78	L	1	3	L	2	3
WC01	40.00	0.07	0.40	1910.46	H	1	6	M	4	8
WC02	45.53	0.53	0.00	2068.67	H	1	6	H	6	10
WC03	26.13	2.40	5.13	2967.40	M	1	5	H	6	9
WC04	33.00	0.20	0.00	4258.29	M	1	5	H	6	9
WC05	31.33	0.07	0.07	1018.21	M	1	5	M	4	7
WC06	24.00	0.27	4.93	2081.74	M	1	5	H	6	9
WC07	28.80	1.40	0.13	1186.43	M	1	5	M	4	7
WC08	20.47	0.00	4.20	1432.10	M	1	5	M	4	7
WC09	20.93	0.60	0.07	1903.38	M	1	5	M	4	7
WC10	9.20	0.00	0.00	2460.17	L	1	3	H	6	7
WC11	24.87	0.80	7.53	2002.56	M	1	5	H	6	9
WC12	36.67	0.00	0.20	2290.84	H	1	6	H	6	10

WC13	41.93	0.13	1.07	3367.01	H	1	6	H	6	10
WC14	35.27	0.13	0.60	2763.91	H	1	6	H	6	10
WC15	24.07	1.00	0.20	1653.38	M	1	5	M	4	7
Av. Taka	24.62	0.11	6.35	488.88	M	1	5	L	2	5
Av. Waka	29.48	0.51	1.64	2224.30	M	1	5	H	6	9

* L= low, M= Medium, H= High

The CHI index on both marine national parks indicated that the reefs were in fair and good condition. Overall, the reef in both locations can bounce back from disturbance. The natural condition that allows flushing into the reef system is good for maintaining the macroalgae growth. The fact that less rubble cover gives a hint of the availability of consolidated substrate for coral juveniles to settle.

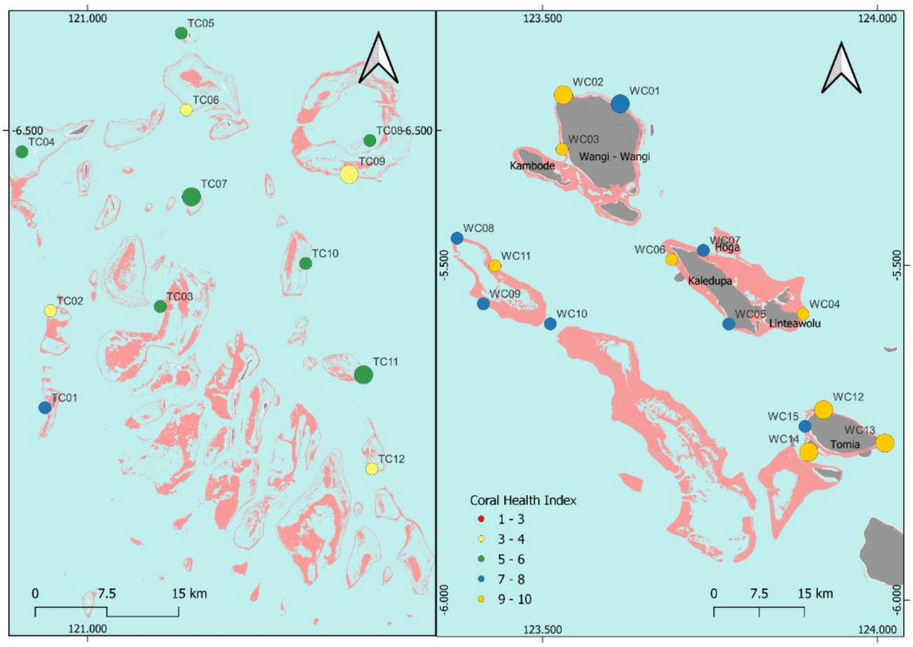

Fig 4. The coral reef health index (CHI) in all sites.

4 Conclusion

Based on the observation, the coral cover was in the medium condition on TMNP (24.62%) and (29.48%) WNMP. The resilience factor is high due to the low cover of macroalgae and rubble. The fish biomass was recorded lower on TMNP than WMNP, which caused the CHI value on the WNMP to be higher than TMNP. The coral reef in both locations can bounce back naturally. However, the fishing pressure has to be controlled, especially in TMNP.

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Table 5. Reef fish abundance and richness at all sites

No	Species	Takabonerate												Wakatobi														
		01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**
I	Chaetodontidae	46	33	25	52	27	16	23	13	50	37	35	17	135	49	161	104	80	62	72	56	120	126	89	294	107	143	69
i	Chaetodon	15	19	19	22	22	8	16	12	29	27	29	15	52	35	37	73	57	46	58	42	70	48	56	62	60	56	19
1	*Ch. adiergastos*															2												
2	*Ch. auriga*												1				2		2				2	2			2	
3	*Ch. baronessa*							2		2	4		2	2		2	6	6	2	3	2	2		2	6	2	2	
4	*Ch. bennetti*																									2	2	
5	*Ch. citrinellus*				2									2	2	2	2	4			2	4	4		2	2		
6	*Ch. ephippium*													2		2				1				2		2		
7	*Ch. kleinii*	7	3	14	13	12		6	9	23	6	14	2	13	7	5	15	10	6	14	12	25	16	9	14	10	12	4
8	*Ch. lineolatus*																				2						2	2
9	*Ch. lunula*	1												2			4	6	2				2		2	2	2	
10	*Ch. lunulatus*	2	6	2	2	4	5		3			2	4	2		8	8	7	4	2	4	7	6	12	4	4	2	3
11	*Ch. melannotus*		3		2	3					7	8	2	4	5		8		2	9	2	8	4	4	8	10	6	
12	*Ch. meyeri*													4		2	2	2		2		2				2	2	2
13	*Ch. ocellicaudus*																	4	4	8	8			2	2	4		
14	*Ch. ornatissimus*							2						2	2	2	4	4	2	2		4	4	2	4	4	2	
15	*Ch. oxycephalus*													2	2		2	2	2						2			
16	*Ch. Punctatofasciatus*	4	1	2			3	2			4	2	2	4	12		4	4	8	6	2	4		7	2	4	10	2
17	*Ch. rafflesii*		2			2		2				3		4	2	4	4	2	4	2		2	2	2	4	4	2	2
18	*Ch. semeion*																											
19	*Ch. speculum*	1	2											1		4	2	2		1		2		4			2	
20	*Ch. trifascialis*									2	4						2		2		2	8		2	2			
21	*Ch. ulietensis*		2		2						2			2		2	2	2	2	2	2		2	2	2	2	2	2
22	*Ch. unimaculatus*									2					2		4		2	4		2	4	2	4	3	4	
23	*Ch. vagabundus*					1		2					2	6	1	2	2	2	2	2			2		4	3	2	2
24	*Ch. xanthurus*			1	1																4			2				
ii	Coradion	0	0	0	0	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
25	*Cor. chryzostomus*						3									2												
iii	Forcipiger	6	0	0	4	0	2	3	0	4	2	4	0	7	4	12	9	4	4	8	4	18	16	9	14	16	6	6
26	*For. flavissimus*	2			4		2	3		4		4		7	4	12	5	4	4	8	4	10	10	9	8	8	6	6
27	*For. longilostris*	4									2						4					8	6		6	8		
iv	Hemitaurichthys	21	14	0	14	0	0	0	0	17	6	0	0	72	0	95	4	6	6	0	4	20	50	12	200	15	75	38
28	*Hem. polylepis*	21	14		14					17	6			72		95	4	6	6		4	20	50	12	200	15	75	38
v	Heniochus	4	0	6	12	5	3	4	1	0	2	2	2	4	10	15	18	13	6	6	6	12	12	12	18	16	6	6

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29	*Hen. chrysostomus*	2		4	12	3	3	2			2		2		6	7	8	6	2		2	6	6	4	10	6	2	2
30	*Hen.dephreutus*															1				2								
31	*Hen.singularis*													2	2	2	2	2	2	2		2	2	2	2	4	2	2
32	*Hen.varius*	2		2		2		2	1			2		2	2	5	8	5	2	2	4	4	4	6	6	6	2	2
II	Seranidae	18	2	7	24	6	7	8	1	11	14	21	7	25	9	27	27	14	15	9	10	26	14	14	29	52	18	13
vi	Aethaloperca	0	0	1	0	0	0	0	0	0	1	0	2	4	0	4	0	2	2	0	0	2	2	2	4	8	2	2
33	*Aet. rogaa*			1							1		2	4		4		2	2			2	2	2	4	8	2	2
vii	Anyperodon	1	0	0	0	0	0	1	0	0	0	1	0	1	1	1	2	1	0	1	0	3	0	1	5	3	0	0
34	*Any. leucogrammicus*	1						1				1		1	1	1	2	1		1		3		1	5	3		
viii	Cephalopholis	12	2	0	16	6	6	3	0	9	8	14	3	13	6	18	19	2	9	6	8	17	11	7	14	26	11	9
35	*Cep. argus*	2			1	2					5	2		5	2	4	7	2	4	1	3	5	4	2	5	6	1	2
36	*Cep. cyanostigma*	3						1					1	2		1			2	1		3		2	2		3	2
37	*Cep. leopardus*																		1		1		1	1				
38	*Cep. miniata*													2		5											1	
39	*Cep. sexmaculata*				1																			1			2	4
40	*Cep. spiloparae*				1										2	1			1	2	2			1		6	3	1
41	*Cep. urodeta*	7	2		13	4	6	2		9	3	12	2	4	2	7	12		1	2	2	9	6		7	14	1	
ix	Diploprion	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	*Dip. bifasciatum*							1	1																			
x	Epinephelus	4	0	6	7	0	1	2	0	1	5	1	0	3	0	1	4	4	3	2	1	0	1	2	4	7	0	0
43	*Ep. fasciatus*	3			5			1		1	4			2			4	4	2	2	1			1	2			
44	*Ep. merra*			5	2		1	1			1	1				1							1			1		
45	*Ep. ongus*	1		1																				1	2	4		
46	*Ep. spilotoceps*													1					1		0					2		
xi	Gracila	1	0	0	1	0	0	1	0	1	0	5	0	2	2	2	2	5	1	0	1	4	0	0	2	4	3	2
47	*Gra. albomarginatus*	1			1			1		1		5		2	2	2	2	5	1		1	4			2	4	3	2
xii	Plectropomus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	2	0
48	*Pl. leopardus*																										1	
49	*Pl. oligocanthus*																							1			1	
50	*Pl. tauvina*													1														
xiii	Variola	0	0	0	0	0	0	0	0	0	0	0	2	1	0	1	0	0	0	0	0	0	0	1	0	4	0	0
51	*Var. louti*												2	1		1								1		4		
III	Lutjanidae	35	7	2	25	4	8	12	0	1	30	34	57	33	35	67	203	14	53	6	8	24	22	79	120	110	62	12
xiv	Aphareus	2	0	0	2	2	0	1	0	0	3	1	1	4	11	4	10	0	3	1	1	7	5	10	4	7	4	2
52	*Aph. furca*	2			2	2		1			3	1	1	4	11	4	10		3	1	1	7	5	10	4	7	4	2
xv	Aprion	0	0	0	0	1	0	0	0	0	4	0	2	0	0	0	1	0	0	0	1	0	0	2	0	1	0	0
53	*Apr. verescens*					1					4		2				1				1			2		1		
xvi	Lutjanus	31	4	2	20	1	6	8	0	0	22	32	52	24	12	50	175	11	32	2	2	8	6	59	109	86	39	2

54	*Lutj. argentimaculatus*													1													1	
55	*Lutj. biguttatus*																4	3	18									
56	*Lutj. bohar*	4			2		4	2			4	2	2	4	7	9	6		1			8	6	14	4	7	8	
57	*Lutj. carponatus*			2																								
58	*Lutj. decussatus*	2	4		4	1	2	2			7	24	1	1		4	8		3	2	2				3	4	3	2
59	*Lutj. fulviflamma*														4	9	3	3	2									
60	*Lutj. fulvus*											6				3	19									20	8	
61	*Lutj. gibbus*	25			14			4			11		47	4		25	135	5	6					44	102	55	18	
62	*Lutj. kasmira*												2															
63	*Lutj. monostigma*													14	1				2					1			1	
xvii	Macolor	2	3	0	3	0	2	3	0	1	1	1	2	5	12	13	17	3	18	3	4	9	11	8	7	16	19	8
64	*Mac. macularis*	2	3		3		2	3		1	1	1	2	5	12	13	15	3	16	3	4	9	11	8	7	14	19	8
65	*Mac. niger*																2		2							2		
IV	Lethinidae	5	0	3	5	5	34	10	12	14	9	15	2	9	8	42	130	18	24	12	28	24	88	27	29	217	41	10
xviii	Gnathodentex	0	0	0	0	0	30	0	0	0	0	0	0	0	0	31	100	0	0	0	23	0	60	0	0	190	31	0
66	*Gna. aureolineatus*						30									31	100				23		60			190	31	
xix	Lethrinus	2	0	1	3	0	1	2	2	0	0	0	0	4	3	5	16	11	11	2	1	10	17	14	14	12	4	4
67	*Leth. erythropterus*	2		1			1	2	2					4	1	3	9	7	7	2		5	7	4	6	6	4	3
68	*Leth. harak*																							1				
69	*Leth. olivaceus*														2						1		2	1		1		1
70	*Leth. ornatus*				3											2	7	4	4			5	8	8	8	5		
xx	Monotaxis	3	0	2	2	5	3	8	10	14	9	15	2	5	5	6	14	7	13	10	4	14	11	13	15	15	6	6
71	*Mon. grandoculis*	3		2	2	5	3	8	10	14	9	15	2	5	5	4	8	7	13	9	3	6	8	11	10	9	6	3
72	*Mon. heterodon*															2	6			1	1	8	3	2	5	6		3
V	Haemulidae	5	0	1	1	0	2	1	1	0	1	2	0	5	0	5	5	3	5	2	1	8	0	1	2	0	2	1
xxi	Plectorhinchus	5	0	1	1	0	2	1	1	0	1	2	0	5	0	5	5	3	5	2	1	8	0	1	2	0	2	1
73	*Plec. chaetodontoides*	4		1	1			1	1		1	1		2		2			3	1	1	1		1				
74	*Plec. lessonii*	1												1		1	3	2				2					1	
75	*Plec. lineata*													1			2	1	1			5					1	1
76	*Plec. vittata*						2					1		1		2			1	1					2			
VI	Acanthuridae	80	101	101	50	130	48	62	55	114	109	63	54	169	149	305	408	120	279	183	241	209	217	139	181	205	104	73
xxii	Acanthurus	25	9	20	13	69	15	14	5	30	32	7	20	30	31	79	46	34	46	16	40	36	32	18	21	18	26	24
77	*Acan. auranticavus*	1						2				1		2					4	2	2		4		4	2		

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78	*Acan. fowleri*													2	1												1	
79	*Acan. lineatus*															3	4											
80	*Acan. mata*			4																								
81	*Acan. nigricans*	4					5	2			3	2			3	6	11				4	6	5	1	5	6		
82	*Acan. nigrofuscus*			8		28	6			3	7		4			25					8		3					
83	*Acan. olivaceus*					19					7	2	2		0	2								3				
84	*Acan. pyroferus*	11	9	8		5	4	10	5	4	9	2	14	16	21	21	26	10	26	14	26	14	16	10	12	10	14	11
85	*Acan. thompsoni*	9			13	17				23	6			10	6	20	5	24	16			16	4	4			11	13
86	*Acan. xanthopterus*															2												
xxiii	Ctenochaetus	18	15	48	11	13	16	33	23	31	31	13	19	7	22	106	30	19	53	19	114	42	39	46	51	38	10	14
87	*Cte. binotatus*	8		23				9			21					41	15	8	6	15	52	25	14	22	12	8		
88	*Cte. striatus*	10	15	25	11	13	16	24	23	31	10	13	19	7	22	65	15	11	47	4	62	17	25	24	39	30	10	14
xxiv	Naso	8	2	0	6	10	1	7	5	8	5	17	0	91	70	65	238	4	130	86	24	89	93	28	66	81	45	12
89	*N. caeruleacaudus*														6		6					15	20			10		
90	*N. braenchycentron*							2																				
91	*N. brevirostris*																5			1		11	6	2				
92	*N. hexacanthus*				1							12		63	27	18	200		85	29	13	45	50	4	51	50	24	
93	*N. lituratus*		2		1	1	1	1	1		1			4	4	4	10		7	4	4	4	3	6	3	4	5	2
94	*N. thynoides*					9				8	4	5																
95	*N. unicornis*															1	2						4	1				
96	*N. vlamingii*	8			4			4	4					24	33	42	15	4	38	52	7	14	10	15	12	17	16	10
xxv	Zebrasoma	6	18	9	7	9	0	4	4	19	4	18	8	23	6	25	8	22	5	32	32	11	13	8	2	22	4	3
97	*Z. scopas*	6	16	9	5	4		4	2	13	4	18	8	21	6	23	8	10	5	30	31	11	11	8		20	3	2
98	*Z. veliferum*		2		2	5			2	6				2		2		12		2	1		2		2	2	1	1
xxvi	Bolbometopon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	3	2	0	0	9
99	*Bol. muricatum*															2			1					3	2			9
xxvii	Calotomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	1	0	0	0	0
100	*Cal. carolinus*																						6	1				
xxviii	Cetoscarus	0	3	0	0	0	0	0	0	3	0	3	0	0	4	2	0	0	0	0	1	0	2	2	3	4	0	0
101	*Cet. ocellatus*		3							3		3			4	2					1		2	2	3	4		
xxix	Chlorurus	23	54	24	13	29	16	4	18	23	37	5	7	18	16	26	86	41	44	30	30	31	32	33	36	42	19	11
102	*Chl. bleekeri*	7	20	6		4	7	4	6	3	5		2	3	4	8	39	21	9		10	7	14	12	6	10	4	2

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103	*Chl. capistratoides*																			3							2	2
104	*Chl. microrhinos*													2	1	2	2	7				3	4		2	4		
105	*Chl. sordidus*	16	34	18	13	25	9		12	20	32	5	5	13	11	16	45	13	35	27	20	21	14	21	28	28	13	7
V	Scaridae	27	1	28	17	26	6	22	31	7	14	14	15	36	27	52	70	36	68	18	98	46	71	47	85	73	44	28
xxxi	Hipposcarus	0	0	0	0	2	0	4	1	0	0	0	0	1	0	4	14	2	0	0	2	2	8	4	4	7	3	4
106	*Hipp. longiceps*					2		4	1					1		4	14	2			2	2	8	4	4	7	3	4
xxxii	Scarus	27	1	28	17	24	6	18	30	7	14	14	15	35	27	48	56	34	68	18	96	44	63	43	81	66	41	24
107	*Sca. chameleon*								2												3							
108	*Sca. dimidiatus*	2		4	2	5		1	2		2	2	2			14	6	11	17			8	8	1	10	2		
109	*Sca. ghobban*			4		3						2	2	5		2	14				15	7	13	10	17	27	10	9
110	*Sca. globiceps*					1			1										1		1							
111	*Sca. niger*	11	1		9	8	1	3	10	3	6	5	2	13	12	17	14	13	37	14	38	25	20	13	32	29	21	7
112	*Sca. ovicep*																						2		3	2		
113	*Sca. porsterni*				1						1										4		2					
114	*Sca. prasiognathos*											1					2		2				8					
115	*Sca. psittacus*						3							2	4	2	4		4		4		4	7	4	2		
116	*Sca. quoyi*					1							2	2		3		5										
117	*Sca. flavipectoralis*	11		18	2	2	1	13	11	1	3	3	5	5	4	10	4	5	7	4	23	3	4	12	10	4	6	8
118	*Sca. rivulatus*																				2	1						
119	*Sca. rubroviolaceus*														1													
120	*Sca. schlegeli*			2					3			1		1							4		2		3		4	
121	*Sca. spinus*				1	1								7	4						2				2			
122	*Sca. tricolor*	3			2	3	1	1	1	3	2		2		2		12											
VI	Siganidae	8	12	12	4	5	1	13	17	7	11	2	2	8	10	19	29	10	20	6	16	4	4	28	6	8	21	6
xxxiii	Siganus	8	12	12	4	5	1	13	17	7	11	2	2	8	10	19	29	10	20	6	16	4	4	28	6	8	21	6
123	*Sig. canaliculatus*		6			4			6		7										4			8				
124	*Sig. corallinus*	2		2				2	3					4		2		2						2			2	
125	*Sig. doliatus*								2							4			4	2								
126	*Sig. guttatus*														3	6	19							8			8	
127	*Sig. laqueus*	2		1					2																			
128	*Sig. puellus*			4				4	2	2				2	2	3	4	2	6	2	2	2	2	2	2	4	4	2
129	*Sig. punctatissimus*			2				3		2					3	2	2	4	4		2			4			5	2
130	*Sig. spinus*																											
131	*Sig. virgatus*																		4		2			2				
132	*Sig. vulpinus*	4	6	3	4	1	1	4	2	3	4	2	2	2	2	2	4	2	2	2	6	2	2	2	4	4	2	2