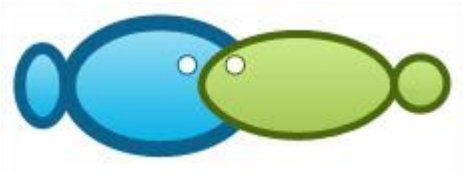

Status of reef fish in Buton Strait, Muna Regency, Indonesia

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Abstract. The Buton Strait has a significant role as a fishing ground for the fishermen in Muna Regency, particularly for reef fish. Overfishing activities pose a significant threat to the health of coral reefs. This study aims to assess the status of coral reefs and reef fish, providing initial information for the development of fisheries management strategies in the areas. The method used point intercept transect (PIT), underwater visual census (UVC), and fishermen's caught reports which provide direct information about the diversity and abundance of reef fish. The results of this study are generally classified as good with an average percentage of coral live cover of 60.05%. The diversity index average for coral reef fish is 1.01, which means that the diversity level is moderate. The evenness index, which ranges from 0.16 to 0.55 with average 0.45 which means that the distribution of individuals between species is uneven. The dominance index indicates the extent to which one or a few species dominate the community. With a value below 0.5, it indicates that no species significantly dominates the community.
Key Words: coral reef, conservation, local fisherman, southeast Sulawesi, TURFT.

Introduction. The distribution of reef fish body size, coral reef area, complexity, and temperature are key predictors of species richness, which significantly contribute to determining the condition of coral ecosystems (Barneche et al 2019; Hensel et al 2019; Brandl et al 2020). One of the area that have high diversity of reef fish is in Buton Strait. The Buton Strait is included in the jurisdiction of Muna District, which is part of the Regional Marine Conservation Area of Southeast Sulawesi. The Regional Marine Conservation Area of Muna District spans approximately 76,417.16 ha[2] (Anggraeni et al 2017). Conservation areas can be integrated with managed access and reserves to benefit more from conservation goals (Nomura et al 2017). The Buton Strait area has become a fishing ground for local fishermen along the coast. The predominant fishing gear used by these fishermen included bottom longlines, gill nets, and hand-line fishing. Field observations revealed that reef fish such as *Caesio cunning*, *Epinephelus* spp., and *Lutjanus* sp. are the most frequently caught species. The fishing activities within coral reef areas exert pressure on the ecosystem. The combination of intense fishing and an intermediate number of fishermen challenges fisheries management, making it difficult to regulate the fishing population. Almost all individuals engage in fishing regardless of their primary occupation, increasing the likelihood of reduced catches. The condition of reef fish can affect the balance of coral ecosystems (Muis et al 2019); therefore, losing a species can damage food webs in an aquatic ecosystem (Burke et al 2011; Gajdzik et al 2019; Hensel et al 2019).

Assessing the status of resources before implementing management can serve as a reference and evaluation material afterward (McClanahan 2021). The condition of coral reefs, reef fish, and megabenthos determines the condition status of reef fish. Especially for fish, data collection is divided based on its ecological function, corallivorous, herbivores, and target fish (English et al 1997; Yuliana et al 2016; Abrar et al 2017). Overall, biogeographic and energy factors mainly influence species richness and fish

density, whereas anthropogenic factors strongly influence functional distribution and biomass (Quimbayo et al 2019). Several studies examined the abundance of reef fish within and outside conservation areas (Lyu et al 2024; Sangaji et al 2024). There has been a decrease in the number of economically important fish species and biomass (target fish) during 2014-2017 in North Nias waters (Purwanto et al 2020). In addition, the coral reef condition continues to decrease. In Spelman Strait, the average coral condition is reported at 37.716% (Muis et al 2019). Studies of reef fish status in the western Indian Ocean showed convergence between biomass and length-based characteristics. They showed characteristic stability in unfished fish biomass around 1,000-1,200 kg ha^{-1} (McClanahan 2019b). Nearshore ecosystems on Great Abaco Island, Bahamas, measured fish abundance, species richness, and evenness after including Nassau grouper (*Epinephelus striatus*), a critically endangered coral reef predator, as fishing showed that the presence of predators and high reef complexity had a positive incremental effect on total fish abundance: fish abundance increased by ~250% and 300%, respectively, compared to the absence of predators and the treatment of reefs of low complexity (Hensel et al 2019).

This study aims to analyze the condition of coral reefs and reef fish using the diversity level, evenness, abundance, and composition of fishermen's catches. Hopefully, this study will provide a comprehensive picture of the state of coral reefs and become the basis for appropriate conservation measures in the studied area. The results of this study are expected to provide preliminary information for the benefit of implementing fisheries access-based management

Material and Method

Description of the study sites. This research was conducted from June 2021 to December 2022 in the Buton Strait, Muna Regency, Southeast Sulawesi, Indonesia. The study site delineates a managed access and reserves region, encompassing a water expanse totaling approximately 30,900 hectares (Figure 1). Therefore, 7 observation stations were utilized to assess coral and reef fish conditions. The location is based from local fisherman due to their actual reef fish site in Buton Strait. That 7 (seven) location can be seen in Table 1. The maps of the research location can be seen in Figure 1.

Table 1

Location site of the coral reef research in Muna Strait

Station	*Location*	*Latitude*	*Longitude*
1.	Kogholifano Island	-4.9670	122.7864
2.	Tanjung Lagara	-4.9673	122.7521
3.	North Tanjung Labora	-5.0919	122.6150
4.	South Tanjung Labora	-5.1229	122.6139
5.	Tanjung Walengkabola	-5.1849	122.6174
6.	Pasikolaga Island	-5.0981	122.7240
7.	Tanjung Tampanubale	-5.1011	122.7027

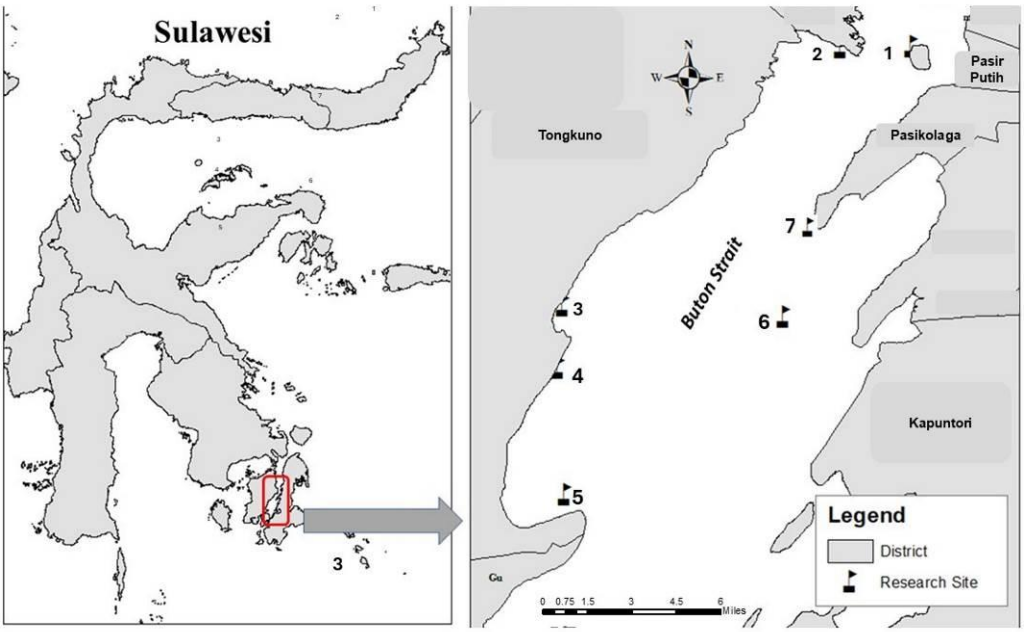

Figure 1. The location of research in Muna Strait.

Assessment of the coral reef. The data on reef fish status will be integrated with fishermen's catch data to provide comprehensive information on the condition of fish in deeper waters (English et al 1997). The data was collected from the managed access and reserves group data center, which collects local fishing reports as part of fisheries management agreements. Coral reef assessment was studied using the PIT method along 150 meters (3 x 50 m) to determine the living coral cover condition in certain areas. The reason for using PIT is that it is able to provide a level of information that is almost comparable to Line Intercept Transect (LIT) while reducing the time spent underwater. Therefore, when managing coastal areas or conducting impact studies to monitor disturbances, it is advisable to conduct surveys with an intermediate level of identification and utilize PIT (Facon et al 2016). The transect was towed 150 meters below the water's surface, allowing systematic surveying of the area. During field surveys, the main focus was assessing live coral cover along the transect. Intercept points were recorded every 0.5 meters, allowing measurement of the percentage of live coral cover at those points. The collected data were then analyzed to evaluate the overall condition of the coral reef.

Assessment of reef fish. Evaluating coral reef fish populations involves visually surveying the fish along 50-meter transects. These transects are surveyed during daylight hours using SCUBA diving. The assessment and monitoring of fish populations utilize a combination of two techniques. This method represents one of the most widely used quantitative and qualitative sampling approaches in coral reef surveys. The first method, the underwater visual census (UVS) method, was used to evaluate the condition of reef fish by recording the presence of fish at a distance of 2.5 meters to the right and left of the transect that stretches 50 meters. The UVS of fishes is one of the prevalent methods employed in quantitative and qualitative sampling during coral reef surveys. This approach is characterized by its swiftness, non-destructiveness, and cost-effectiveness. It requires minimal personnel and specialized equipment, making it practically selected. Additionally, it allows for revisiting the same area over time. Moreover, a visual census holds the potential to swiftly generate extensive databases crucial for management and stock assessment objectives (English et al 1997). The transect stretches for 150 meters (3 x 50 m) with observations 2.5 m to the right and 2.5 m to the left of the transect so that the total area of observation covered 750 m^2. The second method for assessing reef fish involved analyzing catch results conducted by fishermen actively operating within the managed access area of the Muna Fisheries Management Group. Therefore, a clear overview of reef fish living at depths greater than

10 meters could be obtained using data from catch reports provided by fishermen who were part of the fisheries management group. In order to make the fish identification easier for the fishermen, reef fish identification was carried out using Android application made by the NGO "Rare" called "OurFish" that combines with the reliable fish database which is "fishbase.org". The form of the application can be seen in Figure 2.

Figure 2. The form of "OurFish" application in fisherman mobile phone.

The composition of the catch. The composition of fishermen's catches, especially reef fish, can illustrate the condition of coral fisheries at a depth of more than 10 meters. The reef fish catch was recorded of fishing gear such as gill nets, hand-line, and bottom long line within the seven fishing base location mentioned before.

Data analysis. The collected data were analyzed qualitatively and quantitatively. Qualitatively, the data is presented in images, while quantitatively, the data is compiled and analyzed using MS. Excel. The data obtained are the number of species and individuals of each species of coral reefs and reef fish.

The status of reef fish was analyzed using the diversity index (H'), evennes index (E) and dominance index (C). The diversity index (H') was carried out to determine the stability of the community of organisms. It was determined using the Shannon-Wienner formula (Ludwig & Reynolds 1988):

$$H' = -\sum\left(\frac{ni}{N}\right)\log\frac{ni}{N}$$

where: H' = diversity index; ni = the number of individuals of each species; N = the total number of individuals.

The determination of species diversity takes into classification the following criteria: if H' > 3, the species diversity is extremely high; if H' is between 1.6 and 3, the species diversity is high; if H' is between 1 and 1.5, the species diversity is moderate; if H' < 1, the species diversity is low.

The evenness index (E) signifies the number of interspecies individuals in a community. The more evenly distributed individuals between species, the more ecosystem balance will increase. This condition is seen from the value that ranges between 0 and 1. Evenness index is calculated using the formula:

$$E = \frac{H'}{\log s}$$

where: E = evenness index; H' = diversity index; Log s - the number of species in the zone defined by E that ranged from 0 to 1.

The dominance index (C) value ranges from 0 to 1 which means that the value of 0 indicates the absence of dominating fish species, while the value of 1 indicates the presence of dominating fish species. The formula for the dominance index (C) is:

$$C = \Sigma(ni/N)^2$$

where: ni = the number of individuals of each species; N - the total number of individuals.

Results. Components of coral reefs found in the Managed access and reserves of Pasikolaga, Muna District, Southeast Sulawesi are Acropora branching, Acropora encrusting, Acropora submassive, Acropora tabulate, coral branching, coral encrusting, coral mushroom, soft coral, coral submassive, coral massive, coral heliopora, macroalgae, coral foliose, dead coral, coralin algae, sponge, sand, and rubble. The percentage of coral species from each lifeform obtained from the seven stations can be seen in Table 2.

Table 2

Results of coral reef analysis in managed access and reserves Pasikolaga, Muna District, Southeast Sulawesi

Type	*Percentage of coral cover on each station (%)*						
	1	*2*	*3*	*4*	*5*	*6*	*7*
Live corals	71.33	58.00	37.67	47.00	62.00	80.33	64.00
Dead coral	0.33	0.67	5.33	10.67	9.67	1.33	1.00
Other fauna	2.67	1.00	4.00	1.33	0.33	4.33	1.00
Algae	19.00	20.67	23.33	37.67	11.00	2.67	7.67
Abiotic	6.67	19.67	29.67	3.33	17.00	11.33	26.33

The percentage of coral reef cover shows the value of the condition of living coral reefs in certain waters; coral reefs classified as living coral reefs are *Acropora*, non-*Acropora*, and soft coral. According to the Regulation of the Indonesian Minister of Environment No. 4 of 2001 there are four criteria for coral reef cover, which are 0-24.99% (poor), 25-49.99% (medium), 50-74.99% (good), and 75-100% (very good). Table 2 shows live coral cover at station 1 at 71.33% and station 2 at 58%. Table 2 too shows station 3 at 37.67%,

station 4 at 47.00%, station 5 at 62%, station 6 at 80.33% and station 7 at 64.00%. The condition of coral reef cover in Buton Strait is generally classified as good, with an average percentage of coral cover of 60.05%. The lifeform of coral was dominated by massive corals at stations 1, 3, and 6. Meanwhile, branching coral types were most commonly found at stations 2, 4, and 7. Figure 2 shows the condition of the coral reef at each observation station.

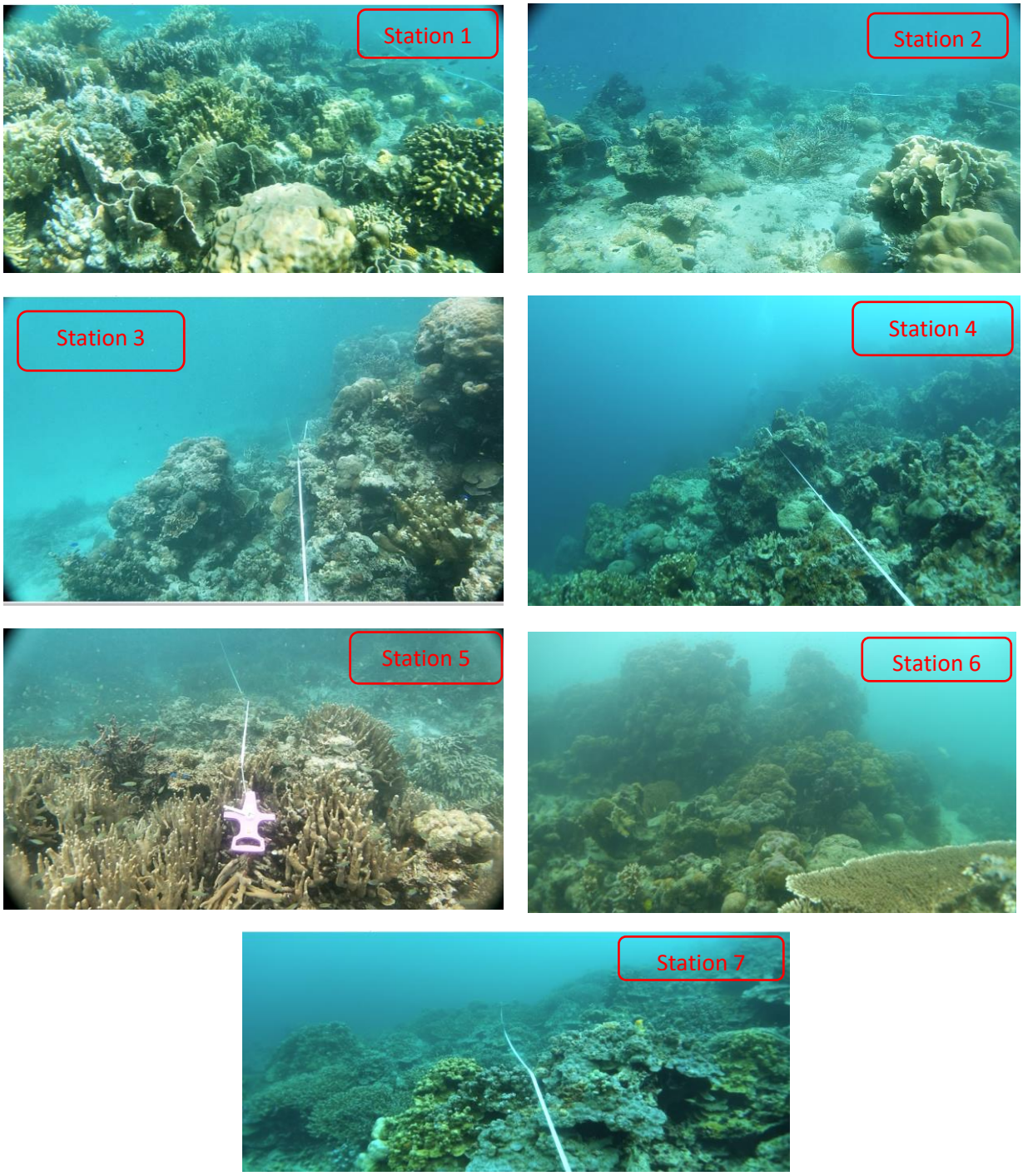

Figure 2. The condition of live coral cover at each station.

Physical factors play a crucial role in supporting coral life. The physical condition of the waters of Muna Strait were still suitable for supporting coral reef life. Including water condition. The water conditions data at each station are detailed in Table 2.

Table 2 provides information on the average survey depth of 5 meters with visibility between 10 and 30 meters, which can be categorized as clear waters. Reef types showed differences at each study station. The type of reef on the slope is observed at North and South Tanjung Labora (station 3 and 4), and Tanjung Tampunabale (station 7). Meanwhile, reef flattening was found at Khogolifano Island (station 1), Tanjung Langara (station 2), Tanjung Walengkabola (station 5), and Pasikolaga Island (station 6).

Table 2

Research station water profile in Muna Strait

Station	*Depth (m)*	*Visibility (m)*	*Reef slope*	*Coral cover (%)*	*Category*
1	5	10	Flat	71.33	Good
2	5	10	Flat	58.00	Good
3	5	25	Slope	37.67	Medium
4	8	30	Slope	47.00	Medium
5	6	20	Flat	62.00	Good
6	5	10	Flat	80.33	Very good
7	8	25	Slope	64.00	Good
Average	6	18.57		60.05	Good

Reef fish composition. The results of observation and identification of reef fish in June 2021, for all station observations displayed 50 species of reef fish consisting of 10 families and 817 individual fish. The fish families found at the observation site are Acanthuridae, Lutjanidae, Scaridae, Serranidae, Siganidae, Lethrinidae, Haemulidae, Labridae, Caesionidae, and Ephippidae; their composition is shown in Table 3.

Table 3

Types of reef fish in the Managed Access and Reserves of Pasikolaga

No.		*Family/species*	*Stat 1*	*Stat 2*	*Stat 3*	*Stat 4*	*Stat 5*	*Stat 6*	*Stat 7*	*Total*
1		Acanthuridae								**46**
	1	*Acanthurus nigricans*				4				4
	2	*Acanthurus olivaceus*				17		4		21
	3	*Acanthurus xanthopterus*				9			7	16
	4	*Ctenochaetus striatus*					3			3
	5	*Ctenochaetus tominiensis*					2			2
2		Lutjanidae								**109**
	1	*Lutjanus biguttatus*	3	1		6				10
	2	*Lutjanus bohar*				3		2		5
	3	*Lutjanus carponotatus*				2	5			7
	4	*Lutjanus kasmira*				38				38
	5	*Lutjanus decussatus*	2	2						4
	6	*Lutjanus fulviflamma*					4			4
	7	*Macolor niger*				41				41
3		Scaridae								**280**
	1	*Chlorurus bleekeri*	4							4
	2	*Chlorurus bowersi*	14							14
	3	*Chlorurus sordidus*	5							5
	4	*Hipposcarus longiceps*			4				20	24
	5	*Scarus dimidiatus*	26				7			33
	6	*Scarus flavipectoralis*	13						41	54
	7	*Scarus ghobban*					3			3
	8	*Scarus niger*					6			6
	9	*Scarus quoyi*			25					25
	10	*Scarus rivulatus*	16	16	50	10		2	9	103
	11	*Scarus schlegeli*			4					4
	12	*Scarus spinus*					5			5
4		Serranidae								**37**
	1	*Cephalopholis boenak*				1				1
	2	*Epinephelus bleekeri*				2				2
	3	*Epinephelus maculatus*				3				3
	4	*Epinephelus merra*						3	4	7
	5	*Plectropomus areolatus*				22				22
	6	*Plectropomus leopardus*				2				2

5		Siganidae								**81**
	1	*Siganus argenteus*		18						18
	2	*Siganus canaliculatus*					8			8
	3	*Siganus corallinus*					4			4
	4	*Siganus guttatus*		6						6
	5	*Siganus spinus*					2			2
	6	*Siganus virgatus*		8			5			13
	7	*Siganus vulpinus*	2	14	3	8	3			30
6		Lethrinidae								**14**
	1	*Gnathodentex aurolineatus*				4				4
	2	*Letrinus harak*			5	3				8
	3	*Monotaxis grandoculis*	2							2
7		Haemulidae								**21**
	1	*Diagramma melanacrum*			8					8
	2	*Diagramma pictum*			9					9
	3	*Plectorhinchus chaetodonoides*			2		2			4
8		Labridae								**35**
	1	*Choerodon anchorago*	5							5
	2	*Cheilinus fasciatus*		2						2
	3	*Thalassoma lunare*	5	4	2	9		2	6	28
9		Caesionidae								**171**
	1	*Caesio cuning*	45	53						98
	2	*Pterocaesio digramma*						40		40
	3	*Pterocaesio tile*						33		33
10		Ephippidae								**23**
	1	*Platax teira*				23				23
		Number of fish	142	124	112	207	59	86	87	**817**
		Number of species	13	10	10	19	14	7	6	
		Number of families	5	5	5	8	5	5	4	

Status of reef fish. The status of coral reef fish in this study was assessed based on aspects of coral reef condition, diversity index, evenness, and dominance. The result can be seen in Table 4.

Table 4

Status of reef fish according to the diversity index (H'), evenness index (E), and dominance index (C)

Description	*Station*							*Average*
	1	*2*	*3*	*4*	*5*	*6*	*7*	
H’	1.53**	0.37*	0.93*	1.38**	1.53**	1.04**	0.32*	1.01
E	0.55**	0.16*	0.41**	0.46**	0.55**	0.54**	0.16*	0.45
C	0.05*	0.02*	0.25*	0.08*	0.05*	0.17*	0.003*	0.09
Status	Fair	Poor	Poor	Fair	Fair	Fair	Poor	

Assessment criteria: High***, Medium**, Low*.

The Shannon-Wiener diversity index (H’) describes the variation of life within a community. The range of values from 0.32 to 1.53 indicated the level of diversity from low to medium. The higher the value, the more diverse the species in the community. The diversity index was used to measure diversity, and values smaller than 1 indicated that the community was likely to be unstable. This could be caused by several factors, such as environmental pressures, external disturbances, or changes in habitat conditions that impact species diversity. The evenness index (E), which ranged from 0.16 to 0.55, indicated how evenly distributed the relative distribution of individuals of different species was in the community. A low to moderate range of values indicated variation in the relative distribution of these individuals. The dominance index (C) indicated the extent to which one or a few species dominated the community; a value below 0.5 indicated no species significantly dominated the community. Low-dominance communities often had a more balanced structure because no species significantly dominated the resources or scope of habitat. The status of coral reef fish, as assessed based on live coral cover, diversity index, evenness, and dominance, can be seen in Table 4.

Table 4 shows the status of coral reef fish at each different station. Overall, none of the stations indicated a favorable status. Some stations, such as stations 1, 4, 5, and 6, showed a fair status. This was because the diversity and evenness indices indicated medium values. Meanwhile, stations 2, 3, and 7 exhibited a poor status due to very low diversity and evenness indices values. This indicated that the fish condition experienced pressure on diversity.

Discussion. Observations of coral reef fishes show some interesting patterns in the presence of certain fish families at various observation stations. The Scaridae family is the only reef fish family present throughout the station, showing a wide degree of adaptation to various environmental conditions (McClanahan 2019a). Meanwhile, other families such as Acanthuridae, Lutjanidae, Serranidae, Siganidae, Lethrinidae, Haemulidae, Labridae, Caesionidae, and Ephippidae are found only at a few stations. This may be related to habitat preferences, migration patterns, or specific tolerances to environmental conditions present at these stations (Brandl et al 2020). There was variation in coral reef fish density at various stations, with station 4 having the highest density (213 ind/750 m^2) and coral cover percentage at 47%, while station 5 having the lowest density (62 and/750 m^2) with a higher percentage of coral cover 62%). The pattern of fluctuations in fish density is not always in line with fluctuations in the percentage of coral cover (Yuliana et al 2016). This suggests that other factors, such as anthropogenic and natural disturbances, also influence the presence of coral reef fish. The decline in coral cover at station 4 (47%) also impacts the decreasing density of coral reef fish, although the pattern of decline is different. This suggests that the interaction between coral cover and fish density is not always linear or in line. It is possible that other factors, such as fish migration patterns, predator-prey interactions, or more complex habitat changes, affect the presence of coral reef fish indirectly (Béguinot 2019). Although there is a correlation between live coral cover and coral reef fish density, using these fish as biological indicators is insufficient because of their unclear relationship. Some reef fishes may not directly prey on corals and may be less sensitive to changes in coral reef systems. Understanding the complexity of interactions between environmental factors, fish population dynamics, and coral reef conditions is essential for planning effective conservation efforts for coral reef ecosystems. The effect of high temperatures of 30^{o}C on the flattening type of reefs and corals on a slope can affect various environmental aspects in coral ecosystems. Relatively high temperatures, such as at 30^{o}C, significantly impact coral reef growth and sustainability (Wismer et al 2019). The high temperatures can affect the photosynthetic process of symbiotic algae (zooxanthellae) that live with corals. Furthermore, at 30^{o}C water temperature coral reefs can experience excessive warming, which can lead to coral bleaching (Madeira et al 2020). This bleaching occurs when corals lose their symbiotic algae, which can reduce coral growth and health. High temperatures can also affect marine organisms' composition and community structure around coral reefs (Genin et al 2020). Some coral species may be more susceptible to high temperatures and bleaching, while others or certain types of reef flattening may be more tolerant (Bargahi et al 2020). Some reefs or corals may be more commonly found on certain slopes and more suitable for certain temperature and light conditions; temperature changes can affect the spatial distribution of such types. Temperature changes can affect the overall balance of coral ecosystems. Therefore, as temperatures continue to increase, there can be changes in the structure of coral ecosystems, including possibly reduced biodiversity and ecosystem productivity (Picq et al 2019). Aditionally, high water temperatures can affect coral reefs' nutrient flow and transport patterns. This can impact nutrient availability for reef organisms and affect overall ecosystem dynamics (Spinks et al 2019).

Conclusions. The coral reef condition in Muna Strait from 7 (seven) stations shows generally in good condition and dominated by living coral. Meanwhile, the reef fish status from diversity index indicates that the diversity was in low category, the evenness index indicates that the reef fish distribution between species in Muna strait was unequal. The dominance index shows that there were no dominant species in Muna Strait reef fish. The

ecological index between evenness and dominance in Muna District was closely related, where the higher the evenness index value, the lower the dominance index value will be due to the decreasing number of biotas dominating at a location.

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

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