Comparative Analysis of Population Estimates and Habitat Conditions for Three Targeted Parrotfish Species in Sulawesi: Implications for Conservation

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ABSTRACT

One of the functional groups of herbivorous reef fish is parrotfish from the family Scaridae. These fish have been categorized as excavators and scrapers, which enables them to support coral resilience by controlling the algae growth. Unfortunately, some species of parrotfish have been reported as targeted fish and faced uncontrolled fishing. This study aims to estimate the targeted parrotfish population in different locations to discern variations of fish in Sulawesi, and to provide information on the relationship between the fish and their habitat conditions. The study was focused on three species from Buton, Kendari, and Makassar, *Scarus dimidiatus, Scarus ghobban,* and *Scarus niger* using UVC and UPT methods to collect the data. The estimated population of fish was reported to be in good condition in Buton, but not in other locations. Moreover, *S. ghobban* showed a good estimated population among locations, while *S. niger* in Makassar indicated uncontrolled fishing conditions. The fish were found to prefer locations with more complex benthic substrate compositions, with Buton being the most populated location compared to Makassar and Kendari. Furthermore, fleshy seaweed was correlated with the biomass of *S. ghobban*. The sea surface temperature (SST) was related to chlorophyll-*a* and indicated a connection to benthic substrate consumed by the fish, which contributed to the abundance and occurrence of parrotfish in Sulawesi.

Keywords: Benthic substrate complexity, Coral reef management, Coral resilience, Functional groups, Scaridae

INTRODUCTION

Parrotfish, a group of herbivorous reef fishes, play an important role in balancing energy flow and structuring coral reef communities (Lokrantz *et al*., 2008) and are found in shallow waters. They undergo a sex change (hermaphroditism) as they mature, marked by a juvenile phase (JP), initial phase (IP), and terminal phase (TP), accompanied by changes in color and body shape (Kuiter and Tonozuka, 2001; Allen *et al*., 2003). Based on their foraging behaviours, herbivorous reef fishes are classified into several functional groups, including scrapers, excavators, grazers, and browsers (Green and Bellwood, 2009). Parrotfish are categorized as either excavators or scrapers (Allen and Erdmann, 2012). They are crucial for coral resilience, controlling algae growth and providing space for coral juveniles to settle (Schumacher *et al*., 2018).

Parrotfish have significant ecological value in coral reefs, contributing to the food web and controlling algae growth (Nanami, 2021). Their foraging behaviour and mobility are influenced by the benthic substrate of coral cover (Nash *et al*., 2012). Thus, they play a vital role in maintaining algal balance and promoting coral recovery (Schumacher *et al*., 2018). Parrotfish show different preferences

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for habitat type, latitude, coral cover, and temperature. Habitat conditions influence their foraging behaviour, competition, and predation risks, which in turn shape the distribution and abundance of different functional groups of herbivorous fish (Nash *et al*., 2012). In addition to their ecological value, parrotfish are also targeted for fishing and export, with species like *Scarus niger* being particularly sought after (Fatihah *et al*., 2021).

Recent studies have mentioned that parrotfish in Sulawesi face uncontrolled fishing pressures (Fatihah *et al*., 2021; Mutiara *et al*., 2021; Ramla *et al*., 2021), which could disrupt the coral reef ecosystem and lead to algal blooms. Previous studies on herbivorous reef fishes have revealed how these fish maintain algal balance and how overfishing can drive shifts in reef ecosystems (Duran *et al*., 2019; Tang *et al*., 2020; Faricha *et al*., 2023). Managing parrotfish, which hold both economic and ecological value, is crucial to prevent imbalances in coral reef ecosystems. Overfishing and other factors like climate change exacerbate these imbalances (Aswani and Sabestian, 2010; Bellwood *et al*., 2012; Zaneveld *et al*., 2016). Effective management, including designated conservation areas and habitat identification, is essential to protect coral reefs and related ecosystems (Bejarano *et al*., 2013; Edwards *et al*., 2013; Olivier *et al*., 2018).

Climate change has resulted in coral mortality and structural alterations in reefs through bleaching, affecting the surrounding biota, reducing reef fish abundance, and increasing algal growth, which competes with corals for space (Cure *et al*., 2021; Rani *et al*., 2023). Monitoring parrotfish provides important information for environmental and fish resource sustainability. Such monitoring helps examine temporal variations in reef fish populations and assess the impact of Marine Protected Area (MPA) (Madduppa *et al*., 2012; Putra *et al*., 2021). Despite their critical role and being targeted by fishermen, there remains a lack of ecological studies focusing on parrotfish in Indonesia, particularly within the Central Indonesian region.

This study addresses the correlation between parrotfish abundance and coral cover, and how habitat conditions relate to their abundance and occurrence. We focused on three species targeted by fishermen in Sulawesi, Central Indonesia, to determine their abundance and occurrence in relation to habitat conditions across different locations. The study aims to estimate targeted parrotfish populations by abundance and biomass, examining variations in Sulawesi. It also explores the relationship between parrotfish and their habitat conditions, including benthic substrate composition, sea surface temperature, depth, and chlorophyll *a* concentration among distinct locales.

MATERIALS AND METHODS

Sampling method

This study was conducted at three locations in Sulawesi, Indonesia: Buton (15 sites), Kendari (9 sites) in Southeast Sulawesi Province, and Makassar (13 sites) in South Sulawesi Province (Table 1). The research focused on coral reef habitats at depths of 3 to 12 m. These depths varied due to differences in reef structure and tidal conditions at the time of the survey. Sampling sites were selected using a combination of area maps, local knowledge, and snorkelling to ensure the chosen locations represented similar habitats for comparative purposes (Hill and Wilkinson, 2004).

The Underwater Visual Census (UVC) method was used to monitor the impacts of fishing on target species. This method is useful for determining the sustainability of fisheries (Hill and Wilkinson, 2004). The number of sampling sites was chosen to represent the reef habitat at each location, depending on the size of the area and scale. Sampling locations were selected based on the reef zones, and variations in depth were influenced by sea tides. A 70 m of line transect was used, with an additional 2.5 m on each side to cover an observation area of 350 m^2. The number of sampling sites varied depending on the area and reef zone of each location. Habitat conditions and the average fish values were assessed around the coral reefs and obtained from multiple sampling sites within each location (site = sampling point, location = Buton, Makassar, or Kendari).

Table 1. Sampling site information.

Site	Location	Local Name	Sampling Date	Longitude	Latitude	Depth (m)	Reef Types
B01	Buton	Balo village	26/05–06/06	122.40323	-5.39958	7	Fringing reefs
B02	Buton	Karenbe village	26/05–06/06	122.51534	-5.43619	7	Fringing reefs
B03	Buton	Lamaraja village	26/05–06/06	122.26234	-5.38395	7	Fringing reefs
B04	Buton	Mutiara beach	26/05–06/06	122.33038	-5.39822	7	Fringing reefs
B05	Buton	Wa Ara village	26/05–06/06	122.60406	-5.41193	7	Fringing reefs
B06	Buton	Lalole village	26/05–06/06	122.46689	-5.67623	7	Fringing reefs
B07	Buton	Tongali village	26/05–06/06	122.51731	-5.62051	7	Fringing reefs
B08	Buton	Liutonglidi village	26/05–06/06	122.49907	-5.60271	7	Fringing reefs
B09	Buton	Kapoa village	26/05–06/06	122.47507	-5.51706	7	Fringing reefs
B10	Buton	Kaofe village	26/05–06/06	122.48058	-5.56261	7	Fringing reefs
B11	Buton	Sampuabalo village	26/05–06/06	123.00836	-5.44030	7	Fringing reefs
B12	Buton	Sampuabalo village	26/05–06/06	123.04491	-5.43466	7	Fringing reefs
B13	Buton	Dongkala village	26/05–06/06	122.86370	-5.51931	6	Fringing reefs
B14	Buton	Holimombo Jaya village	26/05–06/06	122.90259	-5.54531	7	Fringing reefs
B15	Buton	Wabula village	26/05–06/06	122.86743	-5.61554	7	Fringing reefs
K01	Kendari	Bahoe village	08/07–16/07	122.79540	-4.05825	11	Fringing reefs
K02	Kendari	Hari island	08/07–16/07	122.77607	-4.03784	11	Fringing reefs
K03	Kendari	Labutaone village	08/07–16/07	122.78819	-4.09784	12	Fringing reefs
K04	Kendari	Wowosunggu island	08/07–16/07	122.72289	-4.12632	7	Fringing reefs
K05	Kendari	Lara island	08/07–16/07	122.66800	-4.09982	8	Fringing reefs
K06	Kendari	Tanjung Tiram beach	08/07–16/07	122.68120	-4.03714	9	Fringing reefs
K07	Kendari	Atowatu village	08/07–16/07	122.64709	-3.88868	11	Fringing reefs
K08	Kendari	Bokori island	08/07–16/07	122.66895	-3.95586	8	Fringing reefs
K09	Kendari	Pasir Jambe island	08/07–16/07	122.65846	-3.98205	12	Patch reefs
M01	Makassar	Langkai island	29/06–08/07	119.08500	5.03160	6	Fringing reefs
M02	Makassar	Lanjukang island	29/06–08/07	119.06780	4.98490	6	Fringing reefs
M03	Makassar	Gosong Batu Labbua island	29/06–08/07	119.21580	5.10940	7	Patch reefs
M04	Makassar	Lumu Lumu island	29/06–08/07	119.20890	4.97220	7	Fringing reefs
M05	Makassar	Kodingareng Keke island	29/06–08/07	119.28600	5.10220	8	Fringing reefs
M06	Makassar	Kodingareng Lompo island	29/06–08/07	119.26200	5.13880	8	Fringing reefs
M07	Makassar	Bonetambung island	29/06–08/07	119.27770	5.03230	11	Fringing reefs
M08	Makassar	Bonebatang island	29/06–08/07	119.32530	5.01840	3	Patch reefs
M09	Makassar	Barrang Lompo island	29/06–08/07	119.32720	5.04170	6	Fringing reefs
M10	Makassar	Barrang Caddi island	29/06–08/07	119.31630	5.07860	8	Fringing reefs
M11	Makassar	Bonelola island	29/06–08/07	119.35340	5.05280	3	Patch reefs
M12	Makassar	Samalona island	29/06–08/07	119.34030	5.12220	6	Fringing reefs
M13	Makassar	Kayangan island	29/06–08/07	119.39670	5.11230	4	Fringing reefs

Photos were taken along the same line transects, using 44×58 cm quadrat transect to frame the benthic substrates. This frame provided boundaries for photos and helped with borders when analysing using CPCe software (Kohler and Gill, 2006). Photos were taken every meter along the transect, alternating quadrat transect positions to obtain a representative estimate of coral cover. The cover percentage of the benthic substrates was categorized into 13 types (Giyanto, 2012), but the focus was on hard coral (HC), soft coral (SC), dead coral (DC), fleshy seaweed (FS), dead coral with algae (DCA), and sponge (SP) as these substrate types might influence fish abundance and occurrence. Coral cover specifically focused on DCA and FS, with algae turf included in the DCA category.

The study focused on a few species of parrotfish of economic and ecological importance (Kuiter and Tonozuka, 2001) that might prefer specific habitat types in Sulawesi. These species were the blue-barred parrotfish (*Scarus ghobban* Fabricius, 1775), dusky parrotfish (*Scarus niger* Forsskål, 1775), and yellow-barred parrotfish (*Scarus dimidiatus* Bleeker, 1859), chosen based on their feeding of scraping benthic algae from corals or rocks (Fatihah *et al*., 2021; Mutiara *et al*., 2021). The number of individuals of each species was recorded to determine species abundance and occurrence in different locations, and length estimation (cm) were used to calculate fish biomass.

Data analysis

Fish biomass was calculated using the standard allometric length-weight equation $W = a \times L^b$, where W is the weight (g), a and b are constants obtained from FishBase for each species, and L is the total length (cm) using data of fish length estimations obtained from UVC (Eggertsen *et al*., 2020). The nonparametric Kruskal-Wallis method was used to determine if there were statistically significant ($p<0.05$) differences in fish abundance and benthic substrate across at each location (Putra *et al*., 2022). The frequency of occurrence (F) of the fish was calculated using the formula %F = (number of fish present each location / number of sites in each location) × 100 (Campo *et al*., 2006). Variations in biomass and abundance among the sites, as well as Kruskal-Wallis results, were visualized using the 'ggplot2' package in R software (Wickham, 2016). Size distribution was categorized into three groups: class 1 ($TL \leq 10$), class 2 ($11 \leq TL \leq 20$), and class 3 ($21 \leq TL \leq 30$), where TL is total length (cm) (Nanami, 2021). The size distribution of the fish in each location was visualized using bar charts created with 'ggplot2'. To investigate the correlation between fish and habitat type preferences according to benthic substrate categories across the three locations (n = 37), Spearman correlation analysis was conducted using PAST 4.13 (Hammer *et al*., 2001) and the strength of the correlation coefficient was interpreted according to Akoglu (2018).

RESULTS AND DISCUSSION

Variation on fish abundance

The variation in abundance of parrotfish from the genus Scarus in Sulawesi is illustrated in Figure 1b. The abundance of *Scarus dimidiatus*, *S. ghobban*, and *S. niger* across 37 study sites were 178, 256, and 208 individuals per 350 m^2, respectively, with *S. ghobban* showing the highest density. Compared to previous studies on parrotfish in Indonesia, the abundance in Ambon showed similar patterns, where *S. ghobban* was the most abundant, followed by *S. niger*, and *S. dimidiatus* was among the least abundant (Loupatty *et al*., 2021). In contrast, parrotfish in Bali were dominated by *Cholurur sordidus* (El Rahimi *et al*., 2021).

In the Makassar water, specifically around Supermonde Island, the dominant species included *Calotomus bleekeri, C. capistratoides, C. sordidus, Scarus chameleon, S. flavipectoralis, S. ghobban, S. niger, S. quoyi, S. rivulatus,* and *S. schlegeli* (Tresnati *et al*., 2019). Although *S. niger* was previously reported to dominate in Makassar, our 2021 study showed that it had a low density (Figure 1b). This was also reflected in its low frequency of occurrence, < 25% (Figure 4). The limited distribution of *S. niger*, particularly its absence in 2 of the 3 locations in Sulawesi (Kendari and Makassar), might be influenced by factors such as mortality and habitat conditions.

Survival rates during the life history of parrotfish are influenced by predator-prey interactions, habitat preferences, and environmental conditions. Both natural mortality and catch mortality affect the limited distribution of these fish (Mumby *et al*., 2006). The *S. niger* has high economic value, with compact, white meat that is highly sought after as a food source. It has become an essential export commodity to markets such as Hongkong, Taiwan, and Singapore. This demand makes it a primary target for fishermen in the waters of Sulawesi Island (Adrim, 2008; Zulfahmi *et al*., 2022). The variation in fish abundance and biomass in Kendari and Makassar (Figure 2c) suggests that the fish face pressure from several factors.

Additionally, the lowest biomass indicates that most fish found were small in size. This observation aligns with the size distributions of *S. niger*, where class 1 and 2 (≤20 cm) dominated in Makassar and Kendari (Figure 3c). Furthermore, the variation of fish abundance showed that *S. niger* was absent in some study sites, particularly in Makassar and Kendari. Our study suggests that *S. niger* is experiencing overfishing in these areas, indicating that exploitation rates have affected stock assessment. The mortality rate of *S. niger* in Makassar, including natural mortality, fishing mortality, and exploitation rates, were reported to be 0.66, 2.53, and 0.79, respectively, indicating uncontrolled fishing conditions (Fatihah *et al*., 2021).

Three species of parrotfish, *S. dimidiatus, S. ghobban*, and *S. niger*, were reported to have the highest density in Buton, suggesting that fish distributions might indicate zonation in abundance or pressure conditions. The zonation patterns in parrotfish abundance could be related to topographic features such as reef slopes, reef flats, and back reefs (Hernández-Landa and Aguilar-Perera, 2018),

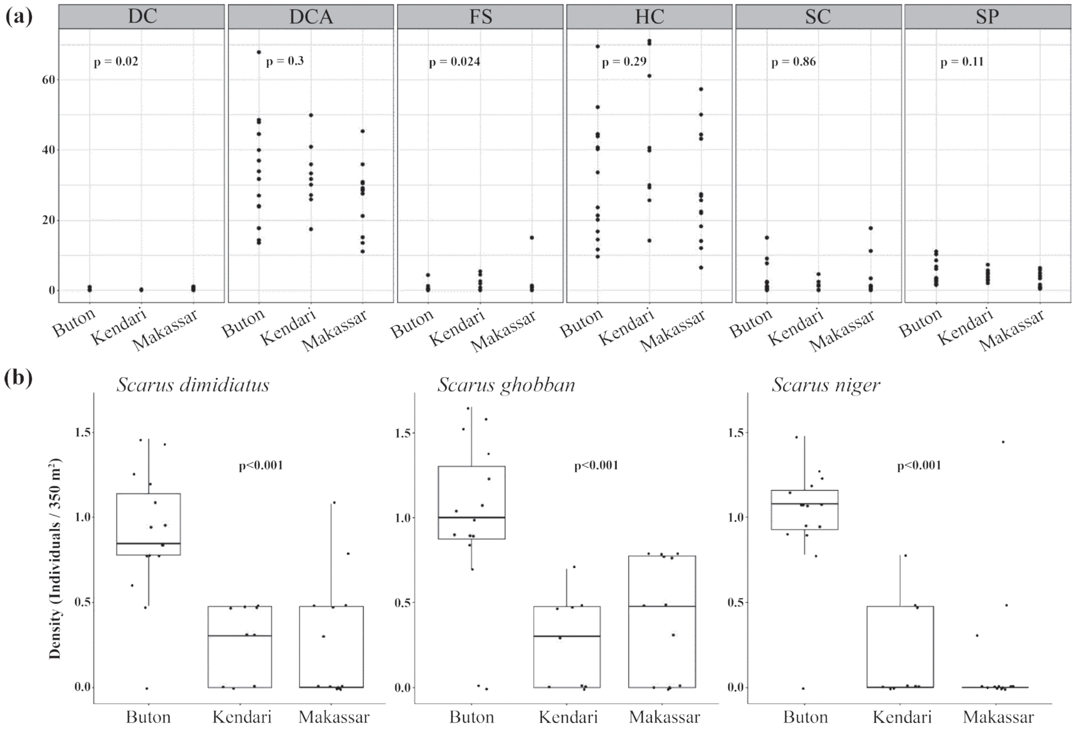


Figure 1. Percent of benthic substrate categories (a), and box-plots showing variation of mean density of parrotfish (b); p value of Kruskal-Wallis test indicated the significance of variation among locations in each categories; Abbreviation: DC = dead coral; DCA = dead coral with algae; FS = fleshy seaweed; HC = hard coral; SC = soft coral; SP = sponge.

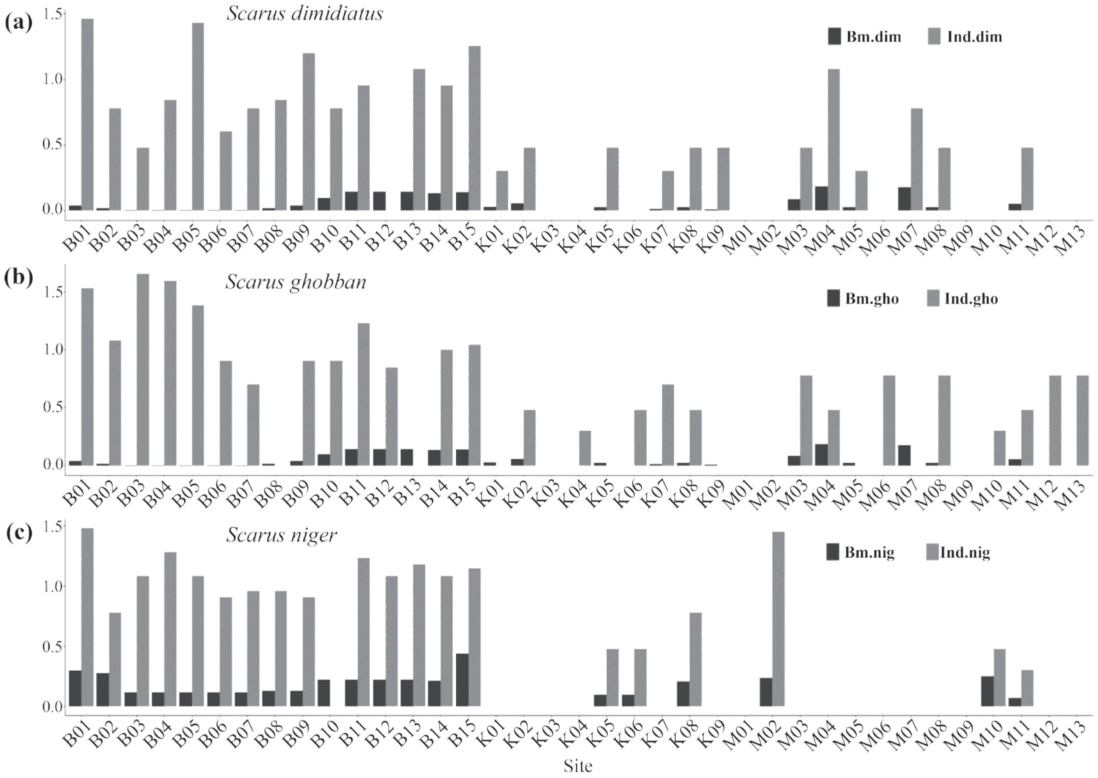


Figure 2. Variation in biomass and abundance of parrotfish in each site; Abbreviation: Ind = abundance, Bm = biomass, dim = *Scarus dimidiatus*, gho = *Scarus ghobban*, nig = *Scarus niger*; e.g., Bm.dim and Ind.dim = biomass and abundance, respectively, of *Scarus dimidiatus*; Details for sampling sites as in Table 1.

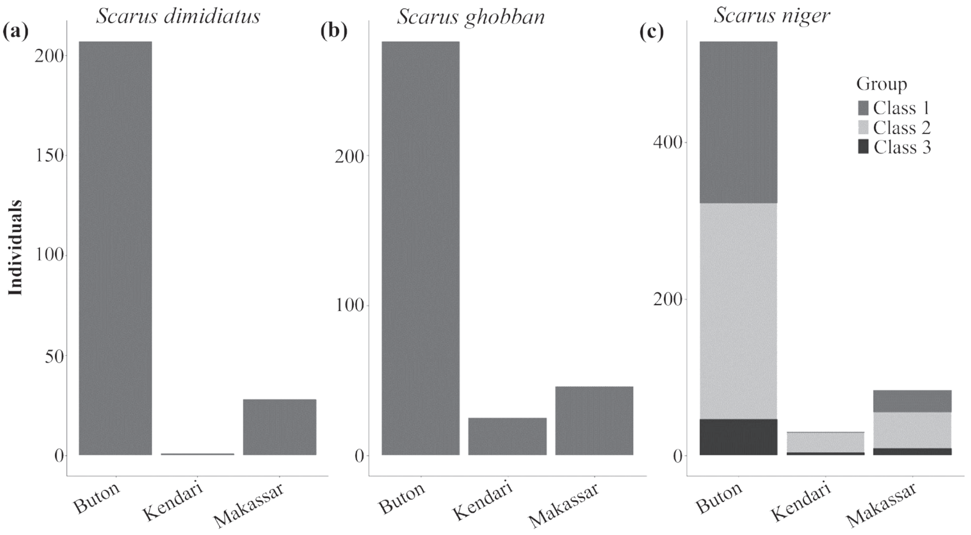


Figure 3. Size distribution of fish in each location; Classification groups: class 1 (TL≤10 cm), class 2 (11≤TL≤20 cm), and class 3 (21≤TL≤30 cm).

as well as variations in substrate types, including live corals, dead corals, and non-coralline substrates (Nanami, 2021). The benthic substrate variation, particularly in dead corals and fleshy seaweed, was slightly different across study sites, with Buton reporting lower average. This contributes to the higher abundance of parrotfish in Buton. Previous studies have also reported that preferences for fleshy algal communities decrease with an increase in parrotfish populations (Smith *et al*., 2018). The benthic substrate in each location showed significant differences in dead coral (DC, p = 0.02) and fleshy seaweed (FS, p = 0.024) (Figure 1a). However, there were no significant differences in benthic substrates of dead coral with algae (DCA), hard coral (HC), soft coral (SC), and sponge (SP) among the three locations. This suggests that the variation in the benthic substrate (DC and FS) supports the growth and habitation of *S. ghobban* better than the other two species.

Difference in fish occurrence

Based on the mean density of the fish, Buton was identified as having the highest density of all three species (Figure 1b). However, another location indicated that *S. ghobban* was more frequently found in Makassar than in Kendari, while *S. dimidiatus* and *S. niger* showed the opposite trend. This indicates variations in the abundance of the three species across different locations (p<0.05). The distribution of these three species in 3 locations in Sulawesi is presented in Figure 4. Wherein *S. ghobban* was reported to be the most frequent species with an occurrence rate of over 50%, while other species were found in specific. Notably, *S. dimidiatus* had an occurrence rate below 50% in Makassar (46%), while *S. niger* in Kendari (35%), and 23% for *S. niger* in Makassar. This suggests that the smaller size of *S. dimidiatus* and *S. niger* influenced their biomass and percentage occurrence. Furthermore, increased fishing pressure significantly impacted the reduction in sizes and abundance of larger fish species (Rivas *et al*., 2022).

Relation to benthic substrate

The average benthic substrate analysis revealed that dead coral with algae and hard coral have a higher percentage in most sites in Buton, Makassar, and Kendari compared to other benthic types. Correlation analysis based on substrate and

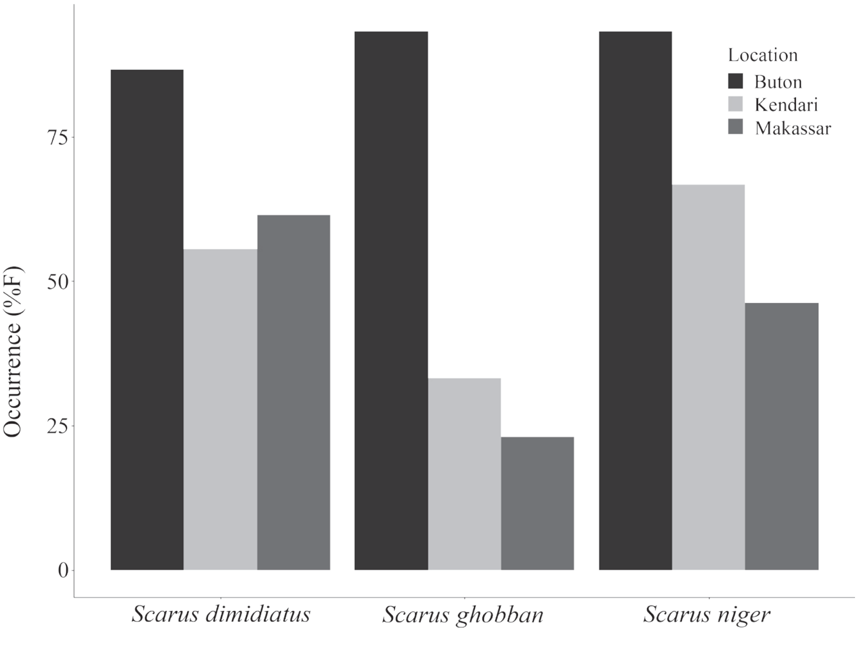
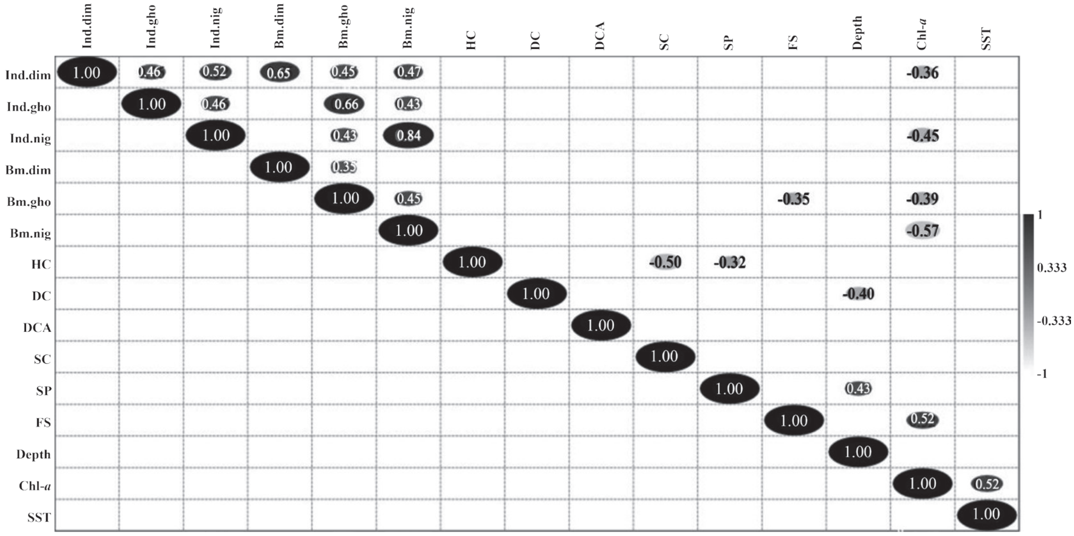


Figure 4. Frequency of occurrence percentage (%F) among locations.

habitat factors showed a fair negative correlation between soft coral and sponge with hard coral. Positive correlations were observed between depth and sponge (0.43), Chl-*a* and fleshy seaweed (0.52), and Chl-*a* and SST (0.52) ($p<0.05$) (Figure 5) indicating that SST influences Chl-*a* concentration, especially in shallow areas (Hussein *et al*., 2021). Regarding the correlation between three parrotfish species and substrate/habitat, a moderate to strong positive correlation was found between the abundance of each fish species and its biomass. However, when considering their correlation with environmental factors/habitats, the abundance of *S. dimiatus* and *S. ghobban*, as well as the biomass of *S. ghobban* and *S. nigger*, showed a fair negative correlation with Chl-*a* ($p<0.05$). Additionally, the biomass of *S. ghobban* was negatively correlated with fleshy seaweed (Figure 5). These findings align with Donovan *et al*. (2023), who observed that lower chlorophyll *a* levels were associated with higher total herbivore biomass, and a higher macroalgal cover relative to calcified cover was associated with lower herbivore group biomass. This aligns with the feeding preference of *S. ghobban* for fleshy seaweed (Smith *et al*., 2018), explaining its high abundance in Buton where fleshy seaweed coverage is lower compared to Kendari and Makassar (Figure 1a).

Previous studies have indicated that the abundance of algae may not always accurately predict fish biomass. They suggest that the ontogeny of the fish influences foraging preferences (Smith *et al*., 2018). In contrast, our present study reveals that the distribution of parrotfish in Sulawesi may be linked to specific benthic substrates, such as fleshy seaweed and other substrates containing chlorophyll *a*. However, a previous study mentions that parrotfish can feed on almost various benthic substrate, including live coral colonies, turf algae, macroalgae, and seagrass (Hoey and Bellwood, 2008). Parrotfish are recognized as key players in maintaining coral covers, regulating algae growth, and enhancing coral resilience (Bonaldo *et al*., 2014). These herbivorous parrotfish play a crucial part in the ecosystem balance of coral reefs and contribute to coral resilience (Glynn and Manzello, 2015). In terms of abundance and biomass, parrotfish as a herbivorous group, are highly noticeable and dominant in coral reefs. They exhibit variations in



	Ind.dim	Ind.gho	Ind.nig	Bm.dim	Bm.gho	Bm.nig	HC	DC	DCA	SC	SP	FS	Depth	Chl-*a*	SST
Ind.dim	1.00	0.46	0.52	0.65	0.45	0.47								-0.36	
Ind.gho		1.00	0.46		0.66	0.43									
Ind.nig			1.00		0.43	0.84								-0.45	
Bm.dim				1.00	0.35										
Bm.gho					1.00	0.45						-0.35		-0.39	
Bm.nig						1.00								-0.57	
HC							1.00			-0.50	-0.32				
DC								1.00					-0.40		
DCA									1.00						
SC										1.00					
SP											1.00		0.43		
FS												1.00		0.52	
Depth													1.00		
Chl-*a*														1.00	0.52
SST															1.00

Figure 5. Spearman correlation between benthic substrate / habitat factors and 3 parrotfish species; Abbreviation: ind = abundance, bm = biomass, gho = *Scarus ghobban*, nig = *Scarus niger*, dim = *Scarus dimidiatus*, hc = hard coral, dc = dead coral, dca = dead coral with algae, fs = fleshy seaweed, sp = sponge, sc = soft coral, SST= sea surface temperature, Chl-*a* = Chlorophyll *a*, ind.gho = abundance of *Scarus ghobban*, bm.dim = biomass of *Scarus dimidiatus*, and so on.

habitat compositions, functional groups, feeding habits, and abundance across different coral reef ecosystems (Green and Bellwood, 2009; Mellin *et al*., 2010; Heenan and Williams, 2013). Furthermore, the habitat characteristics are frequently correlated with presence and abundance of the fish (Pattiasina *et al*., 2020).

When viewed based on location, Buton is distinct, characterized by higher parrotfish abundance and biomass compared to Kendari and Makassar (Figure 1b). Conversely, Kendari and Makassar exhibited overlapping clusters, suggesting homogeneity in environmental variables such as dead coral (DC), fleshy seaweed (FS) and coral types, which is supported by Figure 1a. This result demonstrates an average higher coverage of DC and FS in Makassar and Kendari regions compared to Buton. Additionally, the coral composition in Kendari and Makassar includes a diverse mix of fringing and patch reefs, whereas Buton primarily features fringing reefs. Buton was reported to have a benthic substrate of DCA, with its SP higher than others (Figure 1a). Therefore, three species were examined for their role in mitigating algae shifting by grazing on DCA and supporting resilience after coral disturbance. Buton seems to be the preferred habitat for these fish as it provides food resources. We assumed that *S. ghobban* prefers conditions with a varied benthic composition, including non-coralline substrate, such as fleshy seaweed, even though previous studies reported that most parrotfish species choose to forage in abundance of dead coral and dead coral with algae (El Rahimi *et al*., 2021). Species distribution may also be affected by a benthic condition, with generalist fish dominating homogenous benthic conditions, and heterogenous benthic substrate being dominated by more specialist fish species, even when supported by small percentage covers of benthic substrate, such as fleshy seaweed, sponge, and soft corals (Aulia *et al*., 2021).

The distribution pattern of parrotfish species in Sulawesi was similar among locations. However, the abundance and occurrence of these species are determined by their preference for benthic substrates. This condition may be influenced by the structural complexity of habitat characteristics through benthic substrate compositions and hydrodynamic conditions. Parrotfish distribution patterns are related to habitat characteristics, as inner reefs are associated with substrate complexity regardless of whether the substrate is live or dead coral, while fish in exposed reefs are associated with calcium carbonate substrate and some live coral. In contrast, habitat characteristics have also influenced size-specific differences in parrotfish distribution (Nanami, 2021). The distribution differences in functional herbivorous fish might be caused by changes in the benthic substrate and environmental conditions such as climate change impacts (Faricha *et al*., 2023). Furthermore, our study presented that SST has a negative correlation to chlorophyll *a*, which could indicate the food resources for parrotfish as a group of herbivorous fish. Previous studies have also reported that the distribution of functional herbivorous fish, such as parrotfish, is influenced by fish life history and the spatial configuration of habitat (Eggertsen *et al*., 2020). However, the mobility of these fish might be modified by benthic covers, substrate compositions, and parrotfish density, and changes in these conditions were predicted to shape the fish foraging and change their behaviour (Nash *et al*., 2012).

CONCLUSIONS

Our study reported differences in the targeted parrotfish population in Sulawesi in terms of abundance, biomass, size distribution, and frequency of occurrence among locations. However, three species of parrotfish in Sulawesi were reported to be in good condition in Buton, while unfortunately, the other locations were not. Targeted parrotfish populations in Sulawesi showed that only *Scarus ghobban* was in good condition across locations. Moreover, the estimated population of *S. niger* in Makassar indicated uncontrollable fishing conditions, necessitating more attention to regulated fishing and resource managements in Makassar. Although the relationship of the three targeted parrotfish with their habitat conditions among the three locations in Sulawesi showed that the substrate of FS correlated with the biomass of *S. ghobban* only, in general parrotfish in Buton, Makassar, and Kendari correlated with the substrate containing chlorophyll *a*. Our study also reported that SST is related to the chlorophyll *a*. This information might contribute to better management of the fish and conservation of coral reef ecosystems in Sulawesi, especially Buton, Makassar, and Kendari.

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