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Biodiversity and distribution of rabbitfish (Siganidae) in Tanakeke Island, South Sulawesi, Indonesia

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Abstract. *Awaluddin, Budimawan, Nadiarti, Nafie YAL. 2024. Biodiversity and distribution of rabbitfish (Siganidae) in Tanakeke Island, South Sulawesi, Indonesia. Biodiversitas 25: 2756-2762.* The purpose of this research is to analyze the biodiversity of rabbitfish (Siganidae) in Tanekeke Island, South Sulawesi, Indonesia including species diversity, richness, evenness, and dominance. Data on Siganidae fish catches were collected from four different stations on Tanakeke Island, where each consisting of inside and outside bay zones. The data collection involved recording the total number of Siganidae fish caught with gillnet in each zone every month for a year. The caught fish were identified and categorized by species. A total 1,7421 were collected, with 1,5181 from inside the bay and 224 from outside the bay. The result indicated that species was dominated by *Siganus canaliculatus* (Park, 1797) with a frequency of 952 individuals (62.70%) inside the bay and 173 individuals (77.50%) outside the bay. *Siganus guttatus* (Bloch, 1787) ranks second, with 155 individuals (10.20%) inside the bay and 16 individuals (97.20%) outside the bay, followed by *Siganus javus* (Linnaeus, 1766), *Siganus fuscescens* (Houttuyn, 1782), *Siganus punctatus* (Schneider & Forster, 1801), and *Siganus virgatus* (Valenciennes, 1835). This research provides important insights that could greatly influence social and cultural aspects of local communities that depend on fisheries resources. The findings suggest that the bay provides more stable conditions that support the growth of rabbitfishes, allowing local communities for manage and conservation their fisheries resources.

Keywords: Conservation, ecological index, rabbitfish, Siganidae, Tanakeke Island

INTRODUCTION

Indonesia, the world's largest archipelagic nation, is renowned for its high biodiversity, particularly fish (von Rintelen et al. 2017; Haryono et al. 2022) as well as in Sulawesi, situated at a crucial location within Wallacea and the Coral Triangle, the Sulawesi Seas have served as an origin for species evolution, a hub for species interactions and blending, and a key origin for species dispersal (Ambo-rappe and Moore 2019). One area with a high biodiversity is Tanakeke Island in South Sulawesi, located in Makassar Strait. This island has a unique condition and as habitat essential for some aquatic organisms (Litaay et al. 2017). Research on Tanakeke Island has focused on various ecological aspects, such as the biodiversity of mangrove ecosystem (Malik et al. 2019), vegetation condition (Aswin et al. 2021), biodiversity and distribution of gastropods (Litaay et al. 2017), structure and size of *Siganus* spp. in seagrass (Sari et al. 2019), mangrove cover and density (Jaya et al. 2022). However, studies on fish diversity, particularly the family Siganidae, remain limited. In the tropical ecosystem, Siganidae, commonly known as rabbitfish, play a pivotal role (Jemi et al. 2022).

The family Siganidae (rabbitfish) not only important based on ecology, but also have an economic value in the world (Suwarni et al. 2020), as well as for local community, especially in Tanakeke Island, South Sulawesi (Sari et al. 2019). Rabbitfish arepopular due to their delicious taste and high nutritional content, leading to increase market demand which continues to increase (Suwarni et al. 2019). This bring rabbitfish to have a high market demand for catch as well as can be increased fishing activity for a long time and caused endanger for rabbitfish community. Therefore, studying the sustainable management of rabbitfish is crucial.

Research on biodiversity index is a crucial aspect for managing natural resources, especially fisheries resources (Kar et al. 2006; Sari et al. 2022; Hewindati et al. 2023; Isroni et al. 2023). The biodiversity index not only measures the variety of species in an ecosystem, but also helps in determining conservation policies and sustainable management of fish resources (Hiddink et al. 2008). The study of rabbitfish in the waters of Tanakeke Island is important considering the increasing pressure from both excessive fishing activities and the impact of climate change. The biological systems can adapt to environmental alterations is influenced by biodiversity, which also supports ecological systems and produces goods and services from ecosystems that promote the well-being of humans.

This research aims to evaluate the biodiversity of rabbitfish on Tanakeke Island, an important but understudies marine ecosystem. Rabbitfish, as one of the dominant species in this area, are the main focus due to their significant role in ecological balance and as an indicator of environmental health. High biodiversity is often associated with healthy and stable ecosystems, so it is important to understand the distribution and species composition of rabbitfish to support sustainable natural resource management.

Facing global and regional challenges such as climate change and increasing human activities in Tanakeke Island such as fishing and aquaculture (Rahadiati et al. 2017; Setiawan and Mursidin 2018), marine resources exploitation likely mangrove and coral harvesting (Haya and Fujii 2019; Kusmana 2017), tourism (Latif 2021), so that understanding of the biodiversity and population dynamics of local like the rabbitfish is crucial (Tamario et al. 2019). This research uses the Shannon-Wiener diversity index, a standard method in ecology for measuring the richness and evenness of species in a community (Hasan et al. 2023). By examining the diversity of rabbitfish species, this research aims to provide a clearer picture of current ecological conditions and changing trends that may occur in the future. The results obtained will be very useful in formulating effective management strategies to maintain sustainability and biodiversity in Tanakeke Island, while ensuring responsible and sustainable use of fishery resources.

MATERIALS AND METHODS

Study area

This research was conducted in Tanakeke Island, Takalar District, South Sulawesi, Indonesia. There are four point that have been determined based on geographically criteria including inside bay and outside bay zones respectively (Table 1 and Figure 1).

The inside zone of the bay offers protection from large ocean currents and has minimal human activity, while the outside zone of the bay is directly exposed to more dynamic ocean currents and fishing activity. This location was chosen to examine the influence of differences in ecological conditions on the Siganidae fish diversity index, which reflects the health and stability of the aquatic environment.

Procedures

Data collecting

In this research, data on Siganidae fish catches will be collected from four different stations on Tanakeke Island, where each station consists of the inside and outside bay zones. The selection of stations is based on inside and outside bays, station habitats (mangrove, seagrass, and coral), areas where rabbitfish are regularly caught by fishermen, natural habitats of rabbitfish, and similar characteristics of each station.

The data collection process includes recording the total number of Siganidae fish caught in each inside and outside bay zone every month. The data used in this research is the sum of data from various variations of Siganidae fish species obtained from fishing. The caught fish are separated into species groups for identification. Identification of Siganidae fish refers to the identification method of Saanin (1995) and Carpenter and Niem (2001).

Sampling method

The sampling method used Gilnet with appropriate mesh sizes to avoid size error in fishing. Sampling was carried out monthly for a year, with the aim of capturing variations in Siganidae fish species in different ecological conditions on the fish diversity index. The caught fish are separated into species groups for identification.

Table 1. Sampling sites at the Tanakeke Island, South Sulawesi, Indonesia

Station	Inside the bay	Outside the bay
Station 1	5° 30' 54.88" S 119° 18' 6.02" E	5° 31' 38.14" S 119° 18' 47.97" E
Station 2	5° 31' 17.98" S 119° 16' 15.31" E	5° 31' 51.42" S 119° 15' 49.14" E
Station 3	5° 29' 22.14" S 119° 15' 58.33" E	5° 28' 41.11" S 119° 15' 16.28" E
Station 4	5° 28' 14.61" S 119° 18' 32.56" E	5° 27' 53.77" S 119° 17' 6.49" E

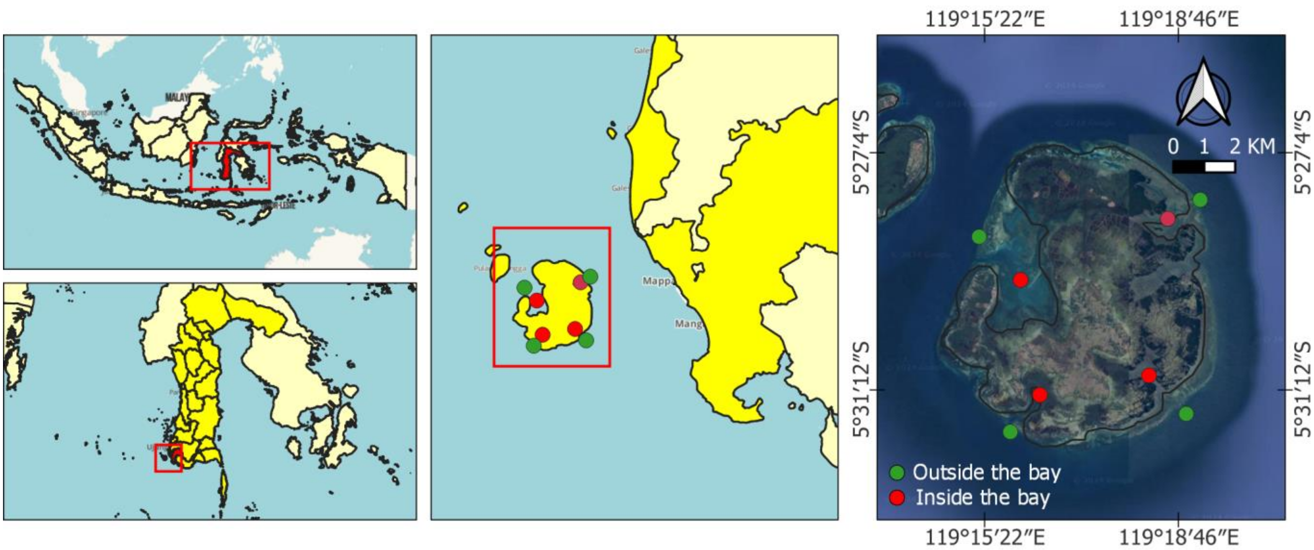

Figure 1. Location of Tanakeke Island indicating the sampling sites of rabbitfish in Takalar District, South Sulawesi, Indonesia

Data analysis

The data used for analysis comprised the number of individual fish species belonging to the Siganidae population. The composition of catch was analyzed descriptively using simple calculations and presented in a tabulation of the percentage value of the number of individuals. Biodiversity analysis focused on the species diversity, richness, evenness and dominance, with value calculated following the mathematical model as recommended by Odum (1971), Pielou (1976), Ludwig and Reynold (1988), and Krebs (1989).

RESULTS AND DISCUSSION

Species composition of Siganidae inside and outside the Bay

The total sample of Siganidae were collected around 1.742 fish including 1.518 fish from inside the bay and 224 fish from outside the bay. The identified species include *Siganus canaliculatus* (Park, 1797), *Siganus guttatus* (Bloch, 1787), *Siganus javus* (Linnaeus, 1766), *Siganus fuscescens* (Houttuyn, 1782), *Siganus punctatus* (Schneider & Forster, 1801), and *Siganus virgatus* (Valenciennes, 1835) (Figure 2). The species distribution of Siganidae in two locations show a significant variation that can be seen in Table 2.

The distribution of species shows that inside the bay there are more Siganidae fish species (*S. canaliculatus, S. guttatus, S. javus, S. fuscescens, S. punctatus, S. virgatus*) compare to outside the bay, where only *S. canaliculatus, S. guttatus, S. punctatus*, and *S. virgatus* are found. The absence of *S. javus* and *S. fuscescens* outside the bay is likely related to their feeding habitat preferences, as these fish are known to be among the most important consumers of macroalgae. This is supported by the fact that the habitat characteristics inside the bay are dominated by a high percentage of seagrass cover, while outside the bay, the area is dominated by coral reefs where the coral cover percentage does not support the presence of these fish. According to Isnaini et al. (2022), *S. javus* and *S. fuscescens* are often found in seagrass habitats, particularly in shallow waters. Seagrass provides areas rich in macroalgae, which are the main food source for these species, thereby also influencing the structure of the fish community (Manangkalangi et al. 2022; Maulita et al. 2023). This can be caused by environmental conditions in the bay that better support the growth and survival of fish (Madduppa et al. 2019; Sajen et al. 2022). Differences in environmental conditions, such as food availability, protection from predators, and physicochemical water parameters, can influence species distribution and abundance (Hamuna et al. 2022; Hasan et al. 2023).

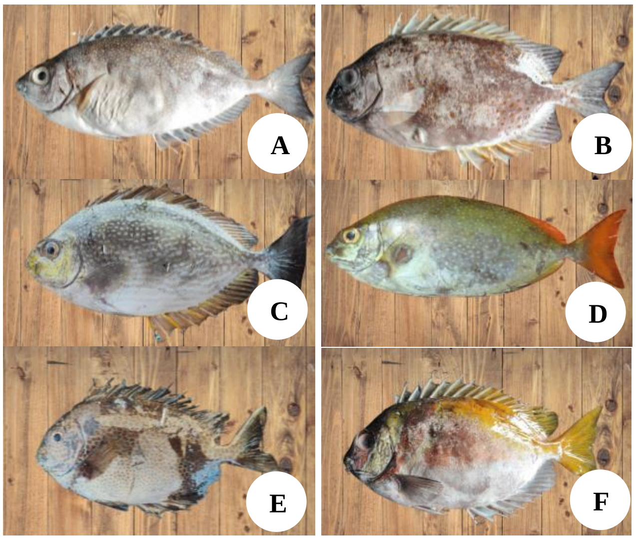

Figure 2. Species of rabbitfish in Tanakeke Island, Takalar District, South Sulawesi, Indonesia: A. *S. canaliculatus*; B. *S. guttatus*; C. *S. javus*; D. *S. fuscescens*; E. *S. punctatus;* F. *S. virgatus*

Table 2. Frequency and morphometric characteristic of Siganidae from inside and outside the Bay of Tanakeke Island, Takalar District, South Sulawesi, Indonesia

Location	Species	Freq.	%	Total length (cm) Min - max (mean±SD)	Total weight (g) Min - max (mean±SD)
Inside bay	*Siganus canaliculatus* (Park, 1797)	952	62.70	10.00 - 25.46 (17.49±4.39)	11.00 - 225.00 (60.28±24.91)
	Siganus guttatus (Bloch, 1787)	155	10.20	10.14 - 25.11 (18.06±4.13)	25.00 - 284.40 (97.06±50.58)
	Siganus javus (Linnaeus, 1766)	15	1.00	10.72 - 25.01 (16.80±4.08)	27.00 - 97.00 (47.27±19.11)
	Siganus fuscescens (Houttuyn, 1782)	126	8.30	10.32 - 25.28 (17.98±4.35)	16.00 - 189.00 (64.47±34.68)
	Siganus punctatus (Schneider & Forster, 1801)	133	8.70	10.51 - 25.22 (17.88±4.33)	27.00 - 183.00 (73.67±37.73)
	Siganus virgatus (Valenciennes, 1835)	138	9.10	10.41 - 25.30 (17.95±4.44)	16.00 - 173.00 (70.57±37.24)
Outside bay	*Siganus canaliculatus* (Park, 1797)	173	77.50	10.39 - 25.23 (17.95±4.14)	15.00 - 192.00 (57.62±30.30)
	Siganus guttatus (Bloch, 1787)	16	7.20	11.59 - 25.20 (18.34±5.18)	36.40 - 151.00 (104.84±42.23)
	Siganus javus (Linnaeus, 1766)	0	0.00	-	-
	Siganus fuscescens (Houttuyn, 1782)	0	0.00	-	-
	Siganus punctatus (Schneider & Forster, 1801)	14	6.30	10.42 - 24.82 (17.91±4.52)	33.00 - 147.00 (75.64±29.61)
	Siganus virgatus (Valenciennes, 1835)	20	9.00	10.28 - 25.07 (18.09±4.15)	34.92 - 139.00 (63.82±26.83)

Inside the bay, *S. canaliculatus* is the dominant species with a frequency of 952 individuals or 62.70% of the total samples inside the bay. The total length of these fish ranged from 10.00 cm to 25.46 cm with an average (mean±SD) of 18.74±4.39 cm, while the total weight ranged from 11.00 g to 225.00 g with an average of average 60.28±24.91 g. *S. guttatus* ranks second with a frequency of 155 individuals or 10.20%. The total length ranged from 10.14 cm to 25.11 cm with an average of 18.06±4.13 cm, and the total weight ranged from 25.00 g to 284.00 g with an average of 97.06±50.58 g. Other species such as *S. javus, S. fuscescens, S. punctatus,* and *S. virgatus* each have lower frequencies but show significant variation in length and weight.

Outside the bay, *S. canaliculatus* also dominates with a frequency of 173 individuals or 77.50% of the total samples outside the bay. Their total length ranged from 10.39 cm to 25.23 cm with an average of 17.95±4.14 cm, while their total weight ranged from 15.00 to 192.00 g with an average of 57.62±30, 30 g. *S. guttatus* had a frequency of 16 individuals or 7.20%, with a total length ranging from 11.59 to 25.20 cm and an average of 18.34±5.18 cm, and a total weight between 36.40 to 151 g. 00 g with an average of 100.04±42.23 g.

The distribution of species shows that inside the bay there are more Siganidae fish species with higher frequency than outside the bay. This can be caused by environmental conditions in the bay that better support the growth and survival of fish (Madduppa et al. 2019; Sajen et al. 2022). Differences in environmental conditions, such as food availability, protection from predators, and physicochemical water parameters, can influence species distribution and abundance (Hamuna et al. 2022; Hasan et al. 2023).

The average length and weight of fish inside the bay tends to vary more than outside the bay. *S. canaliculatus* inside the bay had a slightly higher total length and total weight than outside the bay. This variation indicates differences in individual growth which can be influenced by environmental factors or resource availability in the two locations.

The results of the Mann-Whitney U test (Table 3) show that the total length of fish in the bay is significantly greater than that outside the bay, while the total weight of fish in the bay is also significantly greater than that outside the bay. This indicates that environmental conditions in the bay not only support fish growth in length but also better weight gain. Apart from that, the island which have more complex ecosystems with more biological interactions can also support more optimal fish growth.

The total length and total weight of fish inside the bay were significantly greater than those outside the bay. The median value of the total length of fish in the bay is 18.74 cm, while outside the bay it is 17.95 cm. The median value of total fish weight in the bay was 60.28 g, while outside the bay it was 57.62 g. This difference indicates that environmental conditions in the bay are more favorable for fish growth. Factors such as food availability, protection from predators, stable habitat conditions, and more complex interspecies interactions may contribute to more optimal fish growth within inside the bay (Croll et al. 2023).

Evaluation using the Mann-Whitney U test showed significant differences in total weight of rabbitfish between inside and outside the bay. For further analysis, considering species variation, the Kruskal-Wallis test was used (Table 4). This was done to gain a more comprehensive understanding of the differences in total length and weight of various rabbitfish species in the two locations, as well as the influence of species on the morphometric variability of rabbitfish in different environments.

Based on data in Table 4, the results of the Kruskal-Wallis test for the total length of rabbitfish in the bay between species such as *S. canaliculatus, S. guttatus, S. javus, S. fuscescens, S. punctatus*, and *S. virgatus* do not show significant differences (H=5.097, df=5, p=0.404), indicating that fish length was not affected by species in the bay environment. Outside the bay, a similar situation occurred with no significant differences between the same species (H=0.122, df=3, p=0.989). Meanwhile, for the total weight of rabbitfish, there were significant differences within the bay (H=95.441, df=5, p<0.001), with significant variations between species such as *S. canaliculatus, S. guttatus, S. javus, S. fuscescens, S. punctatus,* and *S. virgatus*. This shows variations in adaptation and resource utilization efficiency between species in relatively homogeneous environments. Outside the bay, a similar analysis yielded significant differences (H=26.589, df=3, p<0.001) between species indicating that more varied and dynamic environmental conditions had an effect on fish weight.

Availability of resources and food plays an important role in fish growth (Pratiwy and Rosidah 2023). The bay tends to have more stable and abundant resource availability. Rollwagen-Bollen et al. (2022) mention that nutrients carried by river flows and sediment are trapped in the bay, creating a fertile environment for the growth of phytoplankton and zooplankton, which are the main food of rabbitfish. Marine vegetation such as seagrass and algae that are more abundant in the bay also provide an important additional food source (Latuconsina and Ambo-Rappe 2013). In contrast, outside the bay, stronger ocean currents can cause more rapid dispersion of nutrients, thereby reducing the constant availability of food for fish. Limited marine vegetation in more open areas can also limit food sources for rabbitfish.

Table 3. The result of Mann-Whitney U test for total length and weight of rabbitfish in Tanakeke Island, Takalar District, South Sulawesi, Indonesia

Variables	Site	Total individual	Median	U value	Z value	Asymp. Sig. (2-tailed)
Total length (cm)	Inside bay	1519	18.74	112324.5	-10.342	<0.001
	Outside bay	223	17.95			
Body weight (g)	Inside bay	1519	60.28	90213.5	-14.204	<0.001
	Outside bay	223	57.62			

Table 4. Kruskal-Wallis test for length and weight of rabbitfish inside and outside the bay of Tanakeke Island, Takalar District, South Sulawesi, Indonesia

Variables	Location	Species	Total individual	Kruskal-Wallis H	df	Asymp. Sig.
Total length	Inside bay	*Siganus canaliculatus* (Park, 1797)	952	5.097	5	0.404
		Siganus guttatus (Bloch, 1787)	155			
		Siganus javus (Linnaeus, 1766)	15			
		Siganus fuscescens (Houttuyn, 1782)	126			
		Siganus punctatus (Schneider & Forster, 1801)	133			
		Siganus virgatus (Valenciennes, 1835)	138			
	Outside bay	*Siganus canaliculatus* (Park, 1797)	173	0.122	3	0.989
		Siganus guttatus (Bloch, 1787)	16			
		Siganus punctatus (Schneider & Forster, 1801)	14			
		Siganus virgatus (Valenciennes, 1835)	20			
Body weight	Inside bay	*Siganus canaliculatus* (Park, 1797)	952	95.441	5	<0.001
		Siganus guttatus (Bloch, 1787)	155			
		Siganus javus (Linnaeus, 1766)	15			
		Siganus fuscescens (Houttuyn, 1782)	126			
		Siganus punctatus (Schneider & Forster, 1801)	133			
		Siganus virgatus (Valenciennes, 1835)	138			
	Outside bay	*Siganus canaliculatus* (Park, 1797)	173	26.589	3	<0.001
		Siganus guttatus (Bloch, 1787)	16			
		Siganus punctatus (Schneider & Forster, 1801)	14			
		Siganus virgatus (Valenciennes, 1835)	20			

Table 5. Ecological index of rabbitfish species in two bay locations in of Tanakeke Island, Takalar District, South Sulawesi, Indonesia

Parameter	Inside bay	Outside bay
Number of species	6	4
Number of individuals	1519	223
Species diversity index (H')	1.21	0.78
Species richness index (R1)	0.68	0.55
Evenness index (E)	0.68	0.56
Species dominant index (C)	0.43	0.62

Ecological index

The diversity index from inside the bay, 6 species of rabbitfish were found with a total of 1,519 individuals. The species diversity index (H') within the bay is 1.21, indicating relatively high diversity. The species richness index (R1) of 0.68 indicates that the bay has sufficient species richness. The evenness index (E) was also 0.68, indicating a relatively even distribution of species. The species dominance index (C) of 0.43 indicates that there is no species that really dominates the fish community in the bay.

Outside the bay, 4 species of rabbitfish were found with a total of 223 individuals. The species diversity index (H') outside the bay was 0.78, which was lower than inside the bay, indicating lower diversity. The species richness index (R1) of 0.55 is also lower than in the bay. The evenness index (E) outside the bay is 0.56, which indicates that the distribution of species outside the bay is less even than inside the bay. The species dominance index (C) of 0.62 indicates that there are species that dominate the fish community outside the bay more than inside the bay (Table 5).

A comparison between the two locations shows that inside the bay has higher species diversity and richness than outside the bay. The distribution of species within the bay is also more even, whereas outside the bay there is a stronger dominance of certain species. These differences can be caused by various environmental factors that differ between inside and outside the bay, such as food availability, physicochemical water conditions, protection from predators, and interactions between species (Pavlov and Kasumyan 2002; Madduppa et al. 2019). The more closed conditions in the bay can provide a more stable and supportive environment for various rabbitfish species.

From the observations, the environment in the bay supports a higher species diversity with six different species and a total of 1519 individuals, compared to outside the bay which only has four species with 223 individuals. The higher diversity index (H') inside the bay (1.21) compared to outside the bay (0.78) indicates that the more stable and homogeneous environment in the bay supports the conservation and survival of more species. The species richness index (R1) inside the bay is 0.68 and outside the bay is 0.55, while the evenness index (E) is also higher inside the bay (0.68) compared to outside the bay (0.56), indicating a more even distribution between species within the bay. This could be interpreted to mean that within the bay, each species has a more equal opportunity to reproduce and survive, most likely due to more stable access to resources and more controlled abiotic conditions (Pursiainen et al. 2021). In contrast, the species dominance index (C) was higher outside the bay (0.62) than within the bay (0.43), indicating that some species dominate the environment due to better adaptation to more diverse and challenging conditions. This condition may reflect ecological dynamics in which certain species that can adapt to harsher external conditions have an advantage in competition for resources (Jackson et al. 2019).

The results of the Kruskal-Walli's test and ecological index analysis show that the environment within the bay supports higher species diversity, species richness, and evenness, and has lower species dominance compared to outside the bay. More stable and nutrient-rich environmental conditions in the bay support more optimal growth and distribution of rabbitfish (Lee and Garcia 2017).

Protection from predators and more stable environmental conditions in the bay also support more optimal fish growth (Erzini et al. 2022; Siriwattanarat et al. 2024). The inside of the bay offers better protection from predators than the more open areas outside the bay. Dense vegetation such as seagrass and algae can provide effective shelter for rabbitfish, reducing the risk of predation (de la Torre-Castro et al. 2014; Salim et al. 2024). Additionally, the environment within a bay tends to be more stable in terms of temperature, salinity, and water currents, all of which can support better growing conditions. Outside the bay, the higher risk of predation and greater variability in environmental conditions can be stressful for fish, inhibiting optimal growth.

Population density and interactions between species also influence fish growth (Madduppa et al. 2019; Hunter et al. 2019). Higher population densities within the bay could lead to more intense intra-species competition for resources. However, if sufficient resources are available, this competition can stimulate faster growth because the fish need to optimize resource utilization. More complex interactions between species within the bay could also create a more stable food web, supporting overall fish population growth. Outside the bay, lower population densities may reduce direct competition, but limited resource availability and higher risk of predation may inhibit fish growth.

In conclusion, this research provides important insights that could greatly influence social and cultural aspects in local communities that depend on fisheries resources inside and outside the bay. The findings suggest that the bay provides more stable conditions that support the growth of rabbitfish, allowing local communities to manage their fisheries resources. However, this can also pose a risk of overfishing and unfair access if not managed well.

Furthermore, knowledge about species diversity and the need to maintain ecosystem balance can encourage conservation and environmental education efforts (Hasan et al. 2021; Hasan and Islam 2020). However, the wrong intervention can disrupt the balance of the ecosystem and reduce biodiversity in the long term. On the economic side, increasing catches and effective management can increase fishermen's income and encourage economic diversification, such as the development of ecotourism (Paul et al. 2020; Nurjirana et al. 2023). However, over-reliance on fisheries without sufficient diversification can leave communities vulnerable to economic or environmental fluctuations (Nurjirana et al. 2022).

From a cultural perspective, these findings can support local wisdom in managing natural resources and cultural revitalization related to aquatic ecosystems. However, increased commercial activity can threaten traditional practices and lead to social conflict (Gani et al. 2021; Ndobe et al. 2022). In conclusion, although this research offers many potential benefits, it is critical to develop management strategies that take into account social, economic and cultural impacts holistically, ensuring equity and sustainability for the future.

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