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Habitat-Driven Differences in Fish Assemblages Caught by Traditional Bubu Traps in Kapota Atoll, Wakatobi National Park, Indonesia

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Abstract

Bubu are traditional passive fishing traps made from natural materials such as bamboo and are widely used in coral reef fisheries due to their low impact on benthic habitats. This study examines the diversity and community structure of fish associated with different benthic habitats in Kapota Atoll, Wakatobi National Park, Indonesia. Five bamboo traps (88 × 78 × 32 cm) were deployed at five stations representing four habitat types: coral, sand, coral rubble, and seagrass. To minimize fish avoidance, traps were initially left in place for 48 hours to allow odors from new bamboo to dissipate. After this period, traps were retrieved to collect the catch and then redeployed. Sampling was conducted twice. A total of 92 individuals representing 25 species from 14 families were recorded. Ecological indices indicated moderate diversity (H' = 1.277-2.094), high evenness (E = 0.778-0.921), and low dominance (D = 0.141-0.306). Correspondence analysis explained 64.6% of the species–habitat relationship (Axis 1: 36.02%; Axis 2: 28.58%) and identified three assemblages associated with sand/coral/rubble habitats, shallow seagrass (3 m), and deeper seagrass (8 m). Overall, the results indicate that bubu traps are effective for capturing fish diversity across different benthic habitats and can provide useful ecological information for fisheries management, despite their relatively limited sampling area.

Keywords: correspondence analysis, community structure, ecological indices, fish trap, Kapota Atoll

1. Introduction

Kapota Atoll is part of the Wakatobi Waters, one of the most important Marine National Parks in Indonesia. The Wakatobi Islands were designated as Wakatobi National Park through Decree of the Minister of Forestry No. 7651/Kpts-II/2002 and were subsequently inaugurated as a UNESCO World Biosphere Reserve in 2012 (Wakatobi National Park Authority, 2020). Located within the "Coral Triangle," Wakatobi National Park harbors extraordinary marine biodiversity, including coral reefs, reef fish, seagrass beds, and other benthic biota (Wilson et al., 2012; Wakatobi National Park Authority, 2020). Kapota Atoll has been designated a traditional use zone (Wakatobi National Park Agency, 2020) and serves as a key coral reef fishing ground for local Wakatobi fishermen as well as fishermen from the surrounding Southeast Sulawesi region (Hasan et al., 2022). However, this fishing activity occurs with limited scientific information on fish diversity and faces threats from destructive practices like the use of Molotov cocktails, which can severely damage the ecosystem. Furthermore, because this fishing activity occurs within a conservation area, understanding its potential ecological impacts is crucial. The choice of fishing gear affects not only catch quantity but also species composition and diversity (Tulloch et al. 2020). In Kapota Atoll waters, fishermen commonly use hooks, gillnets, spears, and traps.

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Bubu (Fish traps) are traditional passive fishing gear that catch fish with or without bait or serve as shelter from predators (Tangke et al., 2018; Azahari et al., 2020; Stevens, 2021). They are widely used in coral reef and demersal fisheries in tropical and subtropical regions (Vadziutsina and Riera, 2020, 2021; Tupamahu et al., 2024) and are particularly common in small-scale fisheries (Bañón et al., 2018). Their selectivity toward certain species and sizes makes them relatively environmentally friendly (Langlois et al., 2015; Azahari et al., 2020; Kopp et al., 2020).

Habitat type and structure significantly influence fish diversity and community composition (Dorenbosch et al., 2007; Darling et al., 2017; Solikin et al., 2018; Komyakova et al., 2018; da Silva et al., 2021; Helder et al., 2022; Luza et al., 2022). Coral reefs often produce the highest fish abundance and diversity (Madduppa et al., 2001; Edrus et al., 2020; Hamuna et al., 2022; Isdianto et al., 2024), but other habitats such as seagrass beds, sand, rubble, or mixed substrates can host distinct assemblages and can serve as complementary habitats supporting various reef fish life stages. A diverse range of benthic habitats has been documented in Kapota Atoll, including live coral, dead coral, seagrass beds, sand, rubble, and mixed habitats (Siregar et al., 2020; Hafizt et al., 2021; Hamuna et al., 2023, 2024).

Rice (2018) stated that the abundance of marine parks leads to a lack of species inventory and a lack of efforts to maintain species diversity. Duarte et al. (2020) stated that rebuilding marine life is a major challenge that can be achieved by humanity and is a smart economic goal for achieving a sustainable future. Understanding habitat-linked differences in fish assemblages is important for ecosystem-based management and to ensure that fishing activities remain compatible with conservation goals. Such information is particularly relevant in Kapota Atoll, where traditional fishing is permitted, but scientific guidance is needed to maintain biodiversity and fishery productivity. This study aims to analyze the species diversity and community structure of fish caught with bubu (fish traps) placed in different benthic habitats of Kapota Atoll. We hypothesize that the diversity and composition of fish species caught differ among habitat types, reflecting habitat heterogeneity and ecological specialization. The results will provide baseline data to support sustainable fisheries management and monitoring of ecosystem health in Wakatobi National Park.

2. Materials and Methods

2.1. Study Area

The study was conducted from July 5 to 10, 2025, in Kapota Atoll, situated inside Wakatobi National Park area, Wakatobi Regency, Indonesia. This study placed 5 Bubu (**Figure 1**) with 4 different benthic habitat characteristics: 1 coral station, 2 seagrass stations, 1 sand station, and 1 rubble station (**Table 1**).

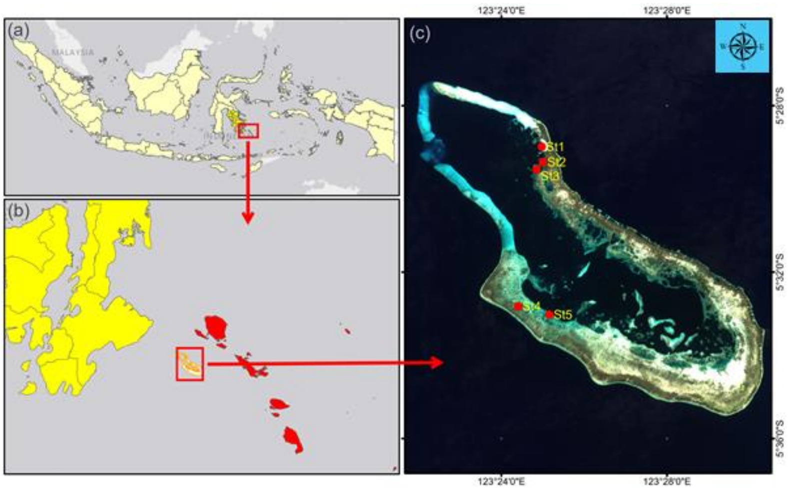

Figure 1. Map of the study area: (a) Indonesian waters, (b) Wakatobi Islands and surrounding areas, and (c) five sites for the placement of Bubu in Kapota Atoll.

Table 1. The five Stations for the placement of Bubu in Kapota Atoll. These stations represent different habitat conditions within the study area.

Sites	Benthic type	Depth (m)
St-1	Sand	10
St-2	Coral	10
St-3	Rubble	10
St-4	Seagrass	3
St-5	Seagrass	8

2.2. Data Collection

A total of five Bubu (fish traps) made of bamboo with the same dimensions were used in this study (**Figure 2**). Each Bubu measured 88 cm × 78 cm × 32 cm, with a mouth diameter of 32 cm to allow fish to enter. The funnel, which serves as the entrance, is a cone-shaped hole that tapers inward, measuring 65 cm. The narrow end of the funnel (24 cm) and opens into the holding chamber. The mesh size of the trap is approximately 3.5 cm. The Bubu was installed for two days (48 hours), then the catch was taken and the trap was reinstalled. This study was conducted with two repetitions.

Bubu deployment was conducted by two SCUBA divers, with one trap installed at each study site. To secure the traps against movement by ocean currents, rocks and coral rubble were placed on top as ballast (Baskoro et al., 2013). The geographic coordinates of each trap location were recorded using a multiband Garmin 65s handheld GPS (Global Positioning System) and marked with small surface buoys to facilitate relocation during hauling operations.

Each Bubu was hauled twice during the sampling period. The first trap was set on July 7, 2025, and removed on July 9, 2025. Afterward, all captured fish were removed, counted, and photographed. The trap was then reset at the same location on July 10, 2025, and the second haul was conducted on July 12, 2025, using the same procedure.

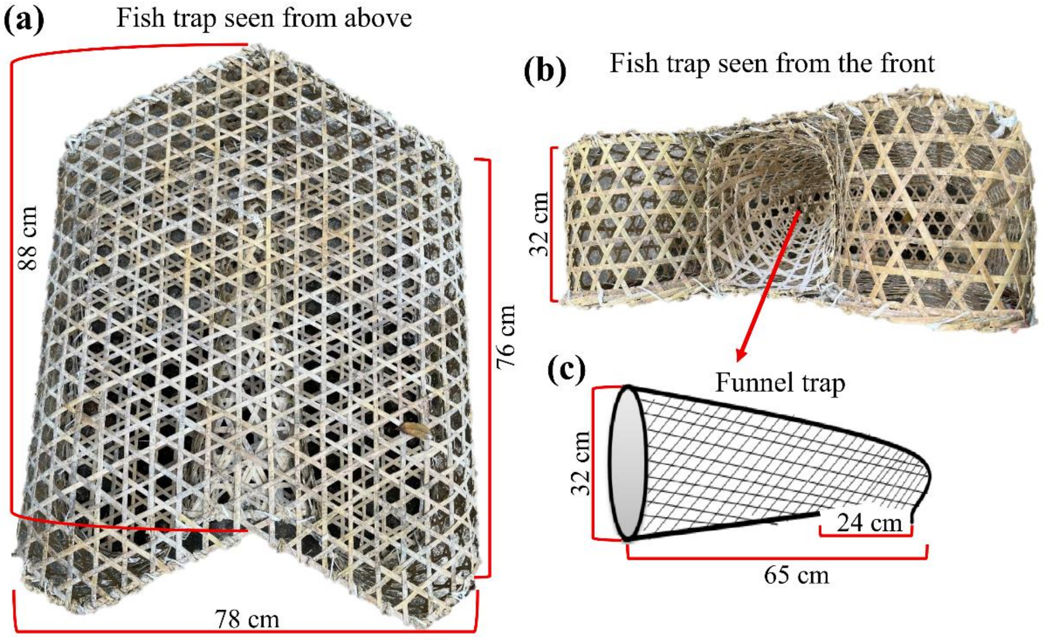

Figure 2. Bubu (fish traps) used in this study: (a) shape and size of the trap body, (b) shape of the trap mouth, and (c) shape and size of the trap funnel. The figure shows the design and structural components of the traps used during sampling.

The photographs were taken using the Xiaomi Redmi 9 T cellphone camera from 4 rear cameras (48MP main, 8MP ultra wide, 2MP macro and 2MP depth sensor) on the boat using a recording board base (**Figure 3**). Measurement of the length of the fish between 10-25 cm using a ruler measuring tool with a length of 30 cm for longer fish using a rolling meter. The weight of the fish was also measured using a digital scale with a capacity of 500 grams and a sitting scale with a capacity of 2 kg.

Figure 3. Fish length measurement. Measurements were taken to ensure consistency and accuracy across all sampled individuals.

2.3. Data Analysis

In identifying fish species, naming each fish species caught by fish traps refers to the valid name in FishBase (Froese and Pauly, 2025). After the fish caught by fish traps are identified at the species and family levels, the fish species are then grouped into two main groups, namely target fish and non-target fish (including major fish, indicator fish, and others) (Madduppa et al., 2012; Hamuna et al., 2022). An ecological analysis was conducted to ascertain the community structure of fish captured by fish traps at each study site. This can be determined by calculating several indices, including the diversity index (Shannon-Wiener diversity index), uniformity index (Pielou's evenness index), and dominance index (Simpson dominance index) using the following equations (Krebs, 2014):

$$Diversity\ index\ (H') = -\sum \left(\frac{n_i}{N}\right) \ln \left(\frac{n_i}{N}\right) \tag{1}$$

$$Uniformity\ index\ (E) = \frac{H'}{\ln S} \tag{2}$$

$$Dominance\ index\ (D) = \sum \left(\frac{n_i}{N}\right)^2 \tag{3}$$

where $n_i$is the number of individuals of the i-th species, $N$is the total number of fish caught, and $S$is the total number of fish species. The diversity index is classified into three categories: low diversity ($H' < 1$), moderate diversity ($1 < H' < 3$), and high diversity ($H' > 3$). The uniformity (evenness) index is categorized into depressed ($0 < E < 0.5$), unstable ($0.5 < E < 0.75$), and stable ($0.75 < E < 1.0$). Meanwhile, the dominance index is also divided into three categories: low dominance ($0 < D < 0.5$), moderate dominance ($0.5 < D < 0.75$), and high dominance ($0.75 < D < 1.0$).

2.4. Statistical Analysis

Multivariate statistical analysis was performed using the Kruskal-Wallis test and correspondence analysis using Paleontological Statistics (PAST) v4.03 software. The Kruskal-Wallis test with Dunn's post hoc was used because the data did not meet the assumptions of normality. It was also used to determine whether there was a significant difference in the number of fish trap catches between study sites at a significance level (α) of 0.05.

$$H = \frac{12}{N(N+1)} \sum_{j=1}^{k} \frac{R_j^2}{n_j} - 3(N+1) \tag{4}$$

where Kruskal–Wallis test statistic (H) is obtained from the calculation based on ranked data across all groups. In this formulation, $R_j$represents the sum of the ranks for the j-th group or category, while $n_j$denotes the number of observations within that group. The term $k$refers to the total number of groups or categories being compared in the analysis. Meanwhile, $N$is the total number of observations across all groups, calculated as the sum of sample sizes from each group $(N = n_1 + n_2 + \cdots + n_k)$. Together, these components are used to evaluate whether there are statistically significant differences between the distributions of the groups.

Correspondence analysis (CA) is a technique that allows to find multidimensional representations between rows and columns of a two-way contingency table. It was performed on a species-by-station matrix to visualize the ordination of fish species in relation to benthic habitat types.

3. Results and Discussion

3.1. Diversity of Fish Species Caught

The number of species and individual fish caught at the five study sites varied. A total of 25 fish species were caught using bubu (fish traps) at five study sites in Kapota Atoll (**Figure 4**). The fish species captured came from 14 fish families, with a total of 92 fish caught (**Table 2**). B. undulatus was caught at five stations. This species is an omnivorous fish, consuming both vegetation (seagrass) and other biota. The fish species caught using traps are mostly fish that are associated with coral reef habitats.

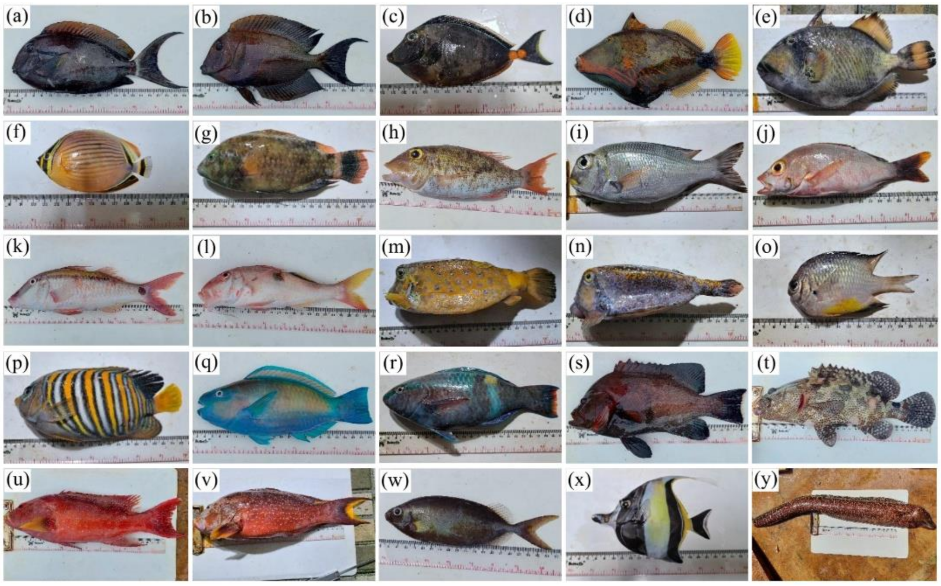

Figure 4. Fish species caught using Bubu in Kapota Atoll: a) *Acanthurus nigricauda*, (b) *Ctenochaetus striatus*, (c) *Naso lituratus*, (d) *Balistapus undulatus*, (e) *Balistoides viridescens*, (f) *Chaetodon lunulatus*, (g) *Cheilinus trilobatus*, (h) *Lethrinus semicinctus*, (i) *Monotaxis grandoculis*, (j) *Lutjanus gibbus*, (k) *Parupeneus barberinus*, (l) *Parupeneus pleurostigma*, (m) *Ostracion cubitus*, (n) *Ostracoin meleagris*, (o) *Amblyglyphidodon leucogaster*, (p) *Pygoplites diacanthus*, (q) *Chlorurus spilurus*, (r) *Scarus schlegeli*, (s) *Aethaloperca rogaa*, (t) *Epinephelus fuscoguttatus*, (u) *Variola albimarginata*, (v) *Variola louti*, (w) *Siganus argenteus*, (x) *Zanclus cornutus*, and (y) *Gymnothorax javanicus*.

Table 2. Taxa (family and species) and number of individual fish caught using Bubu in Kapota Atoll. The table summarizes the composition of fish species recorded during the study.

Family	Species	St-1		St-2		St-3		St-4		St-5	
		T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
Acanthuridae	*A. nigricauda*	2	3	1	0	0	0	0	0	0	0
	C. striatus	1	4	0	0	0	0	1	0	0	0
	N. lituratus	0	0	0	0	0	0	0	2	0	0
Balistidae	*B. undulatus*	2	2	1	3	1	2	1	1	3	0
	B. viridescens	0	0	0	0	0	0	0	0	0	1
Chaetodontidae	*C. lunulatus*	0	0	0	0	0	0	0	2	0	0
Labridae	*C. trilobatus*	0	0	0	0	0	0	0	0	0	3
Lethrinidae	*L. semicinctus*	0	0	0	0	0	0	0	0	7	6
	M. grandoculis	0	0	0	0	0	0	0	0	0	1
Lutjanidae	*L. gibbus*	0	0	0	0	0	0	0	0	0	1
Mullidae	*P. barberinus*	1	0	0	0	0	0	0	0	0	0
	P. pleurostigma	1	0	0	0	0	0	0	0	0	0
Muraenidae	*G. javanicus*	0	0	0	0	0	1	1	1	0	0
Ostraciidae	*O. cubitus*	0	0	0	0	0	0	0	0	0	1
	O. meleagris	0	0	0	0	0	0	1	0	0	1
Pomacanthidae	*A. leucogaster*	0	2	0	0	0	0	0	0	0	0
	P. diacanthus	0	0	0	1	0	0	0	0	0	0
Scaridae	*C. spilurus*	0	0	0	0	2	0	0	0	0	0
	S. schlegeli	0	5	0	0	0	0	0	0	1	0
Serranidae	*A. rogaa*	1	0	0	0	0	0	0	0	0	0
	E. fuscoguttatus	0	0	0	1	1	0	0	0	0	0
	V. albimarginata	2	0	0	1	0	0	0	0	0	0
	V. louti	0	0	0	1	0	0	0	0	0	0
Siganidae	*S. argenteus*	0	0	0	0	0	0	0	0	7	0
Zanclidae	*Z. cornutus*	0	1	0	0	0	0	0	7	0	0
	Number of fish species	10		7		5		9		11	
	Number of individual fish	27		9		7		17		32	

Note : T1 = Trip one ; T2= Trip two

Based on the number of fish caught at each station (**Table 2**), the Kruskal-Wallis analysis did not show significant differences between the five research stations (p value > 0.05) (**Table 3**).

Table 3. Significance value (p-value) of comparison of individual fish caught between study sites (α: 0.05). The table presents the results of statistical comparisons among sampling sites.

	St-2	St-3	St-4	St-5
St-1	0.116	0.522	0.923	0.547
St-2		0.503	0.170	0.294
St-3			0.597	0.853
St-4				0.653

3.2. Community Structure of Fish Caught

Table 4 presents the diversity (H'), uniformity (E), and dominance (D) indices of fish caught using fish traps in Kapota Atoll. The diversity index values of the captured fish were categorized as moderate. The uniformity index of the fish caught at all study sites indicated stable conditions. The dominance index values were categorized as low at all study sites.

Table 4. Community structure of fish caught using Bubu in Kapota Atoll. The table shows key ecological indices used to describe fish community structure. These may include measures of diversity, uniformity, and dominance across the sampling sites.

Sites	Diversity (H')	Uniformity (E)	Dominance (D)
St-1	2.094 (Moderate)	0.909 (Stable)	0.141 (low)
St-2	1.581(Moderate)	0.882 (Stable)	0.259 (low)
St-3	1.277 (Moderate)	0.921 (Stable)	0.306 (low)
St-4	1.706(Moderate)	0.877 (Stable)	0.232 (low)
St-5	1.792(Moderate)	0.778 (Stable)	0.236 (low)

3.3. The relationship between benthic habitat types and fish species caught

The correspondence analysis yielded Eigenvalues and Inertia Proportion (**Table 5**). Dimension 1 (Axis 1) explained 36.02% of the total inertia (variance in categorical data). Dimension 2 (Axis 2) added 28.58%, so the first two dimensions together explained 64.6% of the data variation. The relationship between benthic habitat types and the types of fish caught is evident from the results of the correspondence analysis, as presented in **Figure 5**.

Table 5. Eigenvalues and inertia proportions. The table summarizes the contribution of each axis in the multivariate analysis.

Axis	Eigenvalue	% of total	Cumulative %
1	0.820844	36.02%	36.02%
2	0.651305	28.58%	64.60%
3	0.524009	22.99%	87.59%
4	0.282706	12.41%	100.00%

The results of the correspondence analysis indicate three groups of fish species caught based on their benthic habitats.

1. The first group, which includes fish species caught in sand, coral, and coral rubble habitats, is characterized by *A. nigricauda*, *B. undulatus*, *P. barberinus*, *A. leucogaster*, *S. schlegeli*, *A. rogaa*, *V. louti*, *V. albimarginata*, *P. pleurostigma*, *P. diacanthus*, *C. spilurus*, *E. fuscoguttatus*, and *C. striatus*.
2. The second group consists of fish species that tend to be caught in seagrass habitats at a depth of 3 m, namely *N. lituratus, C. lunulatus, Z. cornutus*, and *G. javanicus.*
3. The third group consists of dominant fish species caught in seagrass habitats at a depth of 8 m, *including B. viridescens, C. trilobatus, L. semicinctus, M. grandoculis, L. gibbus, O. cubitus, S. argenteus,* and *O. meleagris*.

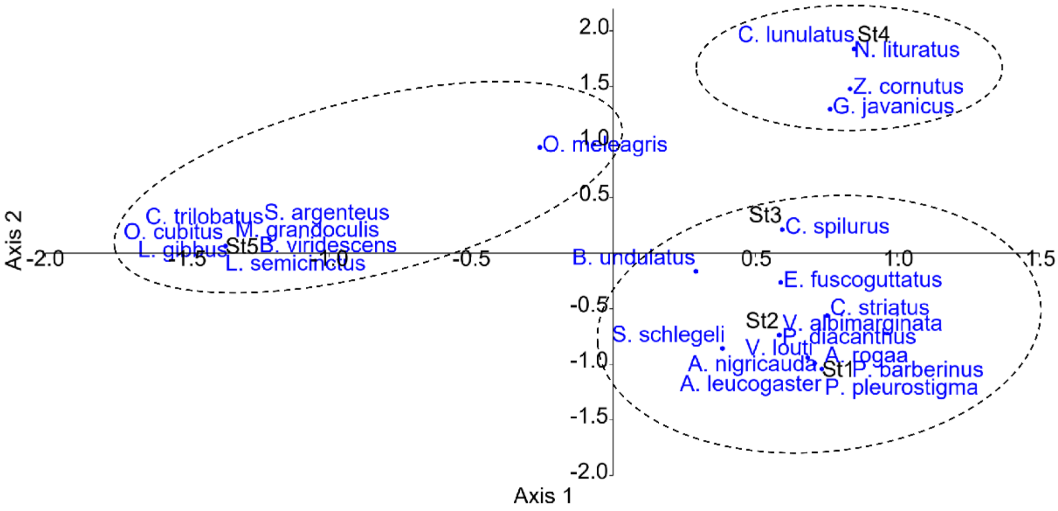

Figure 5. Relationship between benthic habitat types and fish species caught. The figure is based on correspondence analysis (CA), showing the association between habitat categories and species composition.

3.4. Discussion

This study reveals the diversity and abundance of fish among benthic habitat types in Kapota Atoll. These findings indicate that species composition is closely related to habitat characteristics (James et al., 2017; Bacheler and Shertzer, 2020). The structural complexity provided by coral reefs, seagrass meadows, and mixed habitats provides important feeding, shelter, and breeding areas (Elston et al., 2020; Syukur et al., 2021; Tony et al., 2021; Manangkalangi et al., 2022; Utama et al., 2022; Mujiyanto et al., 2023; Isdianto et al., 2024).

Interestingly, the number of species and total fish catches in seagrass and sand habitats are higher than in coral habitats. Seagrass meadows serve as spawning and nursery habitats. (Simanjuntak et al., 2020; Syukur et al., 2021; Erzini et al., 2022; Isnaini et al., 2022; Manangkalangi et al., 2022; Lattanzi et al., 2024), where seagrass-coral reef connectivity supports reef fish biomass and fisheries productivity (Campbell et al., 2011; Honda et al., 2013). Low catches in coral rubble habitats likely reflect habitat degradation, reducing fish diversity and abundance.

Species-level patterns further support the role of habitat heterogeneity. The fish species *L. semicinctus* and *S. argenteus* were most abundant in seagrass habitats, likely due to the availability of foraging opportunities (Allen and Erdmann, 2012). Their schooling behavior increased the likelihood of multiple individuals entering traps simultaneously. Similarly, small groups of *Z. cornutus* were sometimes captured (Krupp, 1995).

From a fisheries management perspective, our results indicate that bubu (fish traps) are effective for catching fish from the families Lethrinidae, Scaridae, Serranidae, Siganidae, and Lutjanidae. This finding is consistent with previous studies reporting relatively high catches per unit effort (±40 kg/trip) in Kapota Atoll (Hasan et al., 2022). The highest trap catches were found in seagrass-associated habitats, suggesting that these areas may serve as key fishing grounds for maintaining reef fish populations. However, economically valuable groupers (Serranidae) (e.g., *V. albimarginata*, *V. louti*, and *E. fuscoguttatus*) were only caught in coral habitats or coral-associated sand and rubble habitats, reflecting their preference for high-relief reef structures (Heemstra et al., 2003; Parenti and Randall, 2020). Therefore, protecting these habitats is crucial for maintaining populations of high-value species.

The findings of this study indicate that the species composition and quantity of individual fish in Kapota Atoll remain high and capable of providing significant economic value. This is consistent with studies in other tropical regions where trap fisheries can selectively capture economically important fish (Langlois et al., 2015; Beenamol et al., 2017; Varghese et al., 2017; Danajaya et al., 2022; Yu et al., 2023). Similar patterns of trap selectivity and fish assemblages related to habitat have been reported in the Caribbean (Johnson, 2010; Renchen et al., 2024), the Mediterranean (Bañón et al., 2018), and the Atlantic coast (Cullen and Stevens, 2017; Bacheler et al., 2022), suggesting that our findings have broader relevance for small-scale tropical fisheries.

A moderate diversity index and a stable evenness index indicate a balanced fish community structure, with no single species dominating the catch (Madduppa et al., 2012; Utama et al., 2022). A low dominance index indicates that fishing pressure is not biased towards a single species group (Baskoro et al., 2013), which is ecologically desirable because it supports ecosystem balance and resilience (Loiseau and Gaertner, 2015; Isdianto et al., 2024).

Overall, our findings highlight the ecological and fisheries management significance of the diversity of benthic habitats in Kapota Atoll. Identifying habitat-species relationships can inform spatial planning, such as prioritizing habitat protection in seagrass and coral zones, regulating trap mesh sizes, and limiting trap density per fisherman to maintain fish stocks. These results provide a scientific basis for ecosystem-based fisheries management in Wakatobi National Park and contribute to broader efforts to balance biodiversity conservation with sustainable resource use.

In conclusion, Data collection using the traps was carried out twice. The study yielded a total catch of 92 individuals representing 25 species from 14 families. Ecological indices across all stations showed moderate diversity (H' = 1.277-2.094), high evenness (E = 0.778-0.921), and low dominance (D = 0.141-0.306). Correspondence analysis showed a diversity value of 64.60% (36.02% on axis 1 and 28.58% on axis 2). This correspondence analysis also found three groups of fish species based on habitat. These results illustrate that the Bubu fishing gear can provide information on biota diversity in different habitat locations with a relatively small catchment area.

This study has elucidated the diversity and community structure of fish species captured using fish traps in Kapota Atoll. The majority of species caught were target fish of economic importance, confirming that fish traps remain an effective and selective gear for small-scale reef fisheries. As previously reported by Hartati et al. (2004) and Iskandar et al. (2020) in the Seribu Islands, the number of species and individuals caught could be further increased through additional traps and strategic placement across habitat types.

While this study provides critical baseline data, we acknowledge its limitations, specifically its short-term nature consisting of only two sampling trips, the small number of traps deployed, and the absence of environmental measurements such as water temperature and visibility, which are known to influence catchability. Despite these constraints, our findings emphasize that the effectiveness of traditional bubu fishing is fundamentally driven by benthic habitat characteristics, making habitat-specific protection (especially for coral and seagrass areas) essential for sustaining high value target species like groupers. To facilitate adaptive fisheries management within Wakatobi National Park, future research should prioritize long-term monitoring across different seasons, increased trap replication, and the integration of environmental data and underwater visual censuses. Such efforts will provide the robust temporal data needed to detect changes in fish diversity and ensure that conservation goals and fishery productivity remain in balance.

4. Conclusions

This study confirms that traditional bubu (bamboo traps) are effective and selective tools for monitoring fish diversity across the diverse benthic habitats of Kapota Atoll. Our findings, encompassing 25 species from 14 families, demonstrate a balanced community structure defined by moderate diversity and high evenness. The identified relationship between fish assemblages and habitat types, specifically the reliance of high-value groupers on coral-associated areas, highlights the importance of habitat heterogeneity in supporting reef fish biomass. To safeguard these resources within Wakatobi National Park, management must transition toward more specific, habitat-based protections. We recommend that park authorities implement adaptive measures, such as standardizing trap mesh sizes and limiting trap density, while establishing a long-term monitoring framework to evaluate the impact of fishing pressure and environmental changes on the atoll’s ecosystem

Conflicts of Interest

There are no conflicts to declare.

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AI Writing Statement

In preparing this manuscript, the authors used ChatGPT (OpenAI) to assist with improving grammar, readability, and overall presentation of the text. The use of this tool was limited to language refinement and did not involve data processing, analysis, or interpretation. All sections were carefully reviewed and edited by the authors, who accept full responsibility for the accuracy and integrity of the work.

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