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Correlation Between Intertidal Zone Fish Community and Water Parameters of Melasti Beach, Bali

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Abstract. The ocean and coastal waters have incredible ecosystem diversity, especially in the intertidal zone where tidal fluctuations occur. Although considered extreme, this zone supports many organisms with specialized adaptations to the physical and chemical conditions. As a result, the biodiversity and abundance of organisms in the intertidal zone are higher than in other habitats. Previous research highlights the importance of ecosystems such as coral reefs, seagrass beds, and mangroves in supporting fish biodiversity in the intertidal zone, including ornamental and commercial species. Environmental factors such as temperature, pH, and salinity play significant roles in determining fish diversity, creating various microhabitats. Melasti Beach is the focus of research because it provides important habitats for various fish species and shows high biodiversity. This research is important for understanding and conserving the structure of intertidal fish communities. The research method consists of fish observation using Underwater Visual Census & capture, as well as measuring water parameters (salinity, pH, temperature, and phosphate), with data analysis covering species composition and abundance, ecological indices, and correlations between water parameters and species abundance. The research shows 28 fish families, totaling 74 species and 488 individuals during high tide, and 61 species and 236 individuals during low tide, with a moderate diversity index. Water parameters such as pH, temperature, salinity, and phosphate exhibit minor variations between high and low tides. During high tide, the results showed that water parameters were negatively correlated with species abundance. Similar to high tide conditions, during low tide, temperature and pH maintain a negative correlation, while salinity and phosphate are the opposite.

Keywords: community, intertidal, parameter correlation, total species

I. INTRODUCTION

The ocean and coastal waters support a remarkable diversity of ecosystems and biological communities. Among these ecosystems, the intertidal zone represents one of the most dynamic environments due to periodic tidal fluctuations that continuously alter physical and chemical conditions. These fluctuations create unique ecological settings that influence the distribution, abundance, and diversity of aquatic organisms, particularly fishes [1]. According to [2], organisms inhabiting intertidal environments possess specialized adaptations that enable them to tolerate rapid changes in environmental conditions. Intertidal fishes exhibit specialized behavioral and physiological adaptations that enable survival under periodic exposure, fluctuating salinity, and temperature stress [3, 4].

Previous studies have demonstrated that intertidal fish communities are strongly influenced by the presence of adjacent coastal ecosystems. Research by [5, 6] identified several ecologically and economically important fish species in intertidal habitats. Their findings emphasized the critical role of coral reefs, seagrass beds, and mangrove ecosystems in sustaining fish diversity. These habitats provide essential ecological functions, including nursery grounds, feeding areas, predator shelter, and breeding sites for various fish species [7].

In addition to habitat availability, Environmental variability is widely recognized as one of the primary drivers shaping fish assemblage structure and ecosystem resilience in tropical coastal habitats [8]. Variations in these parameters can create distinct microhabitats that support different assemblages of fish species. Therefore, understanding the relationship between environmental conditions and fish communities is fundamental for effective ecosystem management and conservation.

Melasti Beach, Bali, is one of the coastal areas characterized by diverse intertidal habitats, including coral reefs and seagrass ecosystems. Despite its growing importance as a tourism destination, information regarding the structure of fish communities and their relationship with environmental parameters in this area remains limited. Therefore, this study was conducted to analyze the composition, abundance, and community structure of intertidal fishes at Melasti Beach and to evaluate the correlation between selected water quality parameters and fish abundance. The findings of this study are expected to provide valuable ecological information for biodiversity conservation, coastal ecosystem management, and the sustainable utilization of marine resources in the intertidal zone [9].

II. METHODS

This research was conducted from the second to the third week of December 2023 and continued into the first week of January 2024. The study was adjusted according to weather conditions. This study was conducted at Melasti Beach, Ungasan, South Kuta, Bali. In this study, methods are divided into two parts: fish observation and measurement of water parameters. Fish observations were conducted using the Underwater Visual Census (UVC) method and the catching method. UVC was performed along a 70-meter transect, with visual observations extending 2.5 meters on each side. The catching method involved a 5-meter by 1-meter beach seine net with a 3 cm mesh size, supplemented by fish nets for narrow areas. Nets were pulled along the transect right after UVC observations. Data were collected twice per station, during high and low tides, with one repetition per station. Fish that are observed or caught were recorded and identified using Allen et al. (2003) reef fish identification book. Tidal conditions were monitored using the Tides Charts Near Me software, selecting the Benoa-B location. The water parameters measured in this research included salinity, pH, temperature, and phosphate content. Water temperature was measured directly at the water surface using a digital thermometer. For other parameters, water samples were collected using a measuring cup and analyzed on land to minimize observation errors and equipment damage. pH levels were measured using a pH meter, salinity with a refractometer, and phosphate content with a measuring kit.

To determine fish composition, abundance, and total species, each fish species is identified by first recording or capturing fish at each station, then categorizing them by species. Three indices measured for ecological index analysis are the Shannon-Wiener Diversity Index, Evenness Index, and the Simpson's Dominance Index, as shown below:

Shannon-Wiener Diversity Index (H')

Fish diversity was calculated using the Shannon-Wiener Diversity Index [3]. This index measures fish species diversity in a water body and illustrates community diversity: higher values indicate less dominance by a single or a few species. Based on the diversity index, if the diversity value (H') is less than or equal to two, the diversity is considered low. A value between 2.1 and 3 indicates moderate diversity, and exceeding 3 is considered high [3]. The formula for the diversity index is as follows:

$$H' = -\sum P_i \ln P_i$$

Explanation:
H' = Shannon-Wiener diversity index
Pi = Proportion of each species in the sample
Ln = Natural logarithm

Eveness Index (E)

The calculation of the Evenness Index refers to Krebs (1978), as shown:

$$E = \frac{H'}{H'max}$$

Where E is the evenness index, S is the number of species, H' is the Shannon-Wiener diversity index, and H'max is the maximum value of the diversity index. The evenness index is classified into three categories as shown in Table 1.

Table 1.
Eveness Index Categories

Index Range	Condition
0 < E ≤ 0,4	Stressed
0,4 < E ≤ 0,6	Unstable
0,6 < E ≤ 1,0	Stable

Simpson's Dominance Index (C)

To determine the dominance value, the formula is used as shown below:

$$C = \sum \left(\frac{ni}{N}\right)^2$$

Explanation:
C = Simpson's Dominance index
ni/N = Proportion of the number of individuals of species ii to the total number of individuals

The criteria for Simpson's Dominance Index range from 0 to 1 and are grouped into three value ranges as shown in Table 2.

Table 2.
Simpson's Dominance Index Categories

Index Range	Condition
$0 < C \leq 0,30$	Low
$0,30 < C \leq 0,60$	Moderate
$0,60 < C \leq 1$	High

Water Parameters and Fish Species Correlation

Water parameters are correlated with the number of fish species using PCA, commonly known as Principal Component Analysis. PCA is used to reduce data or summarize water parameter variables and then correlate them with fish abundance. The variables included in PCA analysis are water parameters (pH, salinity, temperature, and phosphate) and the number of fish species. PCA analysis is applied to research data using OriginPro software. The results of the PCA analysis will be presented as biplot graphs.

III. RESULTS AND DISCUSSION

Fish Composition and Species Abundance

Based on observations at all stations during high and low tide, 28 families were identified. The families with the highest species composition were Pomacentridae and Labridae, each comprising 8 species, accounting for 16% of the total species. This was followed by the family Chaetodontidae, comprising 6 species (12%). The family Acanthuridae comprised 3 species, accounting for 6%. The families Blenniidae, Gobiidae, and Scorpaenidae each had 2 species, accounting for 4% each. The families Aulostomidae, Apogonidae, Atherinidae, Balistidae, Caesionidae, Callionymidae, Carangidae, Cygnoglossidae, Diodontidae, Haemulidae, Muraenidae, Pempheridae, Pinguipedidae, Scaridae, Serranidae, Sillaginidae, Solenostomidae, Synodontidae, Trichonotidae, Tripterygiidae, and Tetraodontidae each had 1 species, accounting for 2% each. The species composition of each family is shown more clearly in Figure 1.

During high tide, 74 fish species were identified, with a total of 488 individual fish. The number of fish species during high tide was higher than during low tide. During high tide, several fish species were dominant, including *Atherinomorus* sp., *Abudefduf vaigiensis*, *Enneapterygius* sp., and *Apogon cookii*. Some fish species were found only during high tide, including Caranx melampygus, a species of trevally. One species of thick-lipped fish from the Haemulidae family, *Plectorhynchus gibbosus*, was found. One species of snapper from the Serranidae family, *Cephalopholis argus*, was found. One species of the family Pinguipedidae, *Parapercis* sp., was found. One species from the Synodontidae family, *Synodus dermatogenys*, was found. Two species from the Tetraodontidae family, *Canthigaster compressa* and *Canthigaster ocellicincta*, were found. One species from the Trichonotidae family, *Trichonotus setiger*, was found.

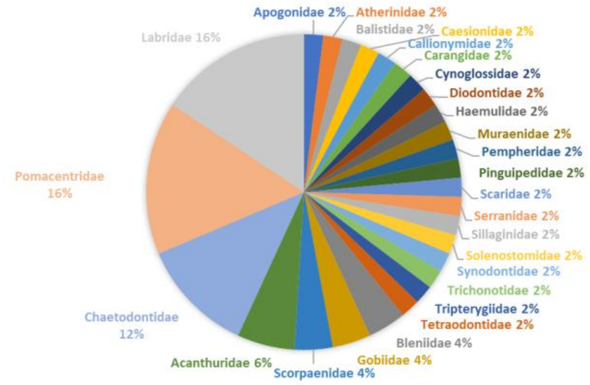

Figure 1. Families of fish found in the intertidal zone of Melasti Beach

During low tide, 61 fish species were found, with a total of 236 individual fish. Compared to high tide, the abundance of individuals and the number of fish species were lower during low tide. During low tide, several fish species were dominant, including *Apogon cookii*, *Salarias guttatus*, *Abudefduf vaigiensis*, *Chromis margaritifer*, and *Enneapterygius* sp. Some fish species were found during low tide but not during high tide, including one species of sillaginid fish, *Sillago sihama*, from the Sillaginidae family. One species of the family Solenostomidae, *Solenostomus cyanopterus*, was found. One species from the Cynoglossidae family, *Cynoglossus bilineatus*, was found. Tripterygiidae and Tetraodontidae, each consisting of 1 species. Table 3 below shows the detailed species composition from each family.

Based on observations, several fish families were found during both high and low tide conditions, such as the families Acanthuridae, Apogonidae, Atherinidae, Bleniidae, Callionymidae, Chaetodontidae, Gobiidae, Labridae, Muraenidae, Pempheridae, Pomacentridae, Scaridae, Scorpaenidae, and Tripterygiidae. The occurrence of these families under both tidal conditions suggests that they are well adapted to intertidal environments and may utilize the habitat as a permanent or semi-permanent residence. This statement is supported by Binsai et al. [3], who found several families in the intertidal zone, including Acanthuridae, Chaetodontidae, Apogonidae, Gobiidae, Blenniidae, Pomacentridae, Labridae, and others. These fish families were found in various habitats, including rocks, seagrass, algae, sand, and coral reefs [10]. This indicates that the intertidal zone at Pantai Melasti can provide a variety of habitats that support the life of several fish families to live or reside permanently. Conversely, some fish families were only found in certain conditions, either during low tide or high tide. These fish families include Sillaginidae, Solenostomidae, and Cynoglossidae, which were only found during low tide. The families Aulostomidae, Balistidae, Caesionidae, Carangidae, Haemulidae, Pinguipedidae, Serranidae, Synodontidae, Tetraodontidae, and Trichonotidae were only found during high tide. The exclusive occurrence of several families under specific tidal conditions may reflect tide-dependent habitat use and ontogenetic migration patterns, in which fishes move between habitats to meet feeding, refuge, and reproductive requirements [11]. Aquatic organisms often experience changes in their feeding preferences and natural habitats as they progress through different life-cycle stages. Thus, these organisms tend to migrate. Migration between habitats is carried out to meet biological needs, such as food and predation, and ecological needs, such as the availability of suitable habitat characteristics. This migratory behavior is thought to be influenced by water conditions; during high tide, sea levels rise, making it easier for fish to access the intertidal zone. Unlike during high tide, when the sea surface is higher, low tide conditions make fish migration more difficult and narrow the available water for fish.

Figure 2. Multiple fish species are found in the intertidal zone of Melasti Beach. a.) Echidna nebulosa, b.) Solenostomus cyanopterus, c.) Lactoria cornuta, d.) Synodus dermatogenys, e.) Atherinomorus sp., f.) Pempheris schwenkii, g.) Cynoglossus bilineatus

Ecological Index (Community Structure)

Based on the analysis, the fish community structure index values are presented in Table 4. Based on Shannon-Wiener Diversity Index calculations, the fish diversity index in the intertidal zone of Melasti Beach is 2.44 during high tide and 2.5 during low tide. Although there is a difference in values between the two conditions, both are still classified as moderate according to the Shannon-Wiener diversity index. The evenness analysis shows a value of 0.67 during high tide and 0.72 during low tide. According to the evenness index by Krebs (1978), the fish community conditions during high and low tide are classified as stable. The dominance analysis shows a value of 0.17 during high tide and 0.15 during low tide. According to Simpson's dominance index, both conditions fall into the low dominance category. The fish community structure consists of the Shannon-Wiener Diversity Index (H'), Evenness Index (E), and Simpson's Dominance Index (C). The diversity index (H') obtained under both conditions is 2.44 for high tide and 2.5 for low tide, both indicating moderate diversity. This shows that the fish diversity at Melasti Beach during both high and low tide exhibits a similar pattern. The ecological quality of coral reef habitats strongly influences fish diversity, abundance, and trophic structure because structurally complex reefs provide greater shelter and resource availability [12]. According to [10], if coral reef conditions are good, diversity is high; if coral reef conditions are poor, fish diversity is low. Melasti Beach itself has two main habitats, namely coral reefs and seagrass beds. The presence of these two habitats is sufficient to support the intertidal zone as a nursery, feeding, and breeding ground [6] for various fish species.

Table 4.
Community Structure

Index	High Tide	Low Tide
Diversity (H')	2.44	2.5
Eveness (E)	0.67	0.72
Dominance (C)	0,17	0,15

The Evenness Index (E) is 0.67 for high tide and 0.72 for low tide. Both fall into the stable category. This indicates that the fish community in the intertidal zone of Melasti Beach has a similar distribution of individual species numbers in both conditions. According to Rizqi et al. (2021), a stable or high evenness level occurs when a community's ecological conditions are balanced, and higher evenness values indicate better environmental quality. This is also supported by the low dominance index in both conditions, with values of 0.17 during high tide and 0.15 during low tide. A low dominance value indicates that no species dominates others during the observation.

Water Parameter Correlation with Species Abundance

The results of the PCA analysis of water parameters and fish species abundance in the intertidal zone of Pantai Melasti during high tide are shown in Figure 4.4, while Figure 4.5 shows the results during low tide. During high tide, the PC1 (Principal Component 1) axis had a variable diversity of 45.41%, while the PC2 axis was 34.08%. The total diversity of PC1 and PC2 during high tide was 79.49% (Figure 4.4). During low tide, the PC1 axis had a diversity of 50.49%, while the PC2 axis had a diversity of

28.98%. The total diversity of PC1 and PC2 during low tide was 79.47%.

The PCA ordination revealed that fish abundance was inversely associated with all measured environmental variables during high tide. Changes in physicochemical conditions are known to alter habitat suitability, leading to shifts in fish assemblage composition and abundance [13, 14]. Although the observed environmental ranges were relatively narrow, Elevated nutrient concentrations may indirectly affect fish communities through habitat degradation, algal proliferation, and reductions in coral reef health. High phosphate concentrations will disrupt metabolic processes and may even cause fish death [15]. The negative correlation with temperature indicates that as water temperature increases, the number of fish species found decreases. This is similar to [16], who found that temperature negatively correlates with fish abundance. Temperature can affect other water quality parameters and metabolic processes in aquatic organisms, as it can stimulate or inhibit their development and reduce oxygen saturation, lowering dissolved oxygen levels [17]. The negative correlation between salinity and the number of species indicates that as the salt content in the water (salinity) increases, the number of fish species found decreases. According to González-Sansón et al. [18], high salinity reduces the richness of aquatic organisms because fish that cannot adapt to high salinity experience osmotic stress, which can disrupt osmoregulation [19]. The pH parameter and the number of species have a negative relationship: as pH increases, the number of species decreases. This is suspected to be due to water pH, as [20] reports that high pH can increase ammonia concentration, which is toxic to aquatic organisms.

The PCA results during low tide showed negative correlations between pH and temperature, but phosphate and salinity were positively correlated with the number of fish species. This means that as phosphate and salinity levels in the water increase, the number of fish species found also increases.

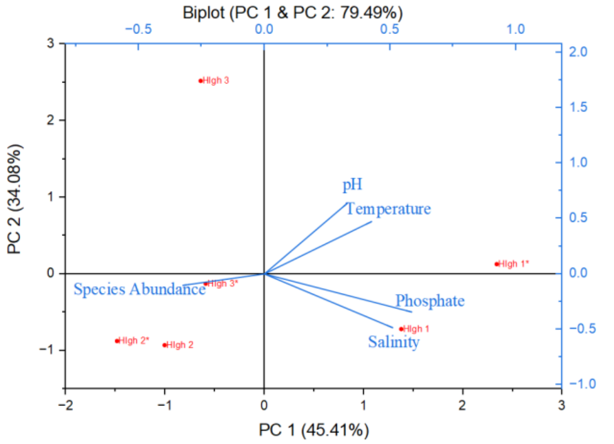

Figure 3. PCA results during high tide.

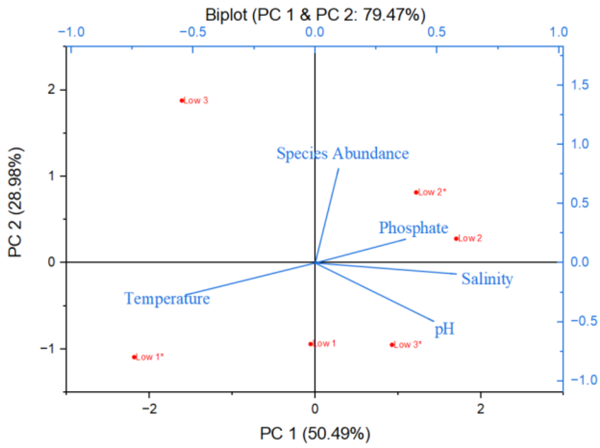

Figure 3. PCA results during low tide

Table 3.
The Number Of Individual Fish Varies Between High Tide and Low Tide Conditions

Family	Species	Condition	
		High Tide	Low Tide
Acanthuridae	*Acanthurus grammaptilus*		1±0,4
	Acanthurus nigrofuscus		1±0,4
	Acanthurus triostegus	1±0,4	
Apogonidae	*Apogon cookii*	38±4,8	27±3,93
Atherinidae	*Atherinomorus* sp.	172±68	3±1,22
Aulostomidae	*Aulostomus chinensis*	1±0,4	
Balistidae	*Rhinecanthus aculeatus*	4±1,63	
Bleniidae	*Salarias guttatus*	13±2,07	18±3,46
	Ecsenius namiyei	1±0,4	
Caesionidae	*Caesio cuning*	3±1,22	

Callionymidae	*Neosynchiropus ocellatus*	13±4,4	3±0,83
Carangidae	*Caranx melampygus*	20±8,16	
Chaetodontidae	*Chaetodon kleinii*	1±0,4	
	Chaetodon lineolatus		4±1,63
	Chaetodonm reticulatus	1±0,4	
	Chaetodon oxycephalus		4±1,21
	Chaetodon rafflesii		3±0,83
	Chaetodon vagabundus	2±0,8	5±2,04
Cynoglossidae	*Cynoglossus bilineatus*		1±0,4
Diodontidae	*Diodon liturosus*	1±0,4	1±0,4
Gobiidae	*Valenciennea sexguttata*	3±1,22	1±0,4
	Exyrias ferrarisi	6±2,44	
Haemulidae	*Plectorhinchus gibbosus*	2±0,51	
Labridae	*Anampses lineolatus*		1±0,4
	Coris dorsomacula		1±0,4
	Halichoeres papilionaceus	13±2,04	4±1,21
	Halichoeres leucoxanthus	5±0,98	2±0,8
	Halichoeres bicolor	4±1,21	3±1,22
	Halichoeres trimaculatus	1±0,4	
	Diproctacanthus xanthurus	9±3,2	
	Pseudojuloides severnsi		1±0,4
Muraenidae	*Echidna nebulosa*	5±1,33	2±0,8
Pempheridae	*Pempheris schwenkii*	2±0,8	6±1,26
Pinguipedidae	*Parapercis* sp.	1±0,4	
Pomacentridae	*Abudefduf vaigiensis*	85±14,64	80±15,56
	Acanthochromis polycanthus	7±2,85	1±0,4
	Centropyge flavicauda		7±1,83
	Chromis margaritifer	7±2,04	12±3,34
	Dascyllus melanurus		2±0,8
	Pomacentrus auriventris	16±3,56	
	Pomacentrus reidi		1±0,4
	Pomacentrus taenimetopon	10±1,94	9±3,67
Scaridae	*Scarus dimidiatus*	1±0,4	1±0,4
Scorpaenidae	*Dendrochirus brachypterus*	6±2	2±0,8
	Pterois miles	1±0,4	3±0,83
Serranidae	*Cephalopholis argus*	1±0,4	
Sillaginidae	*Sillago sihama*		1±0,4
Solenostomidae	*Solenostomus cyanopterus*		1±0,4
Synodontidae	*Synodus dermatogenys*	1±0,4	
Tetraodontidae	*Canthigaster compressa*	1±0,4	
	Canthigaster ocellicincta	1±0,4	
Trichonotidae	*Trichonotus setiger*	1±0,4	
Tripterygiidae	*Enneapterygius* sp.	28±4,96	26±2,94
	Total	488	236

Note: ± (Standard Deviation)

IV. CONCLUSION

A total of 28 fish families were recorded in the intertidal zone of Melasti Beach. During high tide, 74 fish species comprising 488 individuals were identified, whereas 61 species and 236 individuals were recorded during low tide. The fish community exhibited moderate diversity under both tidal conditions, as indicated by Shannon–Wiener Diversity Index values of 2.44 and 2.50 for high and low tides, respectively. The Evenness Index values (0.67–0.72) indicated a stable community structure, while the low Dominance Index values (0.15–0.17) suggested the absence of species dominance.

The relationship between environmental parameters and fish abundance varied according to tidal conditions. During high tide, temperature, salinity, phosphate, and pH exhibited negative correlations with fish abundance. Temperature is among the most influential environmental variables affecting fish metabolism, distribution, and habitat utilization patterns. These findings indicate that tidal dynamics influence the interaction between environmental conditions and fish community structure in the intertidal zone.

Future studies should be conducted over longer temporal scales and incorporate seasonal variability to provide a more comprehensive understanding of the ecological processes governing fish community dynamics in intertidal ecosystems.

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