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Fish Biodiversity at Pulau Tuba and Kilim Geopark, Langkawi, Malaysia

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ABSTRACT

The continuous development of tourism, fishing and other activities in Langkawi, Malaysia have increasingly pressured the island's marine ecosystem. Monitoring the impacts is crucial for ensuring the sustainable development of the area. Fish population dynamics are widely used as an ecological indicator for assessing pollution levels and overall health of aquatic ecosystems. The objective of this research is to assess the biodiversity (richness and evenness) of fish species at Pulau Tuba and Kilim GeoPark as to evaluate the impacts of surrounding activities. This research was conducted at two locations within the waters surrounding Pulau Langkawi: Pulau Tuba and Kilim GeoPark, which were selected due to their similar coastal topology and characteristics but varying level of anthropogenic activities. The fish sampling was carried out three times at three different points in each study area. The data were analyzed using Shannon-Wiener and Simpson's diversity indices to determine the significant differences in fish species diversity between the two locations. Fish biodiversity index at Pulau Tuba was recorded at 1.52 while Kilim GeoPark was 1.32. The results indicated that the biodiversity of fishes found at Pulau Tuba is higher although it is not significantly different than at Kilim GeoPark. These suggest that anthropogenic activities may have given an impact toward the biodiversity of fish, but more data is needed to confirm the hypothesis. A continuous and more rigorous monitoring is suggested to have a more comprehensive input for policy design. The impact of surrounding activities may take some time to affect the fish dynamics, thus more direct impact such as water quality shall be recommending for future studies.

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INTRODUCTION

The Langkawi archipelago is located off the Northwest coast of Malaysia, within the state of Kedah. The natural wonders of the area, along with its emerald green waters and beautiful beaches, make it one of the most popular tourist destinations in Malaysia. Langkawi is also located within the Sundaland biodiversity hotspot, which is one of the most biologically diverse regions in the world. Other than the biodiversity richness on its land, marine ecosystems surrounding Langkawi is also a home to various species including over 500 species of coral, that support over 350 species of fish including several commercially important species such as grouper, snapper, and tuna [1]. Langkawi is envisioned as a world-class tourism destination by the local authorities. However, human-related activities can significantly impact the community characteristics of marine ecosystems [2,3,4]. Current studies have found that some species that are usually found in stressed habitat may have the ability for micropollutant clearance, thus changing water quality will impact the local fish dynamics [5]. Continuous development and increasing population of locals and tourists have caused various issues including waste and water resource management at some areas in Langkawi. Kilim GeoPark is under particular concern where the local authorities highlighted issues related to leachate runoff from the nearby landfill, which is also the only landfill for the whole Langkawi. It is anticipated that this will affect the water quality around the nearshore area and consequently may also affect the occurrence and diversity of fish. For instance, nutrient runoff including leachate from landfills may cause excessive nutrient inputs to the waterbody leading to eutrophication, promote the growth of algae and cause a hypoxic or anoxic conditions for other living creatures including fish [6]. This may later impact fishing industries that is also one of important economic drivers of Langkawi. In recent years, the global diversity of fishes has been declining dramatically under the influence of anthropogenic activities [7,8]. Meanwhile, there are also some areas around Langkawi that is less disturbed. This include coastal areas of Pulau Tuba that is the only inhabited island off the coast of main Langkawi Island. Pulau Tuba shares similar topology to the Kilim GeoPark where both are close to various water exits and estuaries and are encircled by water on all sides. It is hypothesized that the fish evenness and richness at Pulau Tuba will be higher as compared to Kilim GeoPark due to the varying level of anthropogenic activities surrounding the two areas such as island hoping and industrial activities.

Fish plays a role for determining the health of aquatic ecosystems since they are essential consumers in these systems [8,9,10]. Their presence and abundance reflect the condition of multiple trophic levels, making them sensitive to environmental changes like pollution, temperature fluctuations, and habitat degradation. Fish also bioaccumulate contaminants, providing insight into pollution levels [11]. As a result, fish populations are extensively used as ecological indicators for determining and evaluating the level of pollution and health of water bodies at various spatial scales [12]. For instance, physicochemical parameters in marine ecosystems are significant factors not only on the probability of fish surviving, but also in assessment of fish diversity [13,14,15], in order to determine the species richness and distribution [16,17]. Despite growing awareness on the issue, the specific impacts of different anthropogenic activities on fish biodiversity remain poorly understood, particularly in regions with diverse and complex ecosystems such as in Langkawi. This study aims to assess the biodiversity of fish species at Pulau Tuba and Kilim GeoPark by monitoring and evaluating the impact of anthropogenic activities.

Identifying fish species and calculating their populations are important parts of ecological studies and marine management. Traditional photographic techniques to classify fish species and count individual fish in real-time at Pulau Tuba and Kilim GeoPark.and Shannon-Weiner's index equation was applied to estimate the overall fish biodiversity at both research locations. In this study, three fish samplings were conducted during the Southwest Monsoon period from May until September 2023. During the fish sampling activities, static gill nets were used and maintained in position. The gill nets were checked at every 7-10 hours and hauled in after 24 hours [18]. The individual number of fish was recorded for each species and

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the species of fish is classified. The obtained data was analyzed using Shannon-Wiener's index and Simpson's diversity index in order to determine the significant differences between the two locations in term of biodiversity of fish. Data from this study may be used as a reference to support new and better policies related to water and waste management on the island.

METHODOLOGY

Study Area

This study was carried out in Pulau Langkawi. The research was conducted in both Pulau Tuba (99º 50'E to 6º 14'N) as shown in Figure 1(a) and Sungai Kilim at Kilim GeoPark (99º 51' E to 6º 24' E) in Figure 1(b). Pulau Tuba is a traditional fishing village. Numerous tropical fish and other marine creatures make their home in the coral reefs that encircle the island. Kilim GeoPark is a geological park in Langkawi, Malaysia. The Kilim Geopark is committed to the conservation of its one-of-a-kind natural and cultural legacy, and it is recognized as an essential location for education and research of the environment.

(a) (b)

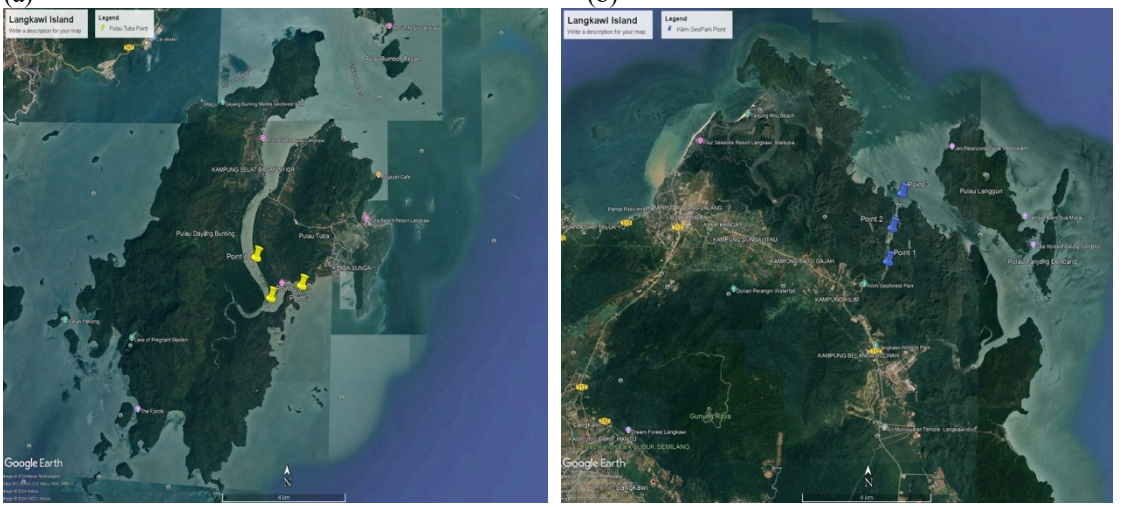

Figure 1. (a) Sampling point at Pulau Tuba, (b) Sampling Point at Kilim GeoPark

Fish Sampling

At each sampling locations, gill net with three-inch size mesh were used to collect fishes in Pulau Tuba and Kilim GeoPark. The static gill nets were maintained in position, checked at every 7-10 hours, and hauled in after 24 hours [18]. The fishes were identified to the species level and counted by using photographic method by referring to Aqmal-Naser et al. (2023) and global fish databases of FishBase [19,20]. A local guide that is also a fish expert was referred to assist in fish identification.

Statistical Analysis

Fish diversity was estimated at both locations using Shannon Diversity Index (H'), Evenness Index (J) and Dominance Index (C).

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The Shannon-Weiner index (H') was calculated using Equation 1:

$$H' = -\sum_{i=1}^{S} Pi \ ln \ Pi \quad (1)$$

Where, *H'* = Shannon-Weiner diversity index [21],
S = Number of species
Pi = n_i/N
n_i = Number of individuals of a species,
N = Total number of individuals.

Pielou's index of evenness (J) was calculated by using Equation 2:

$$J = \frac{H'}{\ln S} \quad (2)$$

Where, *J* = Pielou's evenness index [22],
H' = Shannon-Weiner diversity index,
S = Number of species.

According to Equation 3, Simpson's dominance index (C) was defined as:

$$C = -\sum \left(\frac{ni}{N}\right)^2 \quad (3)$$

Where, *C* = Simpson's dominance index [23],
n_i = Number of individuals of a species,
N = Total number of individuals.

All the data was analysed by independent t-test by using IBM SPSS software in order to determine whether the fish species were significantly different between the two locations.

RESULTS AND DISCUSSION

Figure 2 shows the total number of fish sampled at Pulau Tuba and Kilim Geopark. Pulau Tuba recorded 68 fishes while Kilim Geopark only recorded 24 fishes. Pulau Tuba site 2 recorded the highest total number of fish with 29 fishes while Pulau Tuba site 1 recorded the lowest total number of fish with 4 fishes. The average number of fish at Pulau Tuba was 22 fishes. At Kilim Geopark, Kilim site 2 recorded the highest number of fish with 13 fishes while Kilim site 3 recorded the lowest number with 5 fishes. Average number of fish at Kilim Geopark was 8 fishes at every sampling location. This data shows that Pulau Tuba has a higher number of fish compared to Kilim Geopark. This can also be compared to another study held in Jelutong, Pulau Pinang with similar anthropogenic activities which recorded a much lower number of fishes [24].

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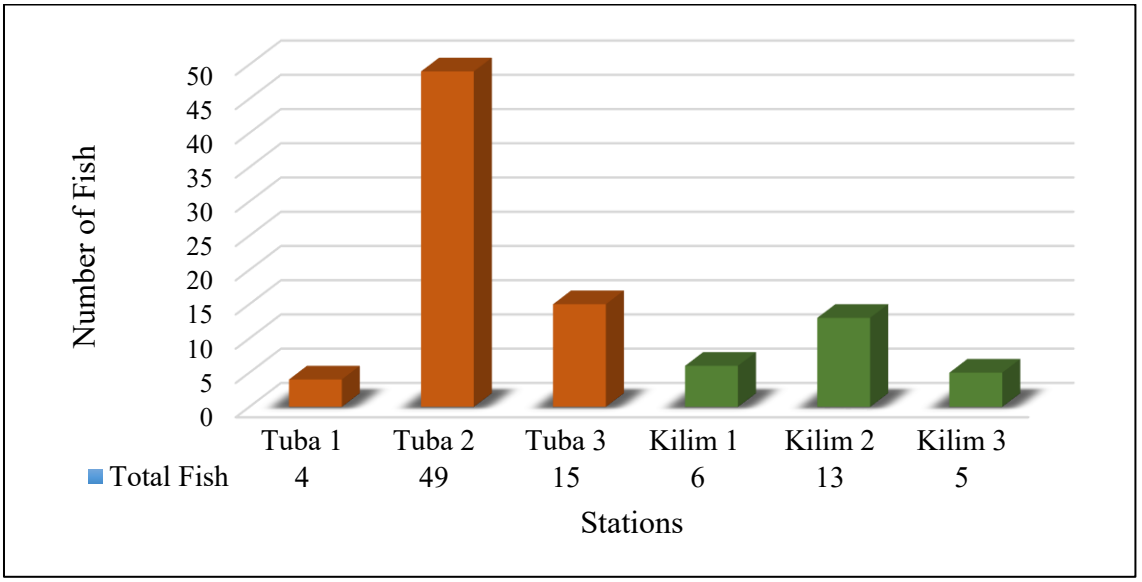

Figure 2. Total number of fish at Pulau Tuba and Kilim Geopark.

Table 1 shows the statistics for total fish at Pulau Tuba and Kilim Geopark. Pulau Tuba (22.67) recorded a higher mean than Kilim Geopark (8) and this indicates that Pulau Tuba has a higher number of total fish compared to Kilim GeoPark. The Standard Deviation (SD) for Pulau Tuba was 23.4592 while Kilim GeoPark was 4.3591. This shows that Pulau Tuba has more variation of the value compared to Kilim GeoPark.

Table 1. Statistics for total fish at Pulau Tuba and Kilim GeoPark

	Location	N	Mean	Standard Deviation	Standard Error Mean
Total Fish	Pulau Tuba	3	22.67	23.4592	13.5441
	Kilim GeoPark	3	8	4.3591	2.5174

Table 2 depicts the number of fish found in Pulau Tuba after 3 sampling occasions. Ten species of fish were found in the area. The most abundant fish species was *Acanthopagrus latus* or locally known as Yellowfin seabream. Other common species of fish sampled in the area include *Hexanematichthys sagor* and *Bagre marinus*. Some species were found in all three sampling points, while some other species could be found in only one of the sites. Only two species of fish sampled all three sites were *Gerres erythrourus* (Deep-bodied Mojarra) and *Leiognathidae sp*. [25] Based on the indices, the average Shannon Diversity index for fish in Pulau Tuba was 1.52 while the evenness index was 0.91.

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Table 2. Fish species and diversity indices of fish at Pulau Tuba

Famili	Species	Station 1	Station 2	Station 3	Total species
Polynemidea	*Eleutheronema tetradactylum*	1	0	0	1
Carangidae	*Chloroscombrus orqueta*	1	0	0	1
Gerreidae	*Gerres erythrourus*	1	3	2	6
Percoidea	*Leiognathidae sp.*	1	2	2	5
Serranidae	*Epinephelus tauvina*	0	2	0	2
Serranidae	*Epinephelus coioides*	0	3	0	3
Sciaenidae	*Genyonemus lineatus*	0	3	1	4
Sparidae	*Acanthopagrus latus*	0	16	7	23
Ariidae	*Bagre marinus*	0	11	0	11
Ariidae	*Hexanematichthys sagor*	0	9	3	12
Total fish every station		4	49	15	
Number of Species (S)					
Standard Deviation (SD)		4	8	5	2.0823
Standard Error (SE)					1.2024
Coefficient of Variation (CV)					36.7249
Shannon Diversity Index (H')		1.3862	1.78624	1.3954	
Evenness Index (J)		0.9999	0.8589	0.8670	
Dominance Index (.C)		0.0156	0.5226	0.1012	

Table 3 shows the number of fish collected from Kilim GeoPark following three sampling occasions. In total, the number of species found in the area was 10 species. Only one species *Tenualosa toli* or Chinese herring was found in all three sampling stations. As for the diversity indices, Shannon diversity index of fish in Kilim GeoPark was estimated to be 1.32 while species evenness was 0.93.

Table 3. Fish species and diversity indices of fish at Kilim GeoPark.

Famili	Species	Station 1	Station 2	Station 3	Total species
Dorosomatidae	*Tenualosa toli*	3	3	2	8
Siganidae	*Siganus javas*	1	0	0	1
Serranidae	*Epinephelus tauvina*	1	0	0	1
Lutjanidae	*Lutjanus synagris*	1	2	0	3
Dasyatidae	*Brevitrygon imbricata*	0	1	0	1
Drepaneidae	*Drepane punctata*	0	2	0	2
Haemulidae	*Pomadasys argenteus*	0	1	0	1
Polynemidea	*Eleutheronema tetradactylum*	0	4	0	4
Clariidae	*Clarias anguillaris*	0	0	2	2
Dorosomatidae	*Anodontostoma chacunda*	0	0	1	1

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Total fish every station	6	13	5	
Number of Species (S)				
Standard Deviation (SD)	4	6	3	1.5281
Standard Error (SE)				0.8822
Coefficient of Variation (CV)				35.2910
Shannon Diversity Index (H')	1.2425	1.6716	1.0549	
Evenness Index (J)	0.8962	0.9329	0.9602	
Dominance Index (.C)	0.0469	0.0274	0.4198	

A comparison of the Shannon Diversity Index between Pulau Tuba (1.52) and Kilim GeoPark (1.32), shows that Pulau Tuba may have a higher species richness. However, since species evenness in Pulau Tuba (0.91) is slightly lower than Kilim GeoPark (0.93), the difference in fish bio6666diversity between the two sites appear to be insignificant. This was supported by the independent t-test which showed that $p > 0.05$ that rejects the hypothesis where the fish biodiversity of Pulau Tuba is significantly higher than Kilim GeoPark.

In terms of family of fish, only two families of fish that is Serranidae and Polynemidea can be found at both Pulau Tuba and Kilim GeoPark showing the big variation of fish between two sites. This can also be compared to other studies in the Western part of Langkawi, where both family of fish were not found, while the most commonly found fish is *Devario regina* from Cyprinidae family [9, 25]. It shows a heterogeneity of fish between different location around Langkawi Island that is interesting to be studied.

CONCLUSION

In conclusion, the biodiversity of fish at Pulau Tuba is slightly higher than Kilim GeoPark although not statistically significant. It is believed that there is a need for continuous monitoring that would cover widest area and include more empirical data to support the findings. The waste management and anthropogenic activities including from tourism (island hoping, jet ski tours) and fishing industries (recreational and commercial) might have delayed impacts on the fish population dynamic. Although this study may not have enough evidence to support the hypothesis of human impacts to fish biodiversity, it has provided some baseline for future reference. For future studies, it is recommended that water quality parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO) and human activity metrics, e.g., the number of tourists, fishing pressure and proximity to development in order to provide a more empirical analysis to the information. Monitoring of fish biodiversity should also be conducted continuously for a better policy design.

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AUTHOR'S CONTRIBUTION

Khairunnisa Ahmad Kamil: Analyzed and interpreted the data; Supervised research progress; Wrote the paper. Jamil Tajam: Designed and planned the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tool; Supervised research progress. Mohamad Najmuddin Mohd Sairi: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare absence of conflicting interests with the funders.

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