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FISH DIVERSITY IN THE MANGROVE RESERVE AREA OF UNIVERSITI MALAYSIA TERENGGANU (UMT)

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Abstract: A research expedition evaluates the current fish diversity and abundance in the "UMT mangrove reserve area - UMT-MRA". Four-sampling survey trips were conducted at three stations on the UMT-MRA, where fish samples were caught using gill nets, traps, and scoop nets. In situ water quality parameters were recorded while one litre of water was collected from each site for nutrients and chlorophyll analysis. Fish community/ environment relationships were evaluated using Pearson Correlation Analysis. A total of 109 fish, representing 19 species from 15 families were captured during the expedition. The most dominant families by species number were Gobiidae (15.8%), followed by Ambassidae and Cichlidae (10.5%). 12 families recorded only one species (5.3%) each. *Aplocheilus panchax* (18.3%), *Terapon jarbua* (13.8%), and *Ophiocara porocephala* (11.9%) were the most abundant species. 10 commercially valuable species were identified and *Oreochromis niloticus* was categorised as "Vulnerable" (VU) on the IUCN Red List. 15 species were labelled Least Concern (LC) and three were not evaluated (DD). No significant differences among stations were found in water quality parameters, nutrients, and chlorophyll, suggesting minimal influence of abiotic factors. In conclusion, this area is crucial for maintaining a diverse mangrove ecosystem, requiring urgent conservation efforts. More research is needed to understand its significance as a fish-feeding and breeding habitat.

Keywords: Fish, teleost, diversity, population, intertidal, brackish.

Introduction

Universiti Malaysia Terengganu (UMT) campus at Mengabang Telipot, Kuala Nerus, Terengganu, Malaysia has a large patch of untouched coastline mangrove forest and is known as "UMT mangrove reserve area (UMT-MRA)". This area is predominantly a coastal mangrove forest and water levels are affected by the tidal cycle from the South China Sea. According to Badli-Sham *et al*. (2019), UMT-MRA consists of over 13 tree species and becomes a habitat, feeding area and breeding ground for various terrestrial fauna, including mammals, reptiles, and amphibian species, as well as for aquatic species such as fish, prawns, shrimp, crab, and shellfish. Therefore, UMT-MRA not only acts as the frontline of protection against giant waves and storms, but it also serves as a teaching and learning natural site for UMT's students to learn the functionality of a healthy mangrove ecosystem, including their nature, diversity, and sustainability. However, the increasingly widespread development activities carried out on the UMT campus have, to some extent, disturbed the ecosystem stability in UMT-MRA. Urbanisation significantly alters the ecosystem, establishing a building facility for an organisation (Merckx *et al*., 2018).

Most aquatic animals are sensitive to habitat modification, thus, making them susceptible to continuous urbanisation. The biodiversity loss caused by damage to habitat and changing environmental climate due to urbanisation has led to competition between inter- and intra-species, hence, resulting in the extinction of minorities in that ecosystem or inviting the presence of invasive species (Adla *et al*., 2022). Therefore, to support sustainable development for their conservation, a four-time field survey of the fish community in the UMT-MRA and its ecological aspects was carried out.

To ensure that fish diversity in an ecosystem is conserved, the checklist of fish species must be updated continuously (Ramli & Hazaman, 2021). A survey on fish diversity and abundance in UMT-MRA was last reported in 2010. Faizal (2005) reported that *Liza subviridis* and *Mystus gulio* were the dominant species captured, whereas *Channa striata*, *Oreochromis mossambicus*, *Gerres silaceus*, and *Selar* sp. were among the lowest number of individuals sampled in this area.

Malidus (2007) conducted a pre-monsoon survey, where 11 species were identified and reported that varies of species found such as *L. subviridis* (n = 22), *Trichogaster trichopterus* (n = 16), *Arius* sp. (n = 10), *Ambasis* sp. (n = 7), *Megalops cyprinoides* (n = 7), *Tetraodon leiurus* (n = 7), *Terapon jarbua* (n = 7), *Gerres* sp. (n = 6), *Oxyeleotris marmorata* (n = 6), *Glossogobius* sp. (n = 5), and *Caranx* sp. (n = 3). In 2007, Zainuddin (2007) focused on identifying fish species from the families Gobiidae and Eleotridae. The study reported the following seven species from the Gobiidae family, which were *Favonogobius reichei*, *Psammomatous biocellatus*, *Pseudogobius iavanicus*, *Schismatogobius borneensis*, *Schismatogobius pleurostigma*, *Periophthalmus walailakae*, and *Pomatoschistus minutus* from the family, whereas only *O. marmorata* was reported for the Eleotridae family. Such diversity has been found in this area since 2007.

Another study had been conducted on stomach content analysis of 21 fish species caught in the swamp of UMT (Nazirah, 2008). Nazirah (2008) stated that the fish feeding habits indicate that each species of fish tends to choose more than one food item in the diet, therefore, it is assumed that the variables of the mangrove swamp estuary area with high productivity and local factors influence eating habits. Another study by Mohd-Nor (2010) reported 19 fish species in the UMT mangrove. It is necessary to conduct another expedition to record the current diversity status.

As the UMT campus continuously undergoes development of facilities, it is an opportune time to record the variety of fish species and estimate the significance of preserving UMT-MRA as a green area that functions as a protective measure against the impact of campus urbanisation on the local fish biodiversity around the campus. The main objective of this study is to determine the current fish diversity and abundance status in the UMT-MRA as updated information for their conservation efforts, habitat management, and understanding the complex relationships in this unique and treasured environment. The conducted fish diversity study will help in recognising threatened species that demand protection, developing comprehension of the well-being and role of the mangrove ecosystem, understanding the unique interactions between fish and their ecology, sustainability in fisheries management, assessing the resilience to climate change, and providing adjustable management strategies to sustain the ecosystem services.

Materials and Methods

Location of Study

This survey expedition was conducted at the mangrove reserve area, starting from the "Jalan Biawak" water inlet to the upstream river at the

UMT campus. The three stations were identified (Figure 1 and Figure 2) and intensively sampled four times, i.e., (i) 16 March 2023, (ii) 22 March 2023, (iii) 13 April 2023, and (iv) 9-10 May 2023, using gill nets, traps, and scoop nets. The sampling stations were recorded with a GPS and mapped with the Arc-Map GIS 14.0 software. The description of the characteristics of each station is shown in Table 1.

Samples Collection and Measurement

The gill nets used for this expedition were sized in 1-inch mesh size, 6.0 m long, and 1.5 m deep. Gill nets were deployed at high tide and pulled before the low tide. Fishing traps with an umbrella shape, measuring 0.5 cm mesh size, 8 holes, 60 cm diameter, and 25 cm height were used with fish and coconut flesh as baits to attract fish. All the fish collected were subjected to image capturing using a smartphone camera with 48 MP (Redmi) and the biometrics of each specimen were measured in situ for their total length (cm). Immediately after measurement, all specimens were released back to the sampling site to avoid any handling injury or loss of the specimens. Fish samples representing each species were brought back to the laboratory for photography purposes.

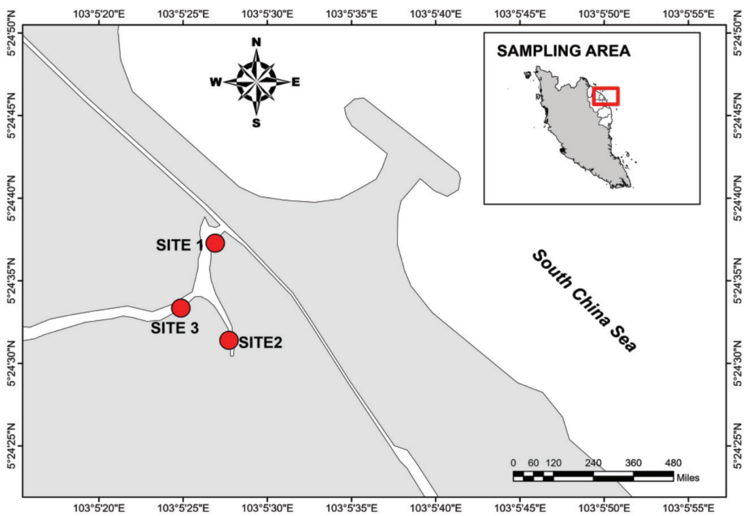


Figure 1: The location of three stations (Station 1, Station 2, and Station 3) at the UMT mangrove reserve area

Figure 2: Three stations in UMT mangrove reserve area (UMT-MRA) - Station 1 (a), Station 2 (b), and Station 3 (c)

Table 1: Description of characteristics of each station in the UMT mangrove reserve area (UMT-MRA)

Station	**Locality**	**Characteristics**			
		Depth (m)	**Flow Velocity**	**Bottom Types**	**Vegetation**
Station 1	Jalan Biawak (Northern part) (N 5^{0}24’36.767” E 103^{0}05’26.177”)	0.1 – 2.0	Fast	Sand and mud	Mangrove tree, nipah, shrubs, and other trees
Station 2	Near mosque (Middle part) (N 5^{0}24’32.645” E 103^{0}05’23.501”)	0.5 – 1.5	Steady	Muddy	Mangrove tree, nipah, shrubs, and other trees
Station 3	Near library (Southern part) (N 5^{0}24’32.700” E 103^{0}05’23.401”)	0.5 – 1.5	Steady	Muddy	Mangrove tree, nipah, shrubs, and other trees

In the laboratory, fish samples were observed, sorted, counted, identified, photographed, and preserved. Prior to fixation, fish samples were euthanised humanely by immersion in an ice slurry following standard ethical procedures. The procedure of fixation, photographing, and preservation of the specimen follows procedures by Motomura and Ishikawa (2013). All fish were counted and identified according to species using available taxonomic keys (Carpenter & Niem, 1999-2001; Matsunuma *et al*., 2011). After identification, all the fish were selected, assigned individual tagging numbers, and measured for Total Length (TL) and weight to the nearest 1 mm and 0.01 g, respectively. The length and weight were measured using a digital calliper (Mitotoyo: 500-197-200 CD- 8”) and ruler board. The weight was measured using a portable electronic balance (Ohaus Scout Pro: Model SPS 4001 - 4,000 X 0.1 g Capacity) and an electronic crane scale (AccuTEC: Model GSE 08526). The fish were fixed in 10% formalin solution and preserved in 70% alcohol. Specimens of each species were deposited in the collections of the South China Sea Repository and Reference Centre (RRC), Institute of Oceanography and Environment (INOS), Universiti Malaysia Terengganu.

Water Quality and Chlorophyll a Measurement

Water quality analyses were performed in situ by using the YSI multiprobe Pro Plus to determine temperature, Dissolved Oxygen (DO), salinity, and pH. While for nutrient analysis, triplicate samples of 1 L of water were collected from each sampling site. Nutrient concentrations such as ammonia, nitrite, and phosphate were measured using a Shimadzu UV-1800 UV-Vis spectrophotometer. Nutrient concentrations were determined using the phenol and cadmium reduction method described in the Pearson 1984 protocol (APHA 2012).

Chlorophyll *a* in water was determined using a modified USEPA Method 446.0 (Arar, 1997). Phytoplankton containing chlorophyll in the measured amount of sampled water was enriched by low vacuum filtration through glass fibre filters. Pigments were extracted from phytoplankton in 90% acetone using an ultrasonic bath and soaked for a minimum of 2 hours and a maximum of 24 hours for complete pigment extraction. The filter slurry was centrifuged at 675 g for 15 minutes (or 1,000 g for 5 minutes) to clarify the solution. An aliquot of the supernatant was transferred to a glass cell and absorbance was determined at four wavelengths (750 nm, 664 nm, 647 nm and 630 nm) to measure turbidity, chlorophyll *a*, *b* and *c*1+*c*2, respectively. If pheopigment-corrected chl-a was preferred, the absorbance of the sample is measured at 750 nm and 664 nm before acidification and at 750 nm and 665 nm after acidification with 0.1 N HCl. The absorbance values are entered into a set of equations that simultaneously calculate the pigment concentration in the mixed pigment solution using the extinction coefficient of the pure pigment in 90% acetone. Chlorophyll Stock Standard Solution were used for quality assurance (Grace Analytical Lab, 1995). Concentrations are given in mg/L (ppm).

Data Analysis

The conservation status of all fish species was determined based on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species 2025 and had the following threat categories: (1) Extinct (EX), (2) Extinct in the Wild (EW), (3) Critically Endangered (CR), (4) Endangered (EN), (5) Vulnerable (VU), (6) Near Threatened (NT), (7) Least Concern (LC), (8) Data Deficient (DD), and (9) Not Evaluated (NE).

Index diversity was calculated in terms of Shannon-Wiener (H’) Diversity Index (Shannon & Weaner, 1989), Pielou’s Evenness Index (J’) (Pielou, 1977), and Margalef’s Species Richness Index (D’) (Margalef, 1958) as a whole ecosystem and for each station. An index of diversity is a numerical statistic that indicates the number of unique species present in a community (Tucker *et al*., 2017). Fish were identified as a commercial fish by using Fishbase. Commercial fish was a term used to describe fish species with considerable economic worth (Froese & Pauly, 2023).

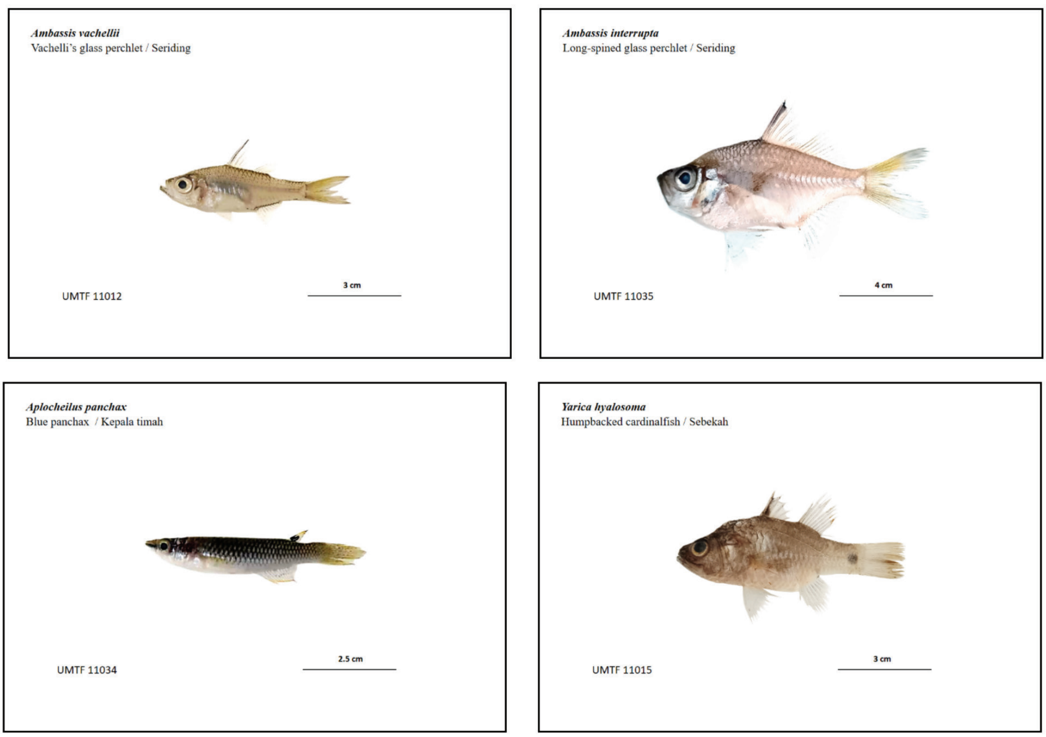
Statistical comparison was performed using Python. One-way analysis of variance (ANOVA) was used for water quality parameters (temperature, dissolved oxygen, pH, salinity, TDS), nutrients (ammonia, nitrite, phosphate), and chlorophyll (chl *a*, chl *b*, and chl *c*) to calculate the existence of differences among the stations. Fish community/environment relationships were evaluated using Pearson Correlation Analysis.

Results and Discussion

Species Composition and Diversity

The survey encompassed four sampling events at three distinct stations, which were downstream (Station 1), midstream (Station 2), and upstream (Station 3). A total of 109 fish were collected during the survey, which represented 19 species from 15 families (Figure 3). The checklist of fish caught from all stations, including family/species name, common name, local name, size range, total number of each species, and percentage abundance of each species is listed in Table 2. The number of species collected was similar to the previous data reported by Faizal (2005) and Mohd-Nor (2010), who recorded the data of species captured, 18 and 19 species, respectively, of fish around the Universiti Malaysia Terengganu area. In contrast, the previous study by Nazirah (2008) recorded UMT-MRA levels that were higher in 33 fish species from 25 families. Only three species have been found in all three stations: *Ophiocara porocephala* (Ubi belontok), *Glossogobius aureus* (Gobi), and *Terapon jarbua* (Kerong).

The number of fish species recorded in UMT-MRA was lower compared to previous studies found in Malaysia. According to Siti-Tafzil Meriam *et al*. (2017), 116 fish species were recorded in the mangrove of Setiu Wetlands, Terengganu while 114 fish species were recorded at Klang mangrove, Selangor (Chong *et al*., 2005); 91 fish species were recorded at Langkawi mangrove (Chong *et al*., 2005); and 47 fish species at Semerak estuary and adjacent inshore waters, Kelantan (Chong *et al*., 2010). In contrast, the previous study by Arshad *et al*. (2006) recorded a low of 22 fish species at Merchang Lagoon, Terengganu. However, in those studies, the researcher used different areas and a long period, which might cause different results compared to this study.



Ophiocara porocephala
Northern mud gudgeon / Ubi belontok

UMTF 11022 — 3 cm

Channa striata
Striped snakehead / Haruan

UMTF 11030 — 7 cm

Oreochromis niloticus
Tilapia hitam

UMTF 11024 — 5 cm

Etroplus suratensis
Pearlspot, Green chromide

UMTF 11007 — 5 cm

Glossogobius aureus
Golden goby / Ubi puntong

UMTF 11019 — 4 cm

Pseudogobius poicilosoma
Goby

UMTF 11025 — 1.5 cm

Stigmatogobius pleurostigma
Goby, Peach Knight Goby

2.5 cm

Lates calcarifer
Barramundi, Asian Sea bass / Siakap

UMTF 11027 — 7 cm

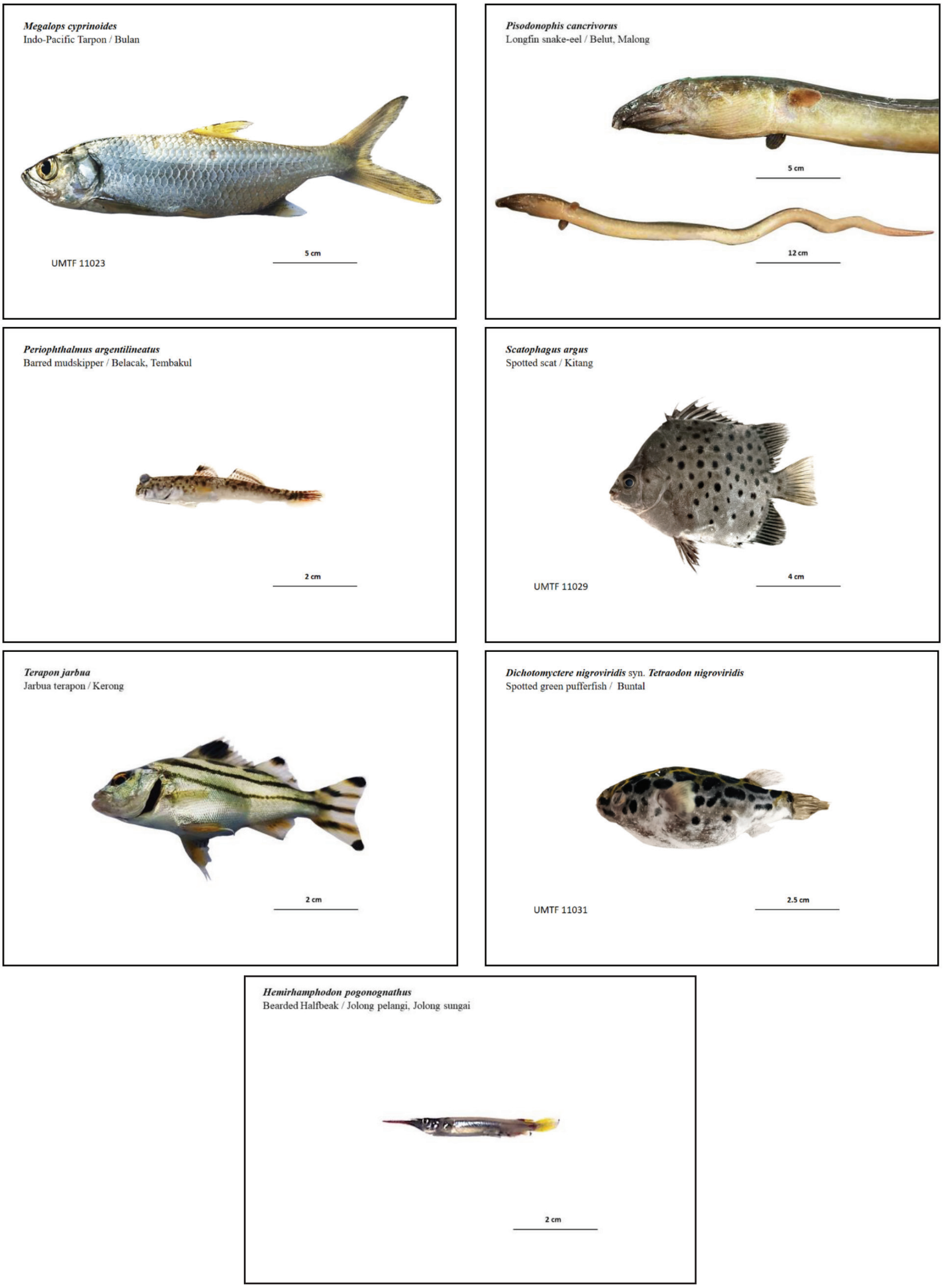


Figure 3: Plates of fish caught throughout this survey consist of 19 species from 15 families

The most dominant families in terms of the number of species were Gobiidae (three species; 15.8% of the total species), followed by Ambassidae and Cichlidae with two species (10.5% of the total species), respectively. 12 families were recorded with only one species (5.3% of the total species) per family (Figure 4; Table 2). This was similar to Nazirah (2008), which also had dominant species with Gobiidae and other family members, Mugilidae and Osphronemidae sharing three fish species. In contrast to Faizal (2005) and Mohd-Nor (2010), the families Butidae, Gerreidae, Latidae, and Mugilidae. Matsunuma *et al*. (2011) stated that the gobies were found in various habitats from torrential freshwater rivers to shelf waters, but were most common in brackish waters and shallow coastal waters. Some gobies may remain in the mangrove at low tide, some may leave their burrows and be caught at high tide. In addition, Blaber *et al*. (1997) noted that gobies are a large component of larval fish assemblages in most tropical estuaries.

Among the observed fish species, *Aplocheilus panchax* (Kepala timah) had the highest number of individuals caught, with a total of 20 individuals (18.3% of the total individuals) recorded (Figure 5; Table 2) and followed by *Terapon jarbua* (Kerong), which had 15 individuals (13.8% of the total individuals) captured. *Ophiocara porocephala* (Ubi belontok) ranked as third in abundance, with 13 individuals (11.9% of the total individuals). *Ambassis vachellii* (Seriding) and *Glossogobius aureus* (Gobi) were each represented by nine individuals (8.3% of the total individuals), followed by *Ambassis interrupta* (Seriding) and *Dichotomyctere nigroviridis* (Buntal) and had seven individuals (6.4% of the total individuals), *Pseudogobius poicilosoma* (Gobi) and *Periophthalmus argentilineatus* (Belacak) had six individuals (5.5% of the total individuals), *Stigmatogobius pleurostigma* (Gobi) and *Hemirhamphodon pogonognathus* (Jolong pelangi) had four individuals (3.7% of the total individuals), *Lates calcarifer* (Siakap putih) had two individuals (1.8% of the total individuals), and other seven species were represented only one individual (0.9% of the total individuals).

Aplocheilus panchax (Kepala timah) had the most individuals caught among the observed fish species, followed by *Terapon jarbua* (Kerong) and *Ophiocara porocephala* (Ubi belontok). *Aplocheilus panchax* (Kepala timah) frequently moves in groups while hunting for insects and mosquito larvae on the water's surface (Parenti, 1999). This species has been caught more frequently with scope nets along the riverbank in Station 1 while the others stations have no riverbank. While different from the two species that can be found in all stations, *Terapon jarbua* (Kerong) and *Ophiocara porocephala* (Ubi belontok) are notable.

There are a few additional species in this area to compare with other studies such as *Ambassis vachellii* (Seriding), *Channa striata* (Haruan), *Etroplus suratensis* (Pearlspot), *Glossogobius aureus* (Gobi), *Stigmatogobius pleurostigma* (Gobi), *Pisodonophis cancrivorus* (Malong), *Periophthalmus argentilineatus* (Belacak), and *Hemirhamphodon pogonognathus* (Jolong pelangi). This survey recorded that most family and fish species found in UMT-MRA are primarily freshwater and brackish species from amphidromous, potamodromous, and anadromous migration types. Amphidromous fish are born in freshwater or estuaries, migrate to the sea as larvae, and then return to freshwater to develop and spawn. Potamodromous fish live and move entirely in freshwater. Anadromous fish, on the other hand are born in freshwater, migrate to the ocean as juveniles, mature, and then return to freshwater to spawn (Froese & Pauly, 2023).

However, 29 fish species from earlier studies are not present in this survey, including the families of the Carangidae, Chanidae, Mugilidae, and others. The majority of these are marine and brackish species. According to Gibson (1988), the spatial scales across which fish migrate during their intertidal movements are influenced by several factors, including their residential status. Resident intertidal species reside within the intertidal zone and do

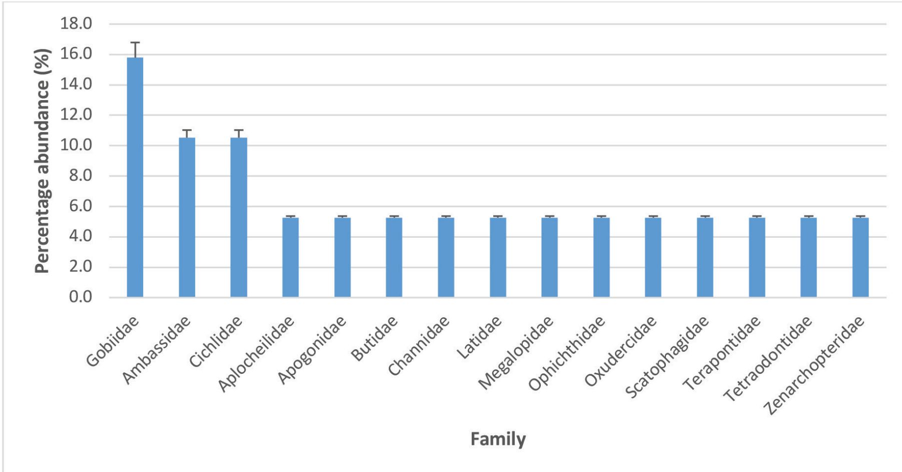


Figure 4: Percentage of fish family abundance in the UMT mangrove reserve area (UMT-MRA)

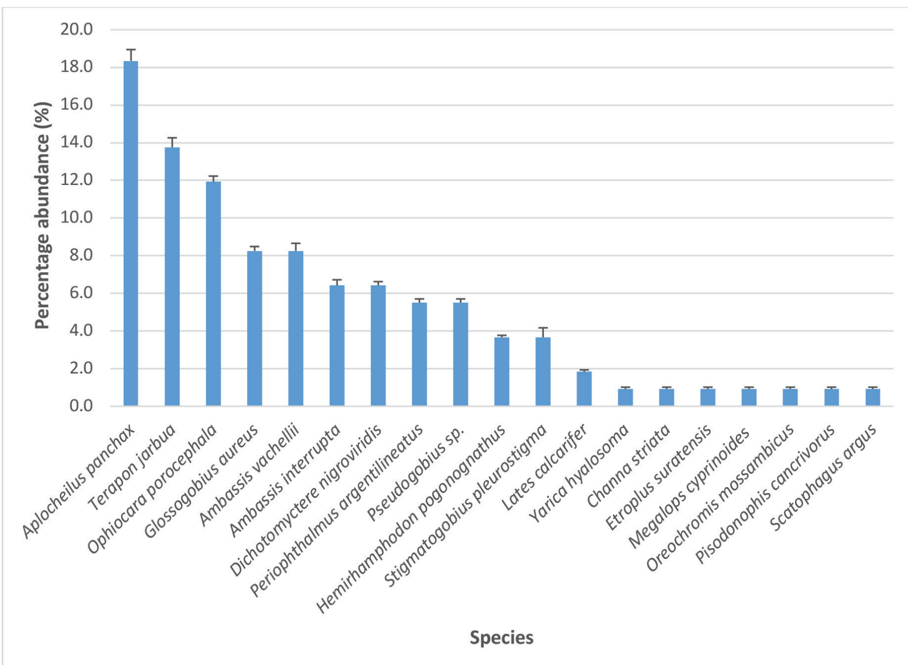


Figure 5: Percentage of species abundance in the UMT mangrove reserve area (UMT-MRA)

not travel far. Several elements, including the sampling method, equipment, types, period, environmental conditions, and season when sampling, contribute to the decline in fish species. This may be caused by the fact that the diversity of these areas has changed over the past 13 to 15 years since the previous study, as well as by the fact that sampling occurred at a different season and at a different time.

The selection of gears used by Nazirah's (2008) study was gill nets, seine nets, cast nets, and scoop nets while in this survey, gill nets, traps, and scoop nets were used. There is also a difference in mesh size between cast nets and gill nets, which results in a different composition of fish collected. The various sampling gear utilised, according to, was the reason for the different species obtained. Another explanation is that there have been numerous advancements and developments in UMT recently, those developments have had a significant impact on the UMT-MRA ecosystem. Fish populations are rapidly declining in both number and species. The majority of the mangrove area on this site has been destroyed. This area is vital to the ecosystem and substantial action is required to conserve it due to its high biodiversity values. Further research should be conducted on frequent sampling using improved sampling equipment to determine the diversity of fish in the UMT area.

The fish species that can be viewed from the sampling were 10 species caught and considered to be commercially valuable species, as listed in Table 2. The observation of the commercial value of fish species was referred to in Fish Base (2025). The fish species that hold high economic values were *Channa striata* (Haruan), *Oreochromis niloticus* (Tilapia hitam), and *Lates calcarifer* (Siakap putih) (Table 1).

Among these, only one species was recorded as "Vulnerable" (VU) on the IUCN Red List, which is *Oreochromis niloticus* (Tilapia hitam), 15 species were listed as Least Concern (LC), and the other three species have not been evaluated and are Data Deficient (DD) (Table 2).

Species Composition and Diversity by Sampling Stations

The distribution of fish species varied across the three sampling stations, as summarised in Table 2. The highest number of fish species collected was recorded at Station 1 with 12 species, followed by Station 2 (10 species) and Station 3 (5 species). *Ophiocara porocephala* (Ubi belontok), *Glossogobius aureus* (Gobi), and *Terapon jarbua* (Kerong) were the most dominant in all three stations (Table 2).

At the downstream station (Station 1: The entrance), a total of 77 fish were caught, representing 12 different species from nine families, namely Ambassidae, Aplocheilidae, Apogonidae, Butidae, Gobiidae, Ophichthidae, Oxudercidae, Terapontidae, and Zenarchopteridae. Station 1 was dominated by *Aplocheilus panchax* (Kepala timah) with a high percentage abundance at 26.0%, followed by *Terapon jarbua* (Kerong) (13.0%), *Ambassis vachellii* (Seriding) (11.7%), and other species with less than 10.0% abundance. Other species such as *Ambassis interrupta* (Seriding), *Ambassis vachellii* (Seriding), *Aplocheilus panchax* (Kepala timah), *Yarica hyalosoma* (Sebekah), *Hemirhamphodon pogonognathus* (Jolong pelangi), *Periophthalmus argentilineatus* (Belacak), *Pisodonophis cancrivorus* (Malong), and *Pseudogobius poicilosoma* (Gobi) have only been found in the first sampling station (Figure 6). Over 20 species were derived from the family Aplocheilidae, 16 species from the family Ambassidae, six species from the family Gobiidae and Oxudercidae, four species from the family Zenarchopteridae, and one species from Apogonidae and Ophichthidae, respectively.

While the midstream station (Station 2: Mosque) yielded 16 captured fishes comprised of 10 species from nine families, including Butidae, Channidae, Cichlidae, Gobiidae, Latidae, Megalopidae, Scatophagidae, Terapontidae, and Tetraodontidae, at Station 2, high percentage abundance was *Glossogobius aureus* (Gobi) (25.0%), followed by *Dichotomyctere nigroviridis* (Buntal), *Lates calcarifer* (Siakap putih), and *Terapon jarbua* (Kerong) (12.5%), respectively. The other six species (6.25%) were *Channa striata* (Haruan), *Etroplus suratensis* (Pearlspot), *Megalops cyprinoides* (Bulan), *Ophiocara porocephala* (Ubi belontok), *Oreochromis niloticus* (Tilapia hitam), and *Scatophagus argus* (Kitang). Six species, in particular *Channa striata* (Haruan), *Etroplus suratensis* (Pearlspot), *Lates calcarifer* (Siakap putih), *Megalops cyprinoides* (Bulan), *Oreochromis niloticus* (Tilapia hitam), and *Scatophagus argus* (Kitang) were only found

Table 2: List of fish species caught from the UMT mangrove reserve area (UMT-MRA)

Family/Species Name	English Name	Local Name	Voucher #UMTF	Size (cm)	Station 1	Station 2	Station 3	Total No. of Fish/ (%) of Fish	Global Status (IUCN 2022)
Ambassidae									
Ambassis vachellii	Vachelli's glass perchlet	Seriding	UMTF 11012	5.3 – 6.3	9	-	-	9/8.3	LC
*Ambassis interrupta**	Long-spined glass perchlet	Seriding	UMTF 11035	6.5 – 7.0	7	-	-	7/6.4	LC
Aplocheilidae									
*Aplocheilus panchax**	Blue panchax	Kepala timah	UMTF 11034	3.9 – 7.8	20	-	-	20/18.3	LC
Apogonidae									
Yarica hyalosoma	Cardinalfish	Sebekah	UMTF 11015	2.6	1	-	-	1/0.9	NE
Butidae									
Ophiocara porocephala	Northern mud gudgeon	Ubi belontok	UMTF 11022	3.7 – 11.6	6	1	6	13/11.9	LC
Channidae									
*Channa striata***	Striped snakehead	Haruan	UMTF 11030	31.2	-	1	-	1/0.9	LC
Cichlidae									
*Oreochromis niloticus***	Nile tilapia	Tilapia hitam	UMTF 11024	18.3	-	1	-	1/0.9	VU
*Etroplus suratensis**	Pearlspot	Tilapia	UMTF 11007	16.4	-	1	-	1/0.9	LC
Gobiidae									
Glossogobius aureus	Goby	Gobi	UMTF 11019	6.9 – 16.0	4	4	1	9/8.3	LC
Pseudogobius poicilosoma	Goby	Gobi	UMTF 11025	2.8 – 4.1	6	-	-	6/5.5	LC
Stigmatogobius pleurostigma	Peach Knight Goby	Gobi	-	3.5 – 6.7	3	-	1	4/3.7	NE
Latidae									
*Lates calcarifer***	Barramundi	Siakap putih	UMTF 11027	26.5 – 31.3	-	2	-	2/1.8	LC

Megalopidae									
*Megalops cyprinoides**	Indo-Pacific tarpon	Bulan	UMTF 11023	27.8	-	1	-	1/0.9	DD
Ophichthidae									
*Pisodonophis cancrivorus**	Longfin snake-eel	Belut, malong	-	99.1	1	-	-	1/0.9	LC
Oxudercidae									
Periophthalmus argentilineatus	Barred mudskipper	Belacak	-	4.3 – 8.1	6	-	-	6/5.5	LC
Scatophagidae									
*Scatophagus argus**	Spotted scat	Kitang	UMTF 11029	10.2	-	1	-	1/0.9	LC
Terapontidae									
*Terapon jarbua**	Jarbua terapon	Kerong	-	4.4 – 8.8	10	2	3	15/13.8	LC
Tetraodontidae									
Dichotomyctere nigroviridis	Spotted green pufferfish	Buntal	UMTF 11031	6.6 – 7.8	-	2	5	7/6.4	LC
Zenarchopteridae									
Hemirhamphodon pogonognathus	Halfbeaks	Jolong pelangi	-	4.1 – 5.0	4	-	-	4/3.7	LC
Total family for each station					9	9	4		
Total family for all stations								15	
Total species for each station					12	10	5		
Total species for all stations								19	
The total no. of the same species occurs in all stations								3	
Total individuals for each station					77	16	16		
Total individuals for all stations								109	

Note: **Highly Commercial Species; *Minor Commercial Species (Froese & Pauly, 2023)
Station: Station 1: Downstream (the entrance); Station 2: Midstream (mosque); Station 3: Upstream (library)
IUCN Red List Status: VU = Vulnerable; LC = Least Concern; DD = Data Deficient; NE = Not Evaluated

in Station 2 (Figure 7). Two species were derived from the family Latidae and Cichlidae and one species from the family Channidae, Megalopidae, and Scatophagidae.

In addition, at the upstream station (Station 3: Library), a total of 16 fish were caught that represented five species from four families: Butidae, Gobiidae, Terapontidae, and Tetraodontidae. Station 3 showed that a high percentage abundance was *Ophiocara porocephala* (Ubi belontok) (37.5%), followed by *Dichotomyctere nigroviridis* (Buntal) (31.25%), *Terapon jarbua* (Kerong) (18.75%), and both species *Glossogobius aureus* (Gobi) and *Stigmatogobius pleurostigma* (Gobi) were 6.25%, respectively (Figure 8).

Based on the sampling at three stations, Station 1 and Station 2 recorded about the same number of families. Station 1 has more species than Station 2. However, the difference is only two species. 12 species from 77 individuals were recorded in Site 1 while 10 species from 16 individuals were recorded in Site 2 throughout this survey. Since both stations are located downstream (at the entrance) and midstream (at the mosque). The flow of water is fast downstream of the swamp while slow upstream of the swamp.

The water in the surveyed region of the UMT-MRA is hazy and its amount is influenced by the tides of the seawater, which cause the water level to rise when the seawater enters the swamp and to fall when the seawater recedes. The decrease in fish species and individuals at Station 3 is attributed to this factor. The large number of fish collected at Site 1 might be due to its location. Site 1 was a transition zone between seawater and freshwater.

Invasive species such as *Oreochromis niloticus* (Tilapia hitam), *Etroplus suratensis* (Pearlspot), and *Trichopodus pectoralis* (Siam sepat) are also contributing to the decline of fish species in the UMT-MRA. Invasive or alien species are regarded as one of the most serious threats to biodiversity across all ecosystems, with the largest impact projected in freshwater lakes and rivers (Sala *et al*., 2000). Globalisation and increased trade and tourism create greater opportunities for fish species to spread both intentionally and unintentionally (Rahim *et al*., 2013). According to Rahim *et al.* (2013), this effect could place a significant strain on the population and diversity of aquatic organisms, notably native fish fauna.

Another explanation is that there have been numerous advancements in UMT recently and those developments have had a significant impact on the environment. Fish populations are rapidly declining in both number and species. The majority of the mangrove area on this site has been destroyed due to a combination of anthropogenic activities such as human development and natural factors like monsoon effects. This area is vital to the ecosystem and

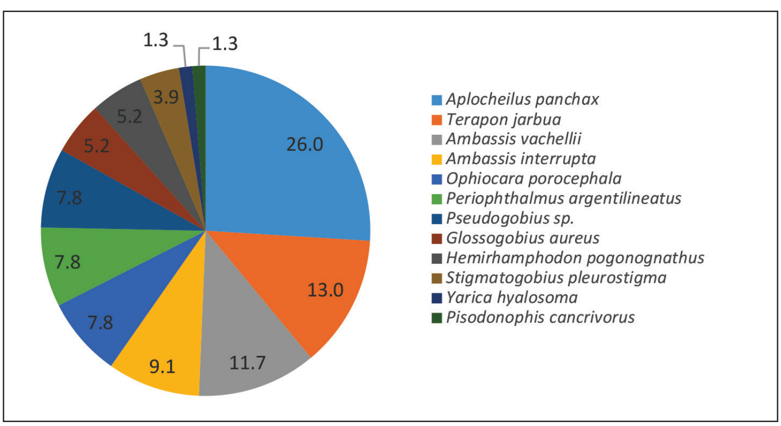


Figure 6: Percentage abundance of fish species in Station 1 in the UMT mangrove reserve area (UMT-MRA)

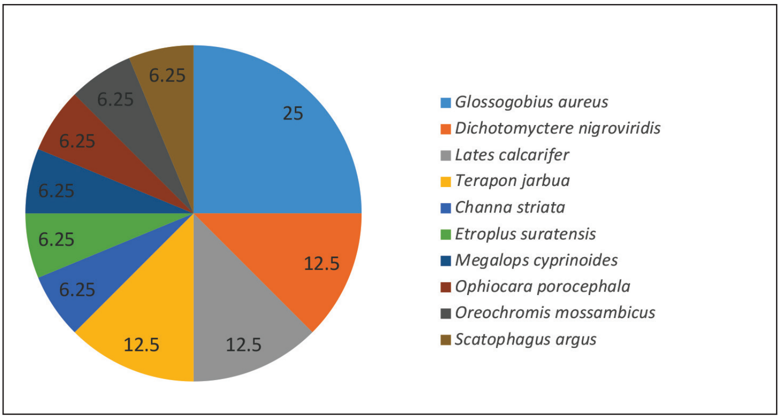


Figure 7: Percentage abundance of fish species in Station 2 in the UMT mangrove reserve area (UMT-MRA)

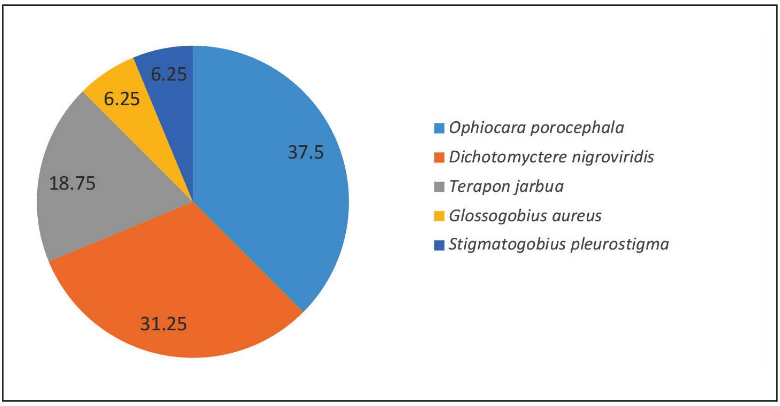


Figure 8: Percentage abundance of fish species in Station 3 in the UMT mangrove reserve area (UMT-MRA)

substantial action is required to conserve it due to its high biodiversity values. Further research should be conducted on the frequently used improved sampling equipment to determine the diversity of fish in the UMT area.

Diversity Indices Value

The calculation of diversity indices is important for measuring attributes of fish community structure. Overall diversity index values of Shannon-Weiner Diversity Index (H'), Margalef Species Richness Index (D'), and Pielou (J') Evenness Index were determined to be 2.54, 18.79, and 0.86, respectively. The H index classified the fish community in the UMT-MRA as intermediate, indicating that it is neither very low nor very high in diversity (Shannon & Wiener, 1989). Table 3 shows the value of estimated ecological indices.

From the analysed data, Station 1 showed higher index values for the Shannon-Weiner Diversity Index (H') (2.23) and the Margalef Species Richness Index (D') (11.77) than the other two stations. The Pielou (J') Evenness Index value was higher in Station 2 compared to Stations 1 and 3. Station 1 had a higher rating since it had straightened tidal channels, a larger area than the other stations, and numerous mangrove trees. Mangrove ecosystems support higher species diversity by providing complex habitats, stabilising water flow, and offering shelter and food resources for aquatic organisms (Mulya *et al*., 2021). As a result, the flow of water is fast in Station 1 of the swamp and slow in Station 3. The structural complexity of mangroves plays a crucial role in influencing fish distribution and community structure (Mulya *et al*., 2021). While the J' Evenness Index value was higher for Station 2 and Station 1, it was lower for Station 3. This suggested that the species from Station 2 were more evenly distributed, but the decreasing value of J' indicated that Station 3 had low evenness and diversity. However, the J' value was almost similar between stations, ranging only between 0.87 and 0.94, which suggests that a particular species may have dominated all stations. Station 1 had a higher D' Species Richness Index value than Stations 2 and 3, suggesting that Station 1 had a greater number of fish species than the other stations.

Fish Species Distribution to Water Quality Parameters, Nutrients, and Chlorophyll

The water quality parameters, nutrients, and chlorophyll in the water of different stations are shown in Table 4. No significant difference was found in all the water quality parameters, nutrients, and chlorophyll among the stations ($p > 0.05$). For that reason, the water quality parameters, nutrients, and chlorophyll are almost similar between stations. It is revealed that the values of water quality parameters, nutrients, and chlorophyll do not influence the stations.

Aplocheilus panchax (Kepala timah), *Terapon jarbua* (kerong), and *Ambassis vachellii* (seriding) were found to be the three most abundant fish species in Station 1, which were recorded at the highest salinity (15.9 ppt), depth (0.83 m), TDS (11525 mg/L), nitrites (1.29 mg/L), and phosphates (0.27 mg/L). However, the salinity was lowest in Station 2 (15.34 ppt), depth, TDS, nitrites, and phosphates were lowest in Station 3, respectively, 0.69 m, 8,738 m g/L, 0.74 mg/L, and 0.20 mg/L. Furthermore, Station 2 identified the three most abundant species: *Glossogobius aureus*, *Dichotomyctere nigroviridis*, and *Lates calcarifer*, which exhibited the highest ammonium (1.12 mg/L) value level. In contrast, Station 3 recorded the lowest ammonium value (0.34 mg/L).

In Station 3, the three most abundant fish species were *Ophiocara porocephala* (Ubi belontok), *Dichotomyctere nigroviridis* (Buntal), and *Terapon jarbua* (Kerong). High numbers of three species were recorded at the highest temperature, DO, TDS, pH, chl *a*, chl *b*, and chl *c* levels. As shown (Table 4), Station 3 recorded the highest temperature (30.69 °C), DO (4.06 mg/L), pH (7.64), chl *a* (0.0162 mg/L), chl *b* (0.00150 mg/L), and chl *c* (0.0023 mg/L) values and Station 2, the lowest value for temperature (30.02 °C), DO (3.11 mg/L), chl *a* (0.0118 mg/L), and chl *b* (0.0003 mg/L). Furthermore, the lowest pH (7.52) and chl *c* (0.0020 mg/L) were the same for Stations 1 and 2.

The association between water quality parameters, nutrients, chlorophyll, and fish population abundance was analysed using Pearson's Correlation. Pearson's Correlation Analysis revealed that all parameters were weakly correlated, with some showing positive or negative correlations between them. There was a negative correlation between temperature (-0.288090), DO (-0.284569), pH (-0.288887), salinity (-0.323502), TDS (-0.326188), chl *a* (-0.320436), chl *b* (-0.167964), chl *c* (-0.128019), and fish abundance and diversity.

Table 3: Ecological indices value calculated for each station in the UMT mangrove reserve area (UMT-MRA)

Ecological Indices	Station 1	Station 2	Station 3
Number of species	12	10	5
Number of individuals	77	16	16
Shannon-Weiner (H') Diversity Index	2.23	2.17	1.4
Pielo (J') Evenness Index	0.9	0.94	0.87
Margalef (D') Species Richness Index	11.77	9.64	4.64

A positive correlation was observed between all nutrients (ammonium, nitrites, phosphates) and fish abundance and diversity, respectively, with coefficients of 0.241709 mg/L, 0.182801 mg/L, and 0.313210 mg/L. However, all nutrients showed a positive correlation but were very weakly correlated to the fish abundance.

The findings suggest that fish species distribution is weakly associated with water quality parameters in the studied area, indicating that the environmental conditions across stations are relatively homogeneous and suitable for various species. In tropical estuarine and mangrove systems, slight variations in temperature, dissolved oxygen, and salinity are generally tolerated by a wide range of euryhaline fish species (Blaber, 2008; Zydlewski & Wilkie, 2012; Duque *et al*., 2020). Therefore, the weak correlation observed is expected, as species like Terapon jarbua and Dichotomyctere nigroviridis are known to inhabit waters with broad salinity and temperature ranges (Breine *et al*., 2019; Momota, 2013).

Although nutrient levels (ammonium, nitrites, phosphates) were positively correlated with fish abundance, the relationships were weak. This could imply that nutrient enrichment may provide some indirect benefits such as increased primary productivity (e.g., phytoplankton growth reflected by chlorophyll *a*, *b*, and *c*), but it is not the dominant driver shaping fish distributions here (Jeppesen *et al*., 2005). Furthermore, high TDS and salinity values recorded at Station 1 may favour species adapted to slightly more saline and mineral-rich conditions such as *Aplocheilus panchax* (Scannell & Jacobs, 2001; Weber-Scannell & Duffy, 2007).

Similarly, higher chlorophyll concentrations in Station 3 suggest greater primary productivity, potentially supporting more abundant fish populations, although again, the correlation is weak. Other factors not measured here such as habitat structure (mangrove density, complexity) and food web dynamics might play a more substantial role in determining fish assemblages

Table 4: Mean and standard deviation (±) of the water quality, nutrients, and chlorophyll recorded in the UMT mangrove reserve area (UMT-MRA)

Parameters	Station		
	1	2	3
Water quality			
Temperature (°C)	30.45 ± 1.46	30.02 ± 1.65	30.69 ± 1.36
DO (mg/L)	3.76 ± 1.24	3.11 ± 1.56	4.06 ± 1.24
pH	7.52 ± 0.55	7.52 ± 0.39	7.64 ± 0.43
Salinity (ppt)	15.9 ± 3.75	15.34 ± 3.65	15.44 ± 3.79
Depth (m)	0.83 ± 0.22	0.71 ± 0.20	0.69 ± 0.16
TDS (mg/L)	11525.60 ± 1323.8	10973.47 ± 1244.1	8738.87 ± 1206.1
Nutrients			
Ammonium (mg/L)	0.64 ± 0.56	1.12 ± 0.58	0.34 ± 0.11
Nitrites (mg/L)	1.29 ± 0.66	0.75 ± 0.36	0.74 ± 0.47
Phosphates (mg/L)	0.27 ± 0.14	0.24 ± 0.12	0.20 ± 0.09
Chlorophyll			
Chlorophyll *a* (mg/L)	0.0121 ± 0.007	0.0118 ± 0.012	0.0162 ± 0.016
Chlorophyll *b* (mg/L)	0.0009 ± 0.001	0.0003 ± 0.000	0.0015 ± 0.002
Chlorophyll *c* (mg/L)	0.0020 ± 0.001	0.0020 ± 0.002	0.0023 ± 0.0072

(Santamaria-Damián *et al*., 2023; Nauta *et al*., 2023).

In conclusion, fish assemblage patterns across stations were relatively stable and weakly associated with variations in water quality, nutrients, and chlorophyll. This suggests that the fish communities in UMT mangrove reserve area (UMT-MRA) are resilient to minor water quality fluctuations but could still respond to more significant environmental changes. It is suggested that the area is not sensitive to changes in fish abundance and water quality parameters, including nutrients and chlorophyll.

Conclusions

A total of 109 fish were collected, representing 19 species from 15 families. Station 1 had the most fish species (12 species), followed by Station 2 (10 species) and Station 3 (5 species). Gobiidae is the dominant family with the highest number of species. Overall diversity index values of diversity, richness, and evenness were found to be 2.54, 18.79, and 0.86, respectively, which were an indication of an intermediate range of fish species composition, richness, and evenness in the population of fishes in the UMT-MRA.

The number rapidly decreased in terms of individuals, species, and families when compared to the previous study. The presence of 10 economically important fish species and one species as valuable (VU) in the IUCN Red List at Universiti Malaysia Terengganu implies that this mangrove's role in maintaining and conserving the mangrove ecosystem for fish is important. No significant difference was found among the stations' water quality parameters, nutrients, and chlorophyll ($p > 0.05$). It is revealed that the values of water quality parameters, nutrients, and chlorophyll do not influence the stations. Further research is needed to better understand the UMT mangrove habitat as a feeding and breeding area for fish.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

References

Adla, K., Dejan, K., Neira, D., & Dragana, S. (2022). Degradation of ecosystems and loss of ecosystem services. *One Health*, *9*, 281-327.

APHA. (2012). *Standard methods for the examination of water and wastewater* (20th ed.). American Water Works Association, Water Environment Federation, Washington, DC. 1496 pp.

Arar, E. J. (1997). *Method 446.0: In vitro determination of Chlorophylls a, b, c + c and Pheopigments in 12 marine and freshwater algae by visible spectrophotometry.* U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/005.

Arshad, A., Bujang, J. S., Zakaria, M. H., Suryana, Y., & Abdul Gaffar, M. (2006). Fish communities from the seagrass bed of Merchang Lagoon, Terengganu, Peninsular Malaysia. *Coastal Marine Science*, *30*, 268-275.

Badli-Sham, B. H., Shahirah-Ibrahim N., Goh, S. X., Syamila-Noh, H., Abdul Shukor, N. S. A., Shafie, F. A., Md-Daud, A., Abdul-Razak, F. A., Rosli, R., Abdul, Aziz. A. A., Mohammad, F. N. F., Kamaruzzaman, M.F., Mohamad, S., Dzu, K., Shariffudin, A., Najwa-Sawawi, S., & Ahmad, A. (2019) Herpetofauna of Universiti Malaysia Terengganu campus: Sustaining biodiversity in campus green area. *Journal of Sustainability Science and Management*, *14*(1), 11-28.

Blaber, S. J. (2008). *Tropical estuarine fishes: Ecology, exploitation and conservation*. John Wiley & Sons. 372p.

Blaber, S. J. M., Farmer, M. J., Milton, D. A., Pang, J., Boon-Teck, O., & Wong, P. (1997). The ichthyoplankton of selected estuaries in Sarawak and Sabah: Composition, distribution and habitat affinities. *Estuarine, Coastal and Shelf Science*, *45*, 197-208.

Breine, J. J., Van den Bergh, E., Terrie, T., Lambeens, I., Maes, Y., Galle, L., & Verreycken, H. (2019). First record of the target fish, Terapon jarbua (Forsskål, 1775) in the Zeeschelde, Belgium. *Estuarine, Coastal and Shelf Science*, *222*, 151-153.

Carpenter, K. E., & Niem, V. H. (1999-2001). *FAO species identification guide for fishery purposes*. Rome, Italy: Food and Agriculture Organisation of the United Nations.

Chong, V. C., Jamizan, A. R., Mohamad-Yazid, Z., Rizman-Idid, M., Muhammad-Ali, S. H., & Natip, P. (2010). Diversity and abundance of fish and invertebrates of Semerak Estuary and Adjacent Inshore Waters, Kelantan. *Malaysian Journal of Science*, *29*, 95-110.

Chong, V. C., Ng, Y. P., Hairi, B. J., Ooi, A. L., Chew, L. L. Amirah, M., & Affendi, B. N. (2005). Update of the fish species of mangrove and coastal waters of Northeastern Langkawi. *Malaysian Journal of Science*, *24*, 167-184.

Chong, V. C., Sasekumar, A., & Zgozi, S. W. (2005). Ecology of fish and shrimp communities. In Chong, V. C., & Sasekumar, A. (Eds.), *Ecology of Klang Strait* (pp. 174-200). Kuala Lumpur: University of Malaya Press.

Duque, G., Gamboa-García, D. E., Molina, A., & Cogua, P. (2020). Effect of water quality variation on fish assemblages in an anthropogenically impacted tropical estuary, Colombian Pacific. *Environmental Science and Pollution Research*, *27*(20), 25740-25753.

Faizal, A. (2005). *Kepelbagaian ikan di kawasan paya Mengabang Telipot, Terengganu pada musim tengkujuh* [Undergraduate Thesis, Bachelor of Science (Hons) Marine Biology, Faculty of Science and Technology, University College of Science and Technology Malaysia].

Froese, R., & Pauly, D. (2023). FishBase [Online].www.fishbase.org, version (05/2023).

Gibson, R. N. (1988). Patterns of movement in intertidal fishes. In Chelazzi, G., & Vannini, M. (Eds.), *Behavioural adaptations to intertidal life* (pp. 55-63). New York: Plenum Press.

Grace Analytical Lab. (1995). Standard Operating Procedure for Chlorophyll *a* and Pheophytin-a (Turner Designs Method).

Jeppesen, E., Jensen, J. P., Søndergaard, M., & Lauridsen, T. L. (2005). Response of fish and plankton to nutrient loading reduction in eight shallow Danish lakes with special emphasis on seasonal dynamics. *Freshwater Biology*, *50*(10), 1616-1627.

Malidus, J. (2007). *Pre-monsoon fish composition and distribution in Mengabang Telipot, Kuala Terengganu, Terengganu.*

Margalef, D. R. (1958). Information theory in ecology. *General Systems*, *3*, 36-71.

Matsunuma, M., Motomura, H., Matsuura, K., Shazili, N. A. M., & Ambak, M. A. (2011). *Fishes of Terengganu-east coast of Malay Peninsula, Malaysia*. National Museum of Nature and Science, University Malaysia Terengganu and Kagoshima University Museum.

Merckx, T., Souffreau, C., Kaiser, A., Baardsen, L. F., Backeljau, T., Bonte, D., Brans, K. I., Cours, M., Dahirel, M., Debortoli, N., Wolf, K. D., Engelen, J. M. T., Fontaneto, D., Gianuca, A. T., Govaert, L., Hendrickx, F., Higuti, J., Lens, L., Martens, K., Matheve, H., Matthysen, E., Piano, E., Sablon, R., Schön, I., Doninck, K. V., Meester, L. D., & Van Dyck, H. (2018). Body-size shifts in aquatic and terrestrial urban communities. *Nature*, *558*(7708), 113-116.

Mohd-Nor, M. Z. (2010). *The abundance of fish in Universiti Malaysia Terengganu (UMT) for the year 2010* [Undergraduate thesis, Bachelor of Applied Science (Fisheries), Universiti Malaysia Terengganu].

Momota, K. (2023). *Experimental ecological study on spawning and development of four genera, four species of pufferfishes distributed in freshwater and brackish water regions* [Doctoral Thesis, Graduate School of Environmental Science, Hokkaido University]. 105 p.

Motomura, H., & Ishikawa, S. (2013). *Fish collection building and procedures manual.* Kyoto: Kagoshima University Museum, Kagoshima and Research Institute for Humanity and Nature.

Mulya, H., Santosa, Y., & Hilwan, I. (2021). Comparison of four species diversity indices in the mangrove community. *Biodiversitas Journal of Biological Diversity*, *22*(9).

Nauta, J., Lammers, C., Lexmond, R., Christianen, M. J., Borst, A., Lamers, L. P. M., Lavieren, H. V., Naipal, S., & Govers, L. L. (2023). Habitat complexity drives food web structure along a dynamic mangrove coast. *Marine Pollution Bulletin*, *196*, 115597.

Nazirah, Z. (2008). *Kepelbagaian ikan di Kawasan paya sekitar kampus Universiti Malaysia Terengganu* [Undergraduate Thesis, Bachelor of Conservation Biology and Management, Universiti Malaysia Terengganu].

Nieder, J. (1993). Distribution of juvenile blennies (Pisces, Blennidae) in small tidepools: Results of low tide lottery or strategic habitat selection. *Bonn Zoological Bulletin*, *44*, 133-140.

Pielou, E. C. (1977). *Mathematical ecology*. New York: Wiley.

Rahim, K. A. A., Esa, Y., & Arshad, A. (2013). The influence of alien fish species on native fish community structure in Malaysian waters. *Kuroshio Science*, *7*(1), 81-93.

Ramli, N. H., & Megat Asrul Hazaman, W. N. A. A. (2021). Diversity and distribution of freshwater fishes at Sungai Muar, Kuala Pilah, Negeri Sembilan. *Journal of Academia*, *9*, 153-165.

Sala, O. E., Chapin III, F. S., Armesto, J. J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L. F., Jackson, R. B., Kinzig, A., Leemans, R., Lodge, D. M., Mooney, H. A., Oesterheld, M., Poff, N. L., Sykes, M. T., Walker, B. H., Walker, M., & Hall, D. H. (2000) Global biodiversity scenarios for the year 2100. *Science*, *287*, 1770-1774.

Santamaria-Damian, S., Tovilla-Hernández, C., Romero-Berny, E. I., Damon, A., Navarro-Martínez, A., & Ortega-Argueta, A. (2023). Effect of mangrove complexity and environmental variables on fish assemblages across a tropical estuarine channel of the Mexican Pacific. *Wetlands*, *43*(5), 50.

Scannell, P. W., & Jacobs, L. L. (2001). *Effects of total dissolved solids on aquatic organisms*. Alaska Department of Fish and Game: Division of habitat and restoration, 1, 4.

Shannon, C. E., & Weaner, W. (1989). *The mathematical theory of communication*. The University of Illinois Press.

Siti-TafzilMeriam, S. A. K., Mohamad-Norizam, M., Baharim, N. B., Arai, T., Motomura, H., Husain, K-L, Gaffar, M. A., & Ambak, M. A. (2017). Diversity and abundance of fish assemblages in the Setiu Wetlands, Terengganu, Malaysia. In Abdullah, M. T. A., Mohammad, M., Zalipah, M. N., & Lola, M. S. (Eds.), *Greater Kenyir landscapes* (pp. 327). Switzerland: Springer Nature Switzerland AG.

Weber-Scannell, P. K., & Duffy, L. K. (2007). Effects of total dissolved solids on aquatic organisms: A review of literature and recommendations for salmonid species. *American Journal of Environmental Sciences*, *3*(1), 1-6.

Zainuddin, A. (2007). *Composition and distribution of fish from suborder goboidei (gobiidae and eleotriade) at intertidal zones of Terengganu and Penang* [Master's Thesis, Faculty of Science and Marine Environment, Universiti Malaysia Terengganu].

Zydlewski, J., & Wilkie, M. P. (2012). Freshwater to seawater transitions in migratory fishes. *Fish Physiology*, *32*, 253-326.