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The Diversity and Distribution of Fish at the Port and Urbanized Areas of Pulau Pinang Strait, Malaysia

(Kepelbagaian dan Taburan Ikan di Kawasan Pelabuhan dan Perbandaran Selat Pulau Pinang, Malaysia)

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ABSTRACT

Marine fish in Malaysian waters are impacted by various stressors, including resource exploitation, urbanization and industrialization. Therefore, this study examines the fish diversity and distribution at five sampling stations with different natural processes and anthropogenic activities in the coastal waters of Pulau Pinang, Malaysia. A total of 669 fish specimens belonging to 47 species from 23 families were collected using drift nets in two sampling periods from October to November 2017 and October to November 2019. The fish abundance is determined based on the catch per unit effort, (CPUE ind/hour). Among the dominant families, Leiognathidae and Ariidae accounted for 21.22 and 14.44 of the total catch, respectively. Three fish species, namely, *Eubleekeria splendens*, *Anodontostoma chacunda*, and *Pennahia anea,* dominated the catches. The CPUE near the ongoing reclamation projects and landfill was lower than that of the port and industrial areas with mangrove estuaries. The dendrogram clearly differentiated the fish species composition between the reclamation sites and natural shorelines. Given no previous research on the fish distribution along the Pulau Pinang strait featuring different habitat types, this study therefore serves as a contemporary fish assemblage for future research and surveys.

Keywords: Fish diversity; mangrove; Pulau Pinang strait; reclamation; urbanization

ABSTRAK

Ikan marin di perairan Malaysia terkesan oleh pelbagai tekanan, termasuk eksploitasi sumber, pembandaran dan perindustrian. Oleh itu, kajian ini meneliti kepelbagaian dan taburan ikan di lima stesen persampelan dengan proses semula jadi dan aktiviti antropogenik yang berbeza di perairan pantai Pulau Pinang, Malaysia. Sebanyak 669 spesimen ikan tergolong daripada 47 spesies daripada 23 famili telah dikumpul menggunakan pukat hanyut dalam dua tempoh persampelan iaitu dari Oktober hingga November 2017 dan Oktober hingga November 2019. Kelimpahan ikan ditentukan berdasarkan tangkapan per unit usaha (TPUU; ind/jam). Antara famili yang dominan ialah Leiognathidae dan Ariidae yang masing-masing menyumbang kepada 21.22 dan 14.44 daripada jumlah keseluruhan tangkapan. Tiga spesies ikan iaitu, *Eubleekeria splendens, Anodontostoma chacunda* dan *Pennahia anea* mendominasi tangkapan ini. TPUU berhampiran projek penambakan yang sedang dijalankan dan tapak pelupusan adalah rendah berbanding kawasan pelabuhan dan perindustrian yang berhampiran dengan muara bakau. Dendogram membezakan dengan jelasnya komposisi spesies ikan antara tapak penambakan dan garisan pantai semula jadi. Memandangkan tiada kajian terdahulu mengenai taburan ikan di sepanjang selat Pulau Pinang yang menampilkan jenis habitat yang berbeza, oleh itu kajian ini berfungsi sebagai himpunan ikan kontemporari untuk penyelidikan dan tinjauan pada masa depan.

Kata kunci: Bakau; kepelbagaian ikan; pembandaran; penambakan; selat Pulau Pinang

Introduction

Malaysia is undoubtedly one of the megadiverse countries in the world (Tong 2020). Mazlan et al. (2005) state that the total number of coastal marine fish species in Malaysian seas is approximately 1500. Later, Chong, Lee and Lau (2010) listed 1400 fish species in Malaysian marine waters. Nonetheless, the common belief is that Malaysian waters contain more species than recorded and stand out as among the highest fish diversity in the world (Arai 2015).

Over the years, the optimum utilisation of Malaysia's marine environment have been declining due to different natural and anthropogenic stressors (Mustafa & Mariani 2011; Yates et al. 2016). Inevitably, such environmental stressors end up in the marine ecosystem and thus, highly affect the aquatic organisms. Of these species, fish is one of the most prominent and crucial inhabitants in water bodies (Bukola et al. 2015). For example, the shoreline hardening alters topographic complexity (e.g., water depth, environmental characteristics, and food availability) resulting in lower fish diversity and distinct fish assemblage (Gittman et al. 2016; Kornis et al. 2018). Moreover, land reclamation might disrupt fish habitat and reshape ecological connectivity (Ding et al. 2020), associated with diel, seasonal, and ontogenetic shifts. Previous literatures (Ab-Rahman et al. 2019; Chee et al. 2017; Chong, Lee & Lau 2010; Razak & Abllah 2014) show that marine fish in Malaysian waters are threatened due to the modification of habitat, oil and grease discharges, overfishing activities, and by-catch. In addition, urbanization and industrialization along the coastal areas and from the mainland have been identified as the main contributors to marine pollution (Gasim et al. 2013; Mustafa & Mariani 2011). As one of the transportation modes, oceans are also used to transfer resources and goods by ships and barges from one location to another. Therefore, to primarily cater to maritime transportation and related industries, various cities in Malaysia have been developed, such as Port Klang, Pasir Gudang, and Pulau Pinang (Gasim et al. 2012).

Pulau Pinang, located on the northwest coast of Peninsular Malaysia, has been experiencing urbanization to support the economic and population growth (Ab-Rahman et al. 2019; Chee et al. 2017; Ramly 2008; Rauff, Abir & Qadir 2020; Ulfa et al. 2021). In Pulau Pinang, the shoreline modification and reclamation projects altered the existing biotic and abiotic profiles and disrupted suitable habitats for marine organisms (SAM 2020; Yin & Kwang 2016), and consequently reducing fisheries stock through pollution, siltation, and habitat loss (Nadzir et al. 2014).

However, documentation on marine fish biodiversity along the Pulau Pinang coast associated with anthropogenic activities is lacking. Therefore, this study aims to characterize the diversity of marine fishes in relation to urbanized development in Pulau Pinang. The data represent the current situation of such areas and thus can be used as a contemporary fish assemblage for future fish diversity assessment.

Methods

Study Area

The state of Pulau Pinang is geographically divided into two parts, namely, the main island (Pulau Pinang) and the mainland (Seberang Perai) on the Malay Peninsula. Five sampling stations with different natural and anthropogenic activities were selected (Figure 1). Three points were selected at each sampling station representing replicates and fish assemblages in the area. Table 1 summarizes all sampling stations and their descriptions.

Fish Sampling

This study was done in two sampling periods: October to November 2017 and October to November 2019. In all, the four sampling excursions covered both neap and spring tides. The standard method of fish sampling was conducted following Murphy and Willis (1996). In this study, three drift nets (100 meter-long and 2 meter-depth) with different stretched mesh sizes (2, 3, and 4 inches), provided by the fishermen were deployed for approximately 40 minutes at each of 15 points (5 sampling stations with triplicates; Table 1). The drift nets were installed by fishermen in easily accessible area and ease of obtaining higher number of specimens. The nets were set up near the bottom most of the time. All fish caught by nets were removed and placed in the labeled plastic bags before being brought back to the laboratory for identification. Species identification was based on taxonomic keys by Ambak et al. (2010) and Froese and Pauly (2016). The number of individuals per species was counted.

In this study, the optimum sample sizes of fish communities were obtained using the total catch data and mean values for the first three sampling efforts based on the following formula by Hansen, Beard Jr. and Hayes (2007):

$$N = t^2 (\infty, 0.05)\, (CV)^2 / D^2$$

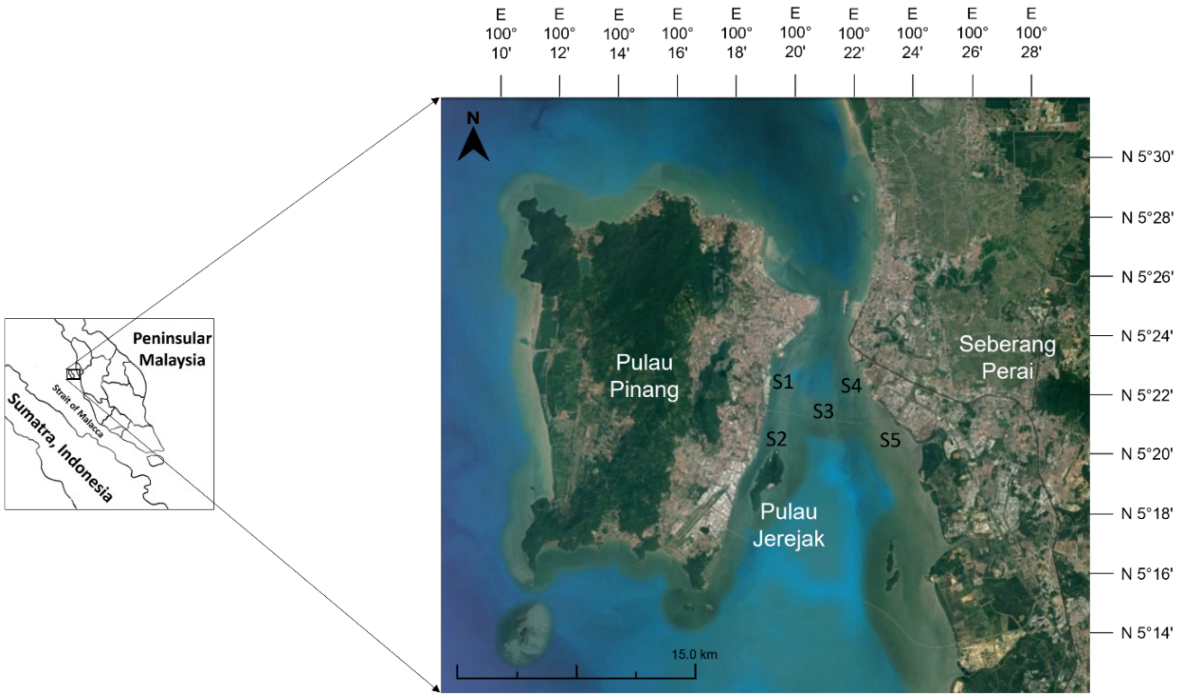


FIGURE 1. Map of Pulau Pinang straits showing the sampling stations; S1 = Jelutong; S2 = Batu Uban; S3 = Penang Bridge; S4 = Perai; S5 = Juru (Inset: Map of Peninsular Malaysia and Sumatra, Indonesia)

where N is the sample size; t (∞, 0.05) = 1.96 (at 95% confidence level); CV is the coefficient of variation (standard deviation/mean); and D is the acceptable error (%).

The sample size requirement was calculated separately for each sampling station. Based on the formula, optimum sample sizes needed for each site with 5% acceptable error for sampling stations 1 - 5 were 1, 55, 38, 189 and 412 individuals, respectively. Hence, the samples collection was proceeded based on the estimates following Hashim (2013). Only one station did not meet the optimum sample size required >95% (i.e., Penang Bridge). However, the trend of abundance at all stations parallels the optimum number estimated.

DATA ANALYSIS

Comparison of mean catch per unit effort (CPUE) The catch per unit effort (CPUE) values at each point were obtained based on the total fish caught per hour (ind/hour), as carried out by Shah et al. (2016). Number of fish from three different mesh sizes for each point were pooled and treated as a single replicate. Normality of distributed data ($p > 0.05$) was confirmed by the Shapiro -Wilk test. Therefore, a one-way ANOVA was proceeded to determine the CPUE (ind/hour) of fish populations between five sampling stations, where data at the three points of each sampling station were treated as three replicates for that station (3 replicates/station × 5 stations). Meanwhile, the Student's t-test was used to assess any significant differences of CPUE (ind/hour) between neap and spring tides, with data from five stations treated as replicates. These analyses were performed using IBM SPSS software version 21.

Ecological indices The CPUE of fish composition was used for the three ecological indices: species diversity (Shannon, H'), evenness index (Hulbert's Pie), and dominance index (Simpsons, D). All indices were computed using PAST software version 2.1.

Cluster analysis The cluster analysis was performed by using a Bray-Curtis dissimilarity matrix to group the sampling stations based on the CPUE values. This analysis was carried out using Unweighted Pair Group Method with Arithmetic Mean (UPGMA) incorporated in Multi-Variate Statistical Package (MVSP) software version 3.1.

TABLE 1. Description of the sampling stations

Sampling station	Habitat type	Description	GPS Coordinate (3 replicates)
S1 Jelutong	Sandy	0.5-1.5 km to former landfill site, residential and coastal reclamation areas	5°22’48.0”N 100°19’27.1”E 5°22’22.2”N 100°19’23.9”E 5°22’03.6”N 100°19’19.2”E
S2 Batu Uban	Sandy	0.5-2.0 km to fishers and Marine Department jetties and Pulau Jerejak	5°21’08.1”N 100°19’03.6”E 5°20’44.6”N 100°18’59.3”E 5°20’21.0”N 100°18’53.4”E
S3 Penang Bridge	Silty-sand	Close to the central section of the Penang Bridge, the fifth-longest bridge in Southeast Asia	5°21’21.0”N 100°19’39.9”E 5°21’08.7”N 100°21’10.3”E 5°21’04.2”N 100°22’22.0”E
S4 Perai	Mudflat	0.5-2.0 km to Sungai Perai mouth, Prai Bulk Cargo Terminal and mangrove zone	5°22’47.9”N 100°22’02.5”E 5°22’12.1”N 100°22’23.9”E 5°21’31.5”N 100°22’30.3”E
S5 Juru	Mudflat	0.5-2.5 km to Sungai Juru mouth, industrial and mangrove zones	5°20’39.8”N 100°22’46.7”E 5°19’52.1”N 100°23’02.1”E 5°19’08.1”N 100°23’22.9”E

RESULTS

A total of 669 fish specimens representing 47 species from 23 families were collected during the study period. Table 2 shows the total number of species, genera, families and their abundance at each sampling station. The dominant family was Leiognathidae, which accounted for 21% (two species), followed by Ariidae with 14% (six species). Both Perai and Juru recorded the highest number of families with 15 each, followed by Batu Uban with ten families, whereas Jelutong and Penang Bridge recorded only two and three families, respectively. The highest abundance and species richness were recorded at Juru (400 ind; 25 species), followed by Perai (194 ind; 21 species) and Batu Uban (61 ind; 16 species), whereas Jelutong and Penang Bridge recorded two individuals (two species) and 12 individuals (four species), respectively.

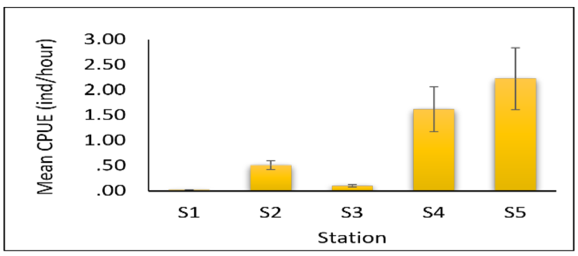
Figure 2(a) shows the summary of CPUE, which was significantly highest ($p < 0.05$) at Juru with 2.22 ± 0.62 ind/hour, followed by Perai (1.62 ± 0.44 ind/hour) and Batu Uban (0.51 ± 0.08 ind/hour). CPUE at Jelutong and Penang Bridge were 0.02 ± 0.01 ind/hour and 0.10 ± 0.03 ind/hour, respectively. Statistically, although the average CPUE in neap tide was higher than that at spring tide, no significant difference ($p > 0.05$) was observed, indicating that the CPUE at five sampling stations were relatively similar between neap and spring tides (Figure 2(b)).

Figure 3 shows the CPUE absolute values for each species at five sampling stations. Three species, namely *Eubleekeria splendens*, *Anodontostoma chacunda*, and *Pennahia anea* dominated the catches during the study period. Among these species, *E. splendens* (2.26 ind/hour; 34%) and *P. anea* (1.13 ind/hour; 17%) were only recorded at Juru, whereas *A. chacunda* was recorded at Perai and Juru with 1.2 ind/hour (25%) and 0.38 ind/hour (6%), respectively.

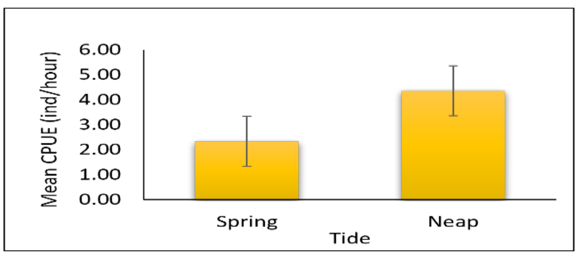
TABLE 2. The fish taxa present at five sampling stations. 'S1' = Jelutong; 'S2' = Batu Uban; 'S3' = Penang Bridge; 'S4' = Perai; 'S5' = Juru. Values under columns S1-S5 represent the actual number of individuals per species

No.	Family	Species / Scientific name	English name	S1	S2	S3	S4	S5
1	Ariidae	*Arius jella* (Day, 1877)	Blackfin sea catfish	0	4	0	0	0
2		*Arius maculatus* (Thunberg, 1792)	Spotted catfish	0	3	0	8	23
3		*Batrachocephalus mino* (Hamilton, 1822)	Beardless sea catfish	0	3	0	0	0
4		*Hexanematichthys sagor* (Hamilton, 1822)	Sagor catfish	0	3	0	7	0
5		*Osteogeneiosus militaris* (Linnaeus, 1758)	Soldier catfish	0	2	0	23	0
6		*Sciades sona* (Hamilton, 1822)	Sona sea catfish	0	3	0	6	0
7	Belonidae	*Strongylura strongylura* (van Hasselt, 1823)	Spottail needlefish	0	0	0	0	3
8		*Tylosurus acus melanotus* (Bleeker, 1850)	Keel-jawed needlefish	0	0	1	0	0
9		*Xenentodon canciloides* (Bleeker, 1854)	Indochinese needlefish	0	0	0	0	6
10	Carangidae	*Carangoides malabaricus* (Bloch & Schneider, 1801)	Malabar trevally	0	0	0	1	0
11		*Caranx heberi* (Bennett, 1830)	Blacktip trevally	0	6	0	0	0
12		*Megalaspis cordyla* (Linnaeus, 1758)	Torpedo scad	0	0	0	0	2
13		*Scomberoides commersonnianus* (Lacepède, 1801)	Talang queenfish	1	13	9	3	15
14		*Trachinotus mookalee* (Cuvier, 1832)	Indian pompano	0	0	0	2	0
15	Chanidae	*Chanos chanos* (Forsskål, 1775)	Milkfish	0	0	0	2	0
16	Clupeidae	*Anodontostoma chacunda* (Hamilton, 1822)	Chacunda gizzard shad	0	0	0	48	23
17		*Escualosa thoracata* (Valenciennes, 1847)	White sardine	0	0	0	0	8
18		*Ethmalosa fimbriata* (Bowdich, 1825)	Bonga shad	0	0	0	0	3
19	Dasyatidae	*Brevitrygon walga* (Müller & Henle, 1841)	Scaly whipray	0	0	0	1	0
20	Drepaneidae	*Drepane longimana* (Bloch & Schneider, 1801)	Concertina fish	0	0	0	0	0
21		*Drepane punctata* (Linnaeus, 1758)	Spotted sickle fish	0	2	0	1	0
22	Dussumieriidae	*Dussumieria elopsoides* (Bleeker, 1849)	Slender rainbow sardine	0	0	0	0	2
23	Engraulidae	*Stolephorus indicus* (van Hasselt, 1823)	Indian anchovy	0	0	0	0	2
24		*Thryssa hamiltonii* (Gray, 1835)	Hamilton's thryssa	0	0	0	0	22
25		*Thryssa mystax* (Bloch & Schneider, 1801)	Moustached thryssa	0	0	0	4	8
26	Gerreidae	*Gerres filamentosus* (Cuvier, 1829)	Whipfin silver-biddy	0	1	0	2	1
27	Haemulidae	*Pomadasys argyreus* (Valenciennes, 1833)	Bluecheek silver grunt	0	1	0	3	0
28	Leiognathidae	*Eubleekeria splendens* (Cuvier, 1829)	Splendid ponyfish	0	0	0	0	136
29		*Nuchequula nuchalis* (Temminck & Schlegel, 1845)	Spotnape ponyfish	0	0	0	23	0
30	Lutjanidae	*Lutjanus johnii* (Bloch, 1792)	John's snapper	0	1	0	0	0
31	Mugilidae	*Ellochelon vaigiensis* (Quoy & Gaimard, 1825)	Squaretail mullet	0	4	1	5	0

32		*Osteomugil speigleri* (Bleeker, 1858)	Speigler's mullet	0	0	0	0	6
33		*Planiliza macrolepis* (Smith, 1846)	Largescale mullet	0	0	0	0	24
34		*Planiliza subviridis* (Valenciennes, 1836)	Greenback mullet	0	0	1	1	0
35	Mullidae	*Upeneus sulphureus* (Cuvier, 1829)	Sulphur goatfish	0	0	0	0	1
36	Paralichthyidae	*Pseudorhombus arsius* (Hamilton, 1822)	Largetooth flounder	0	1	0	0	0
37	Polynemidae	*Eleutheronema tetradactylum* (Shaw, 1804)	Fourfinger threadfin	0	0	0	1	9
38	Pristigasteridae	*Ilisha elongata* (Anonymous [Bennett], 1830)	Elongate ilisha	0	0	0	0	6
39	Scatophagidae	*Scatophagus argus* (Linnaeus, 1766)	Spotted scat	0	3	0	17	0
40	Sciaenidae	*Dendrophysa russelii* (Cuvier, 1829)	Goatee croaker	0	0	0	0	1
41		*Johnius belangerii* (Cuvier, 1830)	Belanger's croaker	0	0	0	0	12
42		*Johnius macrorhynus* (Lal Mohan, 1976)	Big-snout croaker	0	0	0	4	0
43		*Otolithes ruber* (Bloch & Schneider, 1801)	Tigertooth croaker	0	0	0	0	13
44		*Pennahia anea* (Bloch, 1793)	Donkey croaker	0	0	0	0	68
45	Sphyraenidae	*Sphyraena putnamae* (Jordan & Seale, 1905)	Sawtooth barracuda	0	0	0	0	1
46	Triacanthidae	*Triacanthus biaculeatus* (Bloch, 1786)	Short-nosed tripod fish	1	11	0	32	0
47	Trichiuridae	*Lepturacanthus savala* (Cuvier, 1829)	Savalai hairtail	0	0	0	0	5
			Total number of individuals	2	61	12	194	400
			Total number of species	2	16	4	21	25
			Total number of families	2	10	3	15	15



(a)



(b)

FIGURE 2. Catch per unit effort, CPUE (mean ± s.d.) of fish assemblages a) at five sampling stations of Pulau Pinang strait b) in spring and neap tides during the study period

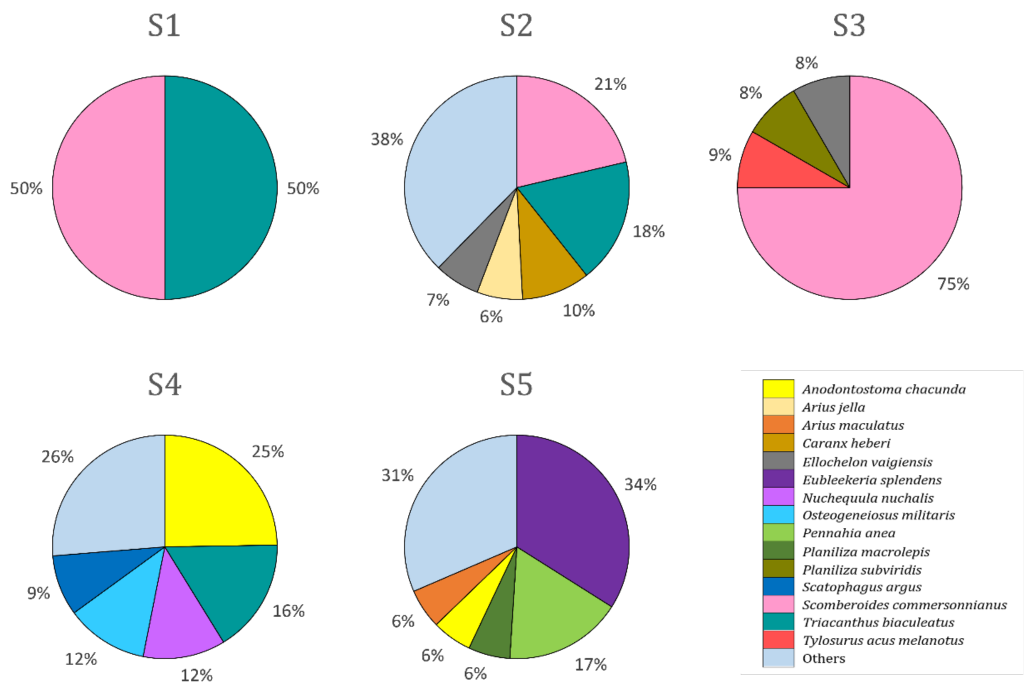


FIGURE 3. Percent relative abundance based on catch per unit effort (CPUE; ind/hour) at five sampling stations of Pulau Pinang strait during the study period

Batu Uban exhibited the highest diversity index with a value of 2.46, followed by Perai (2.38) and Juru (2.36). The highest evenness index was recorded at Jelutong (1.00), followed by Batu Uban (0.73) and Penang Bridge (0.58). Penang Bridge had the highest dominance index (0.58), followed by Jelutong (0.50). Batu Uban, Perai, and Juru recorded relatively similar values with 0.11, 0.13 and 0.16, respectively (Table 3).

Figure 4 shows the dendrogram clustered at the sampling points based on the CPUE of the individual fish caught per hour. In terms of similarity, Batu Uban and Penang Bridge have 28%, while Perai and Juru have 14%. All these four stations had a similarity of 12% CPUE, while Jelutong only had 6% similarity with the others.

TABLE 3. Ecological indices (diversity, evenness, and dominance) at the sampling stations

Station	Shannon diversity	Evenness	Dominance
S1 - Jelutong	0.69	1.00	0.50
S2 – Batu Uban	2.46	0.73	0.11
S3 – Penang Bridge	0.84	0.58	0.58
S4 - Perai	2.38	0.52	0.13
S5 - Juru	2.36	0.42	0.16

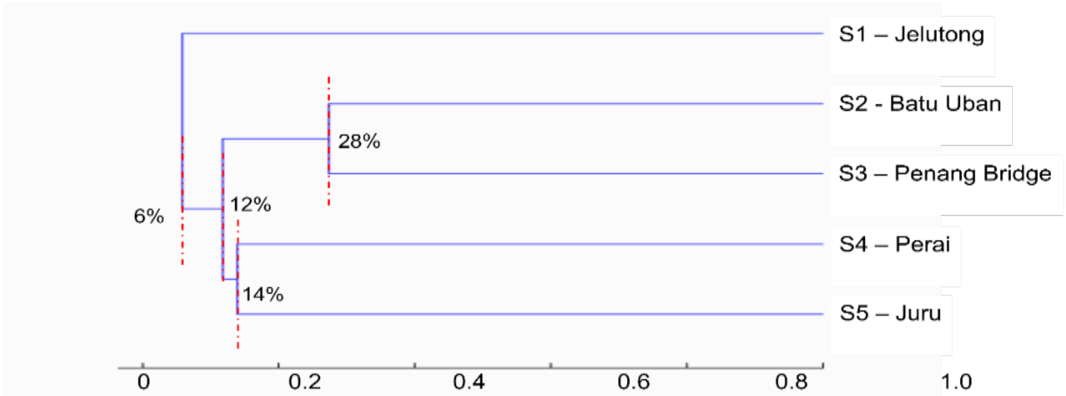


FIGURE 4. The UPGMA dendrogram of CPUE values at five sampling stations at Pulau Pinang strait. The vertical cut lines represented a point of reference where the cluster was formed based on the similarity of Jaccard's Coefficient

DISCUSSION

In this study, Leiognathidae and Ariidae are the dominant families in the investigated areas which have been exposed to various forms and levels of anthropogenic activities; e.g., industrialization and land reclamation for industry, housing, and commercial properties. Leiognathidae is a typical fish composition of tropical coastal ecosystems (Blaber 1997), and in this study, the highest CPUE for this family were recorded at Perai and Juru with mudflat of mangrove estuaries. Similarly, Leiognathids were also abundant in mangrove estuaries in Trang, Thailand (Tongnunui et al. 2002) and Panay Island, Philippines (Ikejima et al. 2006). For the family Ariidae, the factor contributing to its dominance is its high tolerance to adverse water quality conditions (Jalal et al. 2012; Shah Yusuf & Nor 2006).

Apart from the above, the Sciaenidae which comprises five species were mostly caught in Juru, near the river mouth and mangrove estuary. Sciaenids are bottom dwellers who prefer sandy or muddy habitats, such as beaches, sheltered bays, estuaries, and river mouths (Jalal et al. 2012). These habitat preferences contributed to the catch of the Sciaenidae family at Pulau Pinang's shoreline. Similarly, Shah, Yusuf and Nor (2006) reported that the family Sciaenidae and Mugilidae were the common coastal species recorded at Balik Pulau mangrove, Pulau Pinang. Moreover, the presence of Carangidae is expected, given that this family is an essential group of piscivorous predators that are generally found in all coastal waters of subtropical and tropical seas (Blaber & Cyrus 1983).

The ecological indices show that the fish diversities are moderate at Batu Uban, Perai, and Juru with the value $2 < H < 4$, but low at Jelutong and Penang Bridge with $H < 2$ (Odum 1971). For evenness index, most individuals at Jelutong, Batu Uban, and Penang Bridge were equally distributed within species, giving a high value. By contrast, most of the individuals at Perai and Juru belonged to several species, namely, *Anodontostoma chacunda* and *Triacanthus biaculeatus* (Perai), and *Pennahia anea* and *Eubleekeria splendens* (Juru). Moreover, the high number of species represented by one to four individuals at Penang Bridge (0.58) contributed to its slightly higher dominance value than that at Jelutong (0.50); that is, three species at Penang Bridge and two species at Jelutong. These indices also indicated that Batu Uban, Perai, and Juru had moderate fish diversity and less dominance by a single species.

Regarding fish abundance, CPUE is highest at Juru, followed by Perai and Batu Uban. Jelutong recorded the least CPUE, followed by Penang Bridge. The discrepancies in CPUE are associated with various activities around the sampling stations. As a result, each station has its own habitat characteristics including biotic (predation, competition) and abiotic (physicochemical parameters, nutrient, sedimentation) factors, which influences the abundance and diversity of fish communities. Geographically, Perai and Juru were near the mudflat of the mangrove area and estuary from the river mouth of Perai and Juru, respectively. These intertidal zones serve as a fish nursery and breeding ground, as well as a habitat for a diverse range of fish and other animals (Hutchison et al. 2014) due to the shelter, protection, and high food availability within the mangrove roots

(Niehuis et al. 2013; Verweij et al. 2006). Mangroves are important for the improved efficiency of fish production (Anneboina & Kumar 2017). Tongnunui et al. (2002) discovered that the fish assemblages of mangrove areas are greater than those in adjacent habitats such as seagrass and sandflat. In addition, Yingst (2016) reported that the lowest total fish biomass is found at the sampling sites without mangroves, which serve as shelter and protection for juvenile fish. Therefore, the present findings of high CPUE at Perai and Juru could be related to the existing mangrove ecosystem at these stations.

Conversely, the low CPUE recorded at Jelutong may be associated with several anthropogenic activities, including ongoing coastal reclamation projects. Visual observation noted several dredging activities during the sampling periods at Jelutong. Apart from the residential houses, the station is also near a former landfill area. There is a possibility that heavy metals produced from the landfill leachate could still be released into the soil and groundwater, and subsequently into the surface water (Hussin et al. 2021). The high metal concentrations (Fe, Cd, Cu, Mn, Pb, and As) were also documented by Zamri et al. (2015) in the leachate samples from the Pulau Burung sanitary landfill. Moreover, heavy metals could remain within the landfills for up to 150 years, at a rate of 400 mm/year (Adelopo et al. 2018). In Malaysia, the treatment process of landfill leachate is emphasized on removal of organic compounds and ammonia, while the removal of heavy metals is given less attention. Therefore, the accumulation of heavy metals results in water pollution and toxic habitat, which poses risk to the fish community in coastal areas.

Meanwhile, Batu Uban was also near the Jerejak Island Jetty, reclamation ground and ongoing constructions. A construction development with a total land area of 24.79 acres has been reclaimed near Batu Uban for residential and other facilities such as schools (Netto 2016). Previous studies noted that development activities such as land reclamation and extension of natural coastal habitats exert a substantial effect on the Pulau Pinang coastal area (Chee et al. 2017; Gasim et al. 2013; SAM 2020).

Generally, land reclamation initiatives are essential in urban growth for agricultural, industrial, and port development. A large amount of ocean sand is dredged and transported over considerable distances to create a new area for industrial or framework uses. However, reclamation inevitably affects the fishery (Ab-Rahman et al. 2019). The reclamation activity at the Tanjung Tokong has modified the habitat by altering the concentration of dissolved oxygen and carbon dioxide, creating unfavorable habitat for fish to survive (Ab-Rahman et al. 2019; Ramly 2008). Moreover, reclamation activities release toxic effluents and material wastes into groundwater, polluting the structure of the sea and affecting soil quality (Duo & Hu 2018). Near the reclaimed land off Gurney Drive, the concentration of dissolved oxygen is 3.67 mg/L and the turbidity is 1750.8 NTU, which indicated slightly polluted and murky water, respectively. Turbid water can reduce the growth rate of marine life by blocking the penetration of sunlight (Gasim et al. 2013).

The reclamation which increases the suspended sediment concentration offshore has not only decreases water transparency, but also blocks the fish gills or/and inhibit sexual population recruitment, resulting in a significant number of fish reduction and fish deaths (Erftemeijer et al. 2012; Suo et al. 2015). Projects like dredging, which causes the physical removal of substratum and related biota from the seabed, and reclamation, which results in the burial due to subsequent material deposition, have led to a significant loss and deterioration of productive coastal habitats (Erftemeijer et al. 2012). Consequently, fish abundance and diversity significantly reduced. As a result of the habitat disruptions, Priyandes and Majid (2009) highlighted that the land reclamation activities on the northern coast of Batam Island, Indonesia affected the productivity of fishes around the Bengkong coastal area. In particular, the population of mullet (Mugilidae) decreased by approximately 70%, while a few commercially valuable fish species, such as snapper and grouper, were not recorded in a study by Priyandes and Majid (2009). Furthermore, the shoreline hardening decreases the habitat heterogeneity, eliminates critical nursery and spawning habitats, and diminishes the population of fish groups that are particularly vulnerable to these kinds of impacts (Brook et al. 2018).

Increased land reclamation and dredging operations create a national concern because these activities frequently result in the loss of marine benthic ecosystems, destruction of buffer zones, disruption of food chains, coastal water pollution, and an increase in siltation and turbidity (SAM 2020; Yu & Zhang 2011). Mechanical drilling disrupts habitat and may harm fish and other animals. Subsequently, the number of crucial ecosystems and species in the vicinity of these projects are all affected by the dredging activity (Zainal et al. 2012). Dredging in the ocean could alter the natural wave pattern and flow of water bodies, causing ecological destruction (Ab-Rahman et al. 2019).

Meanwhile, the presence of *Scomberoides* *commersonianus* at all five sampling stations cannot be overlooked. Blaber and Cyrus (1983), and Hajisamae and Chou (2003) reported that this species could withstand high turbidity levels. Therefore, *S. commersonianus* can be found even at Jelutong, which is murky/turbid due to reclamation and dredging works. The most important commercial coastal-estuarine species, *Eleutheronema tetradactylum*, which was only recorded at Perai and Juru, was also found at the mangrove estuaries of Balik Pulau, Pulau Pinang (Shah, Yusuf & Nor 2006) and Kuantan, Pahang (Jalal et al. 2012). This species is transient and migrates inshore in response to tidal cycles or spawn and usually swims into the mangroves for feeding.

The present finding that recorded higher fish diversities at Perai and Juru supports that of Jaafar et al. (2004) at Pasir Ris, in the eastern part of Singapore, who found a higher diversity of coastal fish at a reforested mangrove habitat than at a reclaimed sandy shore. Despite the port and industrialization at Perai and Juru, patches of mangrove estuary remain at both sampling stations, balancing the ecosystem. Hajisamae and Chou (2003) denoted that the estuarine of Johor Straits still serves as a vital nursery for fish despite being heavily affected by port facilities and reclamation for land expansion. According to a study by Edwards et al. (2001), despite receiving urban and industrial discharges, the extensive stretches of mangrove and seagrass habitats in Barker Inlet, South Australia, assist in sustaining the delicate balance of marine wetlands ecosystems.

Similarly, although Perai and Juru undergone urbanization such as industry and port activities, that most likely to disrupt the coastal ecology, and resulting in changes in the fish population (Erftemeijer et al. 2012; Khalaf & Kochzius 2002), the mangrove ecosystem at both stations might help in maintaining the fish abundance and diversity. The existence of estuarine and mudflat habitats associated with mangrove areas may assist in maintaining the high fish diversity despite being surrounded by urbanization. This study indicates that mangroves contribute to the ecosystem services that support fisheries in severely developed and fragmented landscapes (Benzeev, Hutchinson & Friess 2017).

Moreover, the nutrient enrichment from the port and industrial zone promotes algal growth, and subsequently increase the number of planktivorous fishes (Khalaf & Kochzius 2002). For instance, Sany et al. (2019) reported that nutrients especially dissolved inorganic nitrogen DIN (1.61 mg/L) and orthophosphate PO43- (0.11 mg/L) are high in West Port coastal water. This was evident in this study that recorded high abundance of the planktivores at Perai and Juru.

The present study involves the fish collection in spring and neap tides. According to Pulver (2017), the behavior of marine life is influenced by changes in the surrounding environment, such as seasons, tides, and moon phases. By contrast, the present findings show that the catches were slightly higher during neap tide than spring tide, suggesting that the moon phenomenon affects only certain marine fish species. The results follow the same pattern as Shah, Yusuf and Nor (2006). Hence, further research is needed to determine the actual influence of the moon phase on the fish presence at the sampling stations.

Conclusion

The diversity and distribution of fish assemblages at the Pulau Pinang strait are closely related to the surrounding activities that influence the biotic and abiotic relationships and other environmental factors. The modification of habitat structure due to anthropogenic activities such as urbanization and reclamation indirectly leads to differences in contemporary fish assemblage compared with natural shorelines such as mangrove estuaries. Understanding the impacts of reclamation activities on fish diversity is still ongoing. Gaps remain to quantify the effects of expanding reclamation activities and evaluate their trends over time. However, although the present study does not directly imply the impact of urbanization on fish assemblages, the low catch near ongoing reclamation projects can signal a disturbance.

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