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Spatial-Temporal Abundance and Diversity of Larval Fish in Different Water Bodies (Estuary and Adjacent Coastal Waters) from Sungai Terengganu, Terengganu, Malaysia

(Kelimpahan Ruang-Masa dan Kepelbagaian Larva Ikan dalam Badan Air Berbeza (Muara dan Perairan Pantai Bersebelahan) dari Sungai Terengganu, Terengganu, Malaysia)

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ABSTRACT

During larval form, various factors will affect the distributions of fish which lead to spatio-temporal variation of their assemblage. Studies on the variation provide knowledge in understanding the fish ecology. Present study aims to survey the fish larval occurrence in the estuary of Sungai Terengganu and its adjacent waters. A total of 402 larvae samples were collected using a 100 µm mesh sized Bongo net. About 334 samples were identified belonging to 23 families while the rest (equivalent to 16.92% of total catch) were unidentifiable. Three most abundant recorded families are Gobiidae (19.65% of total catch, 2.22 *indv.* 100 m^{-3}), Ambassidae (12.94% of total catch, 1.47 *indv.* 100 m^{-3}) and Apogonidae (9.45% of total catch, 1.02 *indv.* 100 m^{-3}). Based on cluster analysis, fish larvae were divided into two groups whereby one from estuary of Sungai Terengganu and another one from its adjacent coastal water with little overlapping between them. Estuary observed higher larval density than adjacent coastal waters while larval taxa diversity recorded to be higher in the adjacent coastal waters compared to the estuary. Throughout sampling months, two larval mean density peaks were observed during June 2019 (76.19 *indv.* 100 m^{-3}) and January 2020 (105.38 *indv.* 100 m^{-3}).

Keywords: Family composition; ichthyoplankton; spatial-temporal; South China Sea

ABSTRAK

Semasa dalam bentuk larva, pelbagai faktor akan mempengaruhi pengagihan ikan yang membawa kepada variasi himpunan ikan terhadap ruang-masa. Kajian ke atas variasi boleh menyediakan pengetahuan dalam memahami ekologi ikan. Kajian ini bertujuan untuk meninjau kejadian larva ikan di muara Sungai Terengganu dan perairan bersebelahannya. Sejumlah 402 sampel larva telah dikumpulkan dengan menggunakan Bongo net bersaiz mata pukat 100 µm. Sebanyak 334 sampel telah dikenal pasti kepunyaan kepada 23 famili manakala yang selebihnya (bersamaan dengan 16.92% jumlah tangkapan) tidak dapat dikenal pasti. Tiga rekod famili yang paling banyak ialah Gobiidae (19.65% jumlah tangkapan, 2.22 individu 100 m^{-3}), Ambassidae (12.94% jumlah tangkapan, 1.47 individu 100 m^{-3}) dan Apogonidae (9.45% jumlah tangkapan, 1.02 individu 100 m^{-3}). Berdasarkan analisis kelompok, larva ikan dibahagikan kepada dua kumpulan dengan satu di dalam muara dan lagi satu di perairan bersebelahannya. Muara merekodkan kepadatan larva yang lebih tinggi daripada perairan pantai bersebelahan namun kepelbagaian larva yang lebih tinggi telah ditunjukkan di perairan pantai bersebelahannya. Sepanjang tempoh persampelan, dua min puncak kepadatan larva telah diperhatikan iaitu pada Jun 2019 (76.19 individu 100 m^{-3}) dan Januari 2020 (105.38 individu 100 m^{-3}).

Kata kunci: Iktioplankton; komposisi famili; Laut China Selatan; ruang-masa

INTRODUCTION

The early life history of fish (eggs and larvae) usually termed as ichthyoplankton and interact with plankton community as part of the meroplankton in nature (Rodríguez, Alemany & García 2017). Fish larval stage is a transitory stage for fish where newly hatched larva undergoes metamorphosis, shedding larval features and resembling juvenile-adult characteristics. During this period, mortality rate of fish was extremely high as they are vulnerable to predators, oceanographic, biological, and anthropogenic activities (Holliday et al. 2012; Keane & Neira 2008; Smith et al. 2018). Besides, environmental factors like water temperature, salinity, dissolved oxygen level, water pH and water turbidity often influenced the abundances of fish larval community and leads to variation in spatial and temporal structure of ichthyoplankton assemblage (Morson, Grothues & Able 2019; Ramos et al. 2006). In fact, the assemblages of ichthyoplankton are crucial for the understanding of fish ecology as well as the fish recruitment (Govoni 2005; Swalethorp et al. 2015). Additionally, ichthyoplankton surveys can be an efficient tool to monitor regional fish communities and consequently supervising an appropriate fishery management (Auth & Brodeur 2013).

To date, numerous studies have been designed in surveying ichthyoplankton distribution in coastal and estuarine ecosystems. However, large gap of knowledge is still yet to be explored, especially in the tropical regions where studies are less progressive than in the temperate regions (Chu et al. 2019). In Malaysia, ichthyoplankton studies have been focusing on the west coast of Peninsular Malaysia. For example, Ooi and Chong (2011) observed 19 fish larval families in Matang Mangrove Estuary, Perak, Ara et al. (2013) recorded 20 fish larval families in Johor Strait, Johor and Chu et al. (2019) showed 21 fish larval families along Klang Strait, Selangor. However, as a country with long coastal line, there is still a big area has been overlooked, especially in the east coast of Peninsular Malaysia which contributed 19% of total fish landings for the country (DOF 2021).

Kuala Terengganu is a waterfront city located in the east coast of Peninsular Malaysia. The city pinpointed on the estuary of Sungai Terengganu which flows from Tasik Kenyir into Laut China Selatan (Suratman et al. 2018). Despite being a major political and economic centre to the Terengganu state, its geographic features encourage the development of fisheries industry, making it one of the important fishing ports in Peninsular Malaysia (Ruhaizan & Ishak 2007). However, like many other coastal cities, this city experiences rapid urbanization too. Recently, major construction of reclaimed area and Kuala Terengganu Drawbridge happened in the river mouth of Kuala Terengganu. This development project resulted the formation of small lagoon as breakwater structures were built along Kuala Terengganu coast to mitigate coastal erosion (Salim et al. 2018). In fact, urbanisation and constructions of coastal defences structures in coastal remodel the nature environment that eventually interrupted fish migration route (Firth et al. 2016) and changes the local fish communities (Macura et al. 2019). Nevertheless, the impacts of urbanization in Kuala Terengganu on native fish communities were unknown due to the absence of research data. In turn, surveillance on fish larval abundance provide an opportunity for monitoring native fish communities (Koslow & Wright 2016). Therefore, present study was designed as the preliminary study to explore the composition of fish larval family in Sungai Terengganu and adjacent water. The objective was to investigate the spatial temporal of fish larval family abundance, diversity and density that able to function as a reference for future studies.

MATERIALS AND METHODS

FISH LARVAL SAMPLES COLLECTION

Monthly sampling was carried out monthly from May 2019 until March 2020 in the waters around Sungai Terengganu. Four sampling stations were established along the main water channel of Sungai Terengganu and each sampling stations were approximately 3 km far from each other (Figure 1). Despite the fact that fish larval diversity varied with sampling time, sampling activities for the present study was designed for day collection only. Samples were collected during the day using a 100 μm mesh sized Bongo net, fitted with flow meter. The net was towed at a speed of 1 knot horizontally at approximately 0.5 m water depth. Samples in the collection bucket of net was washed down, filtered, and fixed into sample bottle with 95% ethanol immediately for further laboratory process (Ghaffar, Low & Talib 2010).

LABORATORY ANALYSIS

All fish larvae were first sorted out from other organisms under dissecting microscope. Fish larvae were grouped according to observable external morphology and identified to family level using available references following Ghaffar, Low and Talib (2010), Konishi et al. (2012), Leis and Rennis (1984), Leis and Trnski (1989), and Qiu (1999).

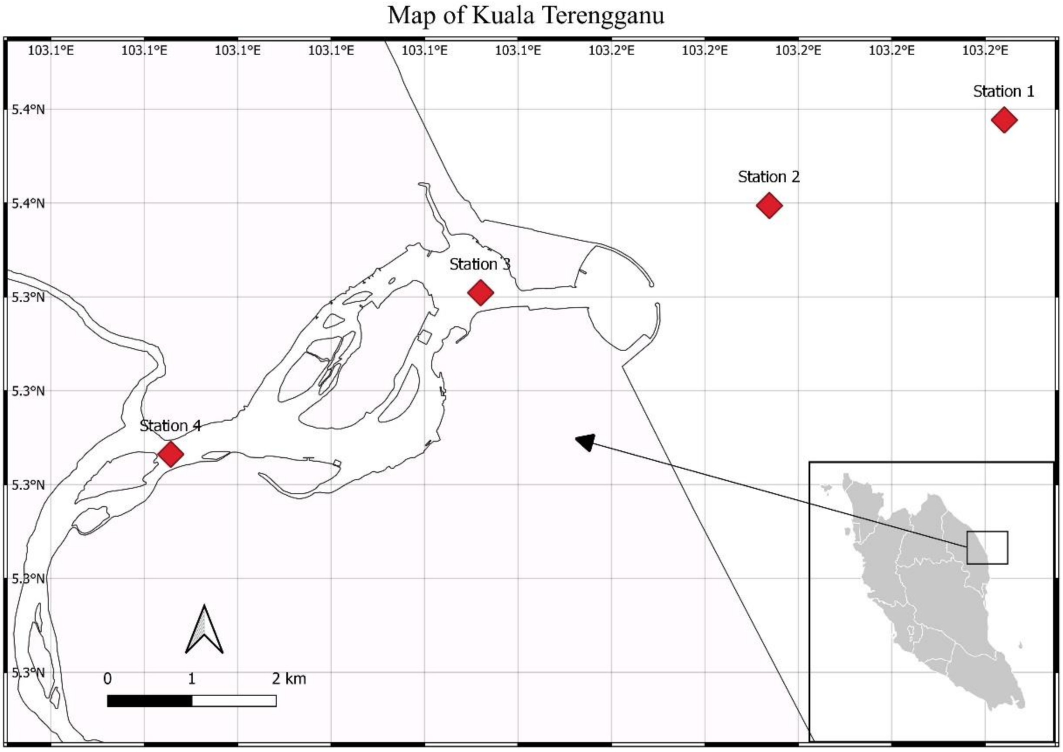


FIGURE 1. Map of sampling stations at the study site

BIODIVERSITY AND DATA ANALYSIS

Catch Index was calculated as n_i / N where n_i is the number of individuals in particular groups and N is the total number of specimens collected. Catch Index was used to express the number of individuals collected and hence the most abundant families can be determined. The fish larval density was calculated based on a standard volume of 100 m^{-3} (Ooi & Chong 2011).

To observe the spatial differences in the assemblage structure of fish larvae, multivariate analyses were performed with the PRIMER-6 software package (PRIMER-E, West Hoe, Plymouth, UK). A cluster analysis was conducted to investigate the spatial differences in the fish larval assemblage. Larval abundances were log(x+1)-transformed first to reduce weighting of dominant taxa (Clarke & Warwick 2001). Bray Curtis similarity was used to determine the assemblages with standardized data of station averages (Bray & Curtis 1957) and a 2-D visualization of assemblage structure in the study area was generated using multi-dimension scaling (MDS) (Kruskal & Wish 1978).

Furthermore, permutational multivariate analysis of variance (PERMANOVA) was performed using 9999 permutations to test for fish larval community differences between stations. The pair-wise tests between all stations will be performed if the PERMANOVA result rejected the null hypothesis of no differences in community structures between stations.

Several diversity indices were used in present study to compare fish larval taxa diversity from different bodies and months. Shannon-Weaver Index (Shannon & Weaver 1949) for taxa diversity, Pielou's Evenness Index (Pielou 1966) for taxa evenness and Menhinick Index (Menhinick 1964) for taxa richness were used in present study. The indexes were calculated as follows:

$$Shannon - Weaver\ Index, H' = -\sum_{i=1}^{S}(p_i \ln p_i)$$

$$Pielou's\ Evenness\ Index, J = \frac{H'}{H'_{max}}$$

$$Menhinick\ Index, D = \frac{S}{\sqrt{N}}$$

whereby p_i is the proportion of individuals of one species; S is the number of family; $\sum$ is the sum of calculations and H'$_{max}$ is the maximum diversity possible.

RESULTS AND DISCUSSION

TAXA COMPOSITION AND ABUNDANCE OF FISH LARVAE

A total of 402 fish larvae were collected. Morphological analyses identified 334 fish larvae belonging to 23 families. Meanwhile, 68 fish larvae which make up of 16.92% of the total catch failed to be verified because majority of these unidentified fish larvae were specimens with broken body parts which is equivalent to 9.45% of the total catch, followed by dried specimens, 4.48% and yolk-sac larvae 2.99%, respectively (Table 1). Among the 23 families, Gobiidae was the most abundant family, which contributed to 19.65% of the total catch, with an overall mean density of 2.22 *Indv.* 100 m^{-3}, followed by Ambassidae (12.94% of total catch, 1.47 *Indv.* 100 m^{-3}), Apogonidae (9.45% of total catch, 1.02 *Indv.* 100 m^{-3}), Clupeidae (5.72% of total catch, 0.47 *Indv.* 100 m^{-3}) and Mullidae (4.48% of total catch, 0.42 *Indv.* 100 m^{-3}) (Table 2). Other families that contributed less than 4% catches were Scombridae, Engraulidae, Terapontidae, Nemipteridae, Eleotridae, Carangidae, Atherinidae, Polynemidae, Sparidae, Blennidae, Soleidae, Sillaginidae, Bothidae, Serranidae, Lutjanidae, Malacanthidae, Pomacentridae and Pempheridae, arrange in descending order.

TABLE 1. Number of identified and unidentified fish larvae samples

Fish larvae	Total number of individuals	Percentage
Identifiable	334	83.08
Unidentifiable broken samples	38	9.45
Unidentifiable dried samples	18	4.48
Unidentifiable Yolk-sac larvae	12	2.99
Total	402	100.00

SPATIO-TEMPORAL VARIATION OF FISH LARVAE

In present study, an overall mean density of fish larvae was recorded at 9.85 *Indv.* 100 m^{-3}. Fish larval density differed significantly among the stations whereby Station 1 recorded the lowest value with 34.37 *Indv.* 100 m^{-3} while the highest larval mean density (140.89 *Indv.* 100 m^{-3}) was recorded at Station 3, followed by Station 2 (119.16 *Indv.* 100 m^{-3}) and Station 4 (99.66 *Indv.* 100 m^{-3}) (Table 2).

In Station 1, a total of 11 families were observed and fish larvae from family Mullidae and Nemipteridae recorded abundantly (4.77 *Indv.* 100 m^{-3}). Meanwhile, Station 2 recorded the highest family number (18 families), dominated by Clupeid larvae (15.28 *Indv.* 100 m^{-3}), followed by Scombrid and Engraulid larvae which both recorded mean density of 9.93 *Indv.* 100m^{-3} (Table 2). In addition, 15 families were observed at Station 3, dominated by Gobiidae (44.67 *Indv.* 100 m^{-3}), Apogonidae (26.35 *Indv.* 100 m^{-3}) and Ambassidae (16.04 *Indv.* 100 m^{-3}). Station 4 observed the least family number with only 6 families recorded whereby Gobiidae and Ambassidae observed abundantly with larval mean density of 41.24 *Indv.* 100 m^{-3}. Notably, several families were distributed and observed in several stations. For instance, larvae from family Ambassidae, Apogonidae and Mullidae were observed across all sampling stations. In addition, Gobiid larvae which found to be the most abundant family were mainly distributed at Stations 3 and 4 which are located at the estuary of Sungai Terengganu.

TABLE 2. Number of sampled fish larvae and their mean density (*Indv.* 100 m^{-3}) by family and stations

Family	Total number of larvae	Station				Overall mean density	Catch index
		1	2	3	4		
Gobiidae	79	0.00	3.06	44.67	41.24	2.22	0.1965
Ambassidae	52	0.95	0.76	16.04	41.24	1.47	0.1294
Apogonidae	38	0.95	5.35	26.35	8.02	1.02	0.0945
Clupeidae	23	0.00	15.28	1.15	2.29	0.47	0.0572
Mullidae	18	4.77	6.11	4.58	1.15	0.42	0.0447
Scombridae	15	1.91	9.93	0.00	0.00	0.30	0.0373
Engraulidae	13	0.00	9.93	0.00	0.00	0.25	0.0323
Terapontidae	13	3.82	6.87	0.00	0.00	0.27	0.0323
Nemipteridae	12	4.77	3.82	2.29	0.00	0.27	0.0299
Eleotridae	12	0.00	9.17	0.00	0.00	0.23	0.0299
Carangidae	12	0.00	7.64	2.29	0.00	0.25	0.0299
Polynemidae	8	1.91	4.58	0.00	0.00	0.16	0.0199
Atherinidae	8	2.86	1.53	3.44	0.00	0.20	0.0199
Sparidae	7	2.86	3.06	0.00	0.00	0.15	0.0174
Blennidae	6	0.00	0.00	6.87	0.00	0.17	0.0149
Soleidae	4	0.00	0.00	0.00	4.58	0.11	0.0100
Sillaginidae	3	0.00	0.76	2.29	0.00	0.08	0.0074
Bothidae	2	0.00	1.53	0.00	0.00	0.04	0.0050
Serranidae	2	0.00	0.76	1.15	0.00	0.05	0.0050
Lutjanidae	2	0.95	0.00	1.15	0.00	0.05	0.0050
Malacanthidae	2	0.95	0.00	1.15	0.00	0.05	0.0050
Pomacentridae	2	0.00	0.76	1.15	0.00	0.05	0.0050
Pempherididae	1	0.00	0.00	1.15	0.00	0.03	0.0024
Yolk-Sac Larvae	12	1.91	0.00	10.31	1.15	0.33	0.0299
Unidentified	56	5.72	28.26	14.89	0.00	1.21	0.1393
Total	402	34.37	119.16	140.89	99.66	9.85	1.0000

The observation from MDS diagram derived clearly that fish larvae in the study area were divided into two groups: (1) one cluster from nearby stations from estuary of Sungai Terengganu (Stations 3 and 4) and (2) another one from its adjacent coastal water (Stations 1 and 2) with little overlapping between both groups (Figure 2). Consequently, PERMANOVA result showed significant differences between stations (Pseudo-*F* = 2.6902; *P* = 0.0003) (Table 3). Hence, the null hypothesis was rejected, and pair-wise tests were performed. Results from pair-wise tests showed fish larval communities differ clearly from one another except for communities between Stations 1 and 2 (*t* = 0.9257, *P* = 0.505) as well as Stations 3 and 4 (*t* = 0.7837, *P* = 0.668) (Table 4). Notably, the pair-wise tests results were similar as the derivation from the MDS diagram.

In the aspect of temporal variation, two larval mean density peaks were observed in the month of June 2019 (76.19 *Indv.* 100 m^{-3}) and January 2020 (105.38 *Indv.* 100 m^{-3}) (Figure 3(A)). At the same time, the mean density of larvae Gobiidae and Ambassidae achieved the highest record (44.67 *Indv.* 100 m^{-3} and 42.38 *Indv.* 100 m^{-3}, respectively) in January 2020 (Figure 3(B)). Interestingly, among all recorded families, Gobiidae is the only family that occurred every month. Meanwhile, fish larvae from family Apogonidae were observed to be the most abundant in August 2019 (13.36 *Indv.* 100m^{-3}) while family Clupeidae occurred abundantly in November 2019 (11.46 *Indv.* 100m^{-3}) (Figure 3(C)). Notably, zero catch was recorded in the month of December 2019. This is due to sampling activity was unable to be carried out during monsoon season in year-end when all boat operation was forced to cancelled.

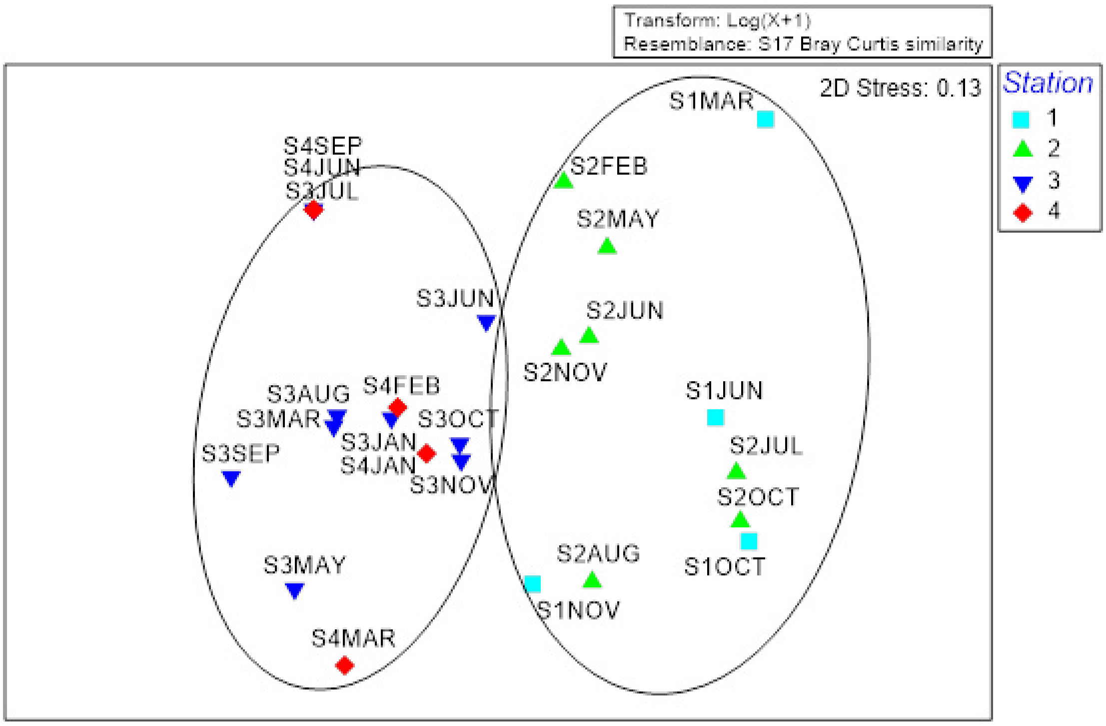


FIGURE 2. Multidimensional scaling (MDS) diagram of the fish larval assemblages in the study area associated with the Bray-Curtis similarity

FISH LARVAL DIVERSITY

Overall, Station 2 recorded the highest diversity index (H'=2.5119) based on the Shannon-Weaver Index analysis, whereas Station 4 has the lowest value (H'=0.4899). Meanwhile, Pielou's Evenness Index indicated the highest value was recorded at Station 1 (E=0.9279), followed by Station 2 (E=0.8691), Station 3 (E=0.6640) and Station 4 (E=0.2734). Although Station 1 recorded the least number of collected fish larvae (8.96% of the total catch), a total of 11 families occurred proven its high taxa richness. This can be indicated by the record of its highest Menhinick index value (D=2.0788) when compared between other stations (Table 5).

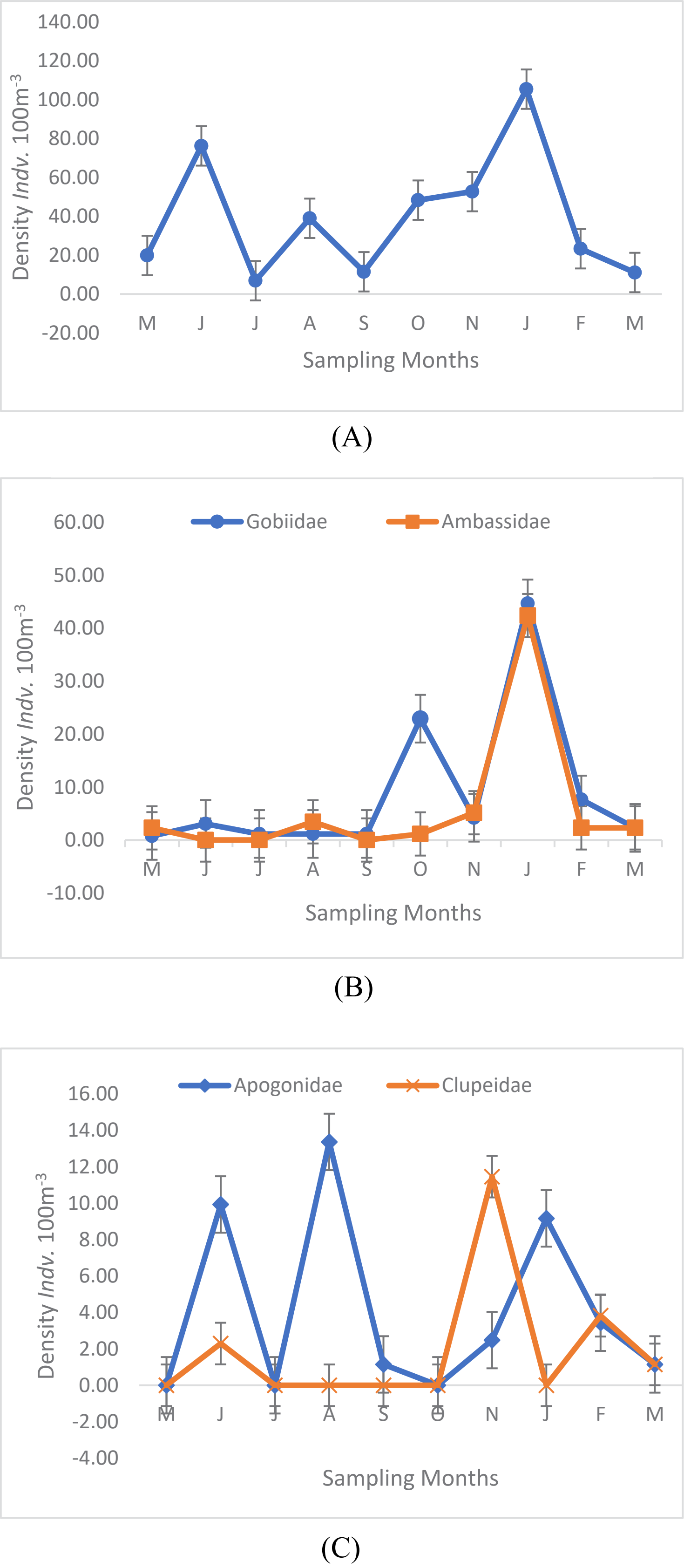


FIGURE 3. (A) Total mean larval density, (B) Total mean larval diversity of Gobiidae and Ambassidae, and (C) Total mean larval diversity of Apogonidae and Clupeidae in study area among sampling months

TABLE 3. PERMANOVA results based on fish larval densities from all stations with relative abundance >1% during sampling period

Source	df	SS	MS	Pseudo-*F*	P(perm)	Unique perms
Station	3	22222	7407.2	2.6902	0.0003	9920
Res	21	57822	2753.4			
Total	24	80044				

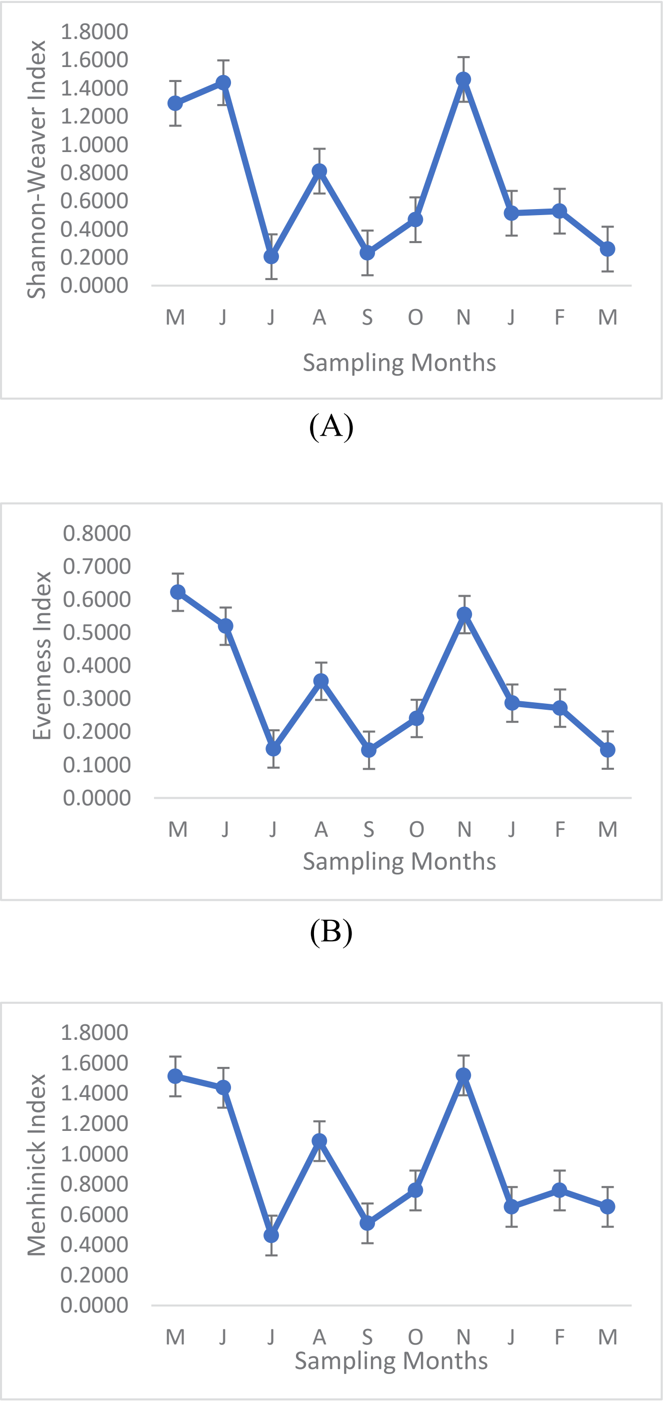
TABLE 4. Pair-wise tests between fish larval communities from all stations

Groups	t	P(perm)	Unique perms
2, 3	2.1543	0.001	956
2, 1	0.9257	0.505	314
2, 4	1.7927	0.005	456
3, 1	1.9244	0.004	531
3, 4	0.7837	0.668	588
1, 4	1.6555	0.015	91

Besides, Shannon-Weaver Index indicated two diversity peaks in June 2019 (H'=1.4399) and November 2019 (H'=1.4632) (Figure 4(A)). In the view of Pielou's evenness index, May 2019 recorded the highest taxa evenness (E=0.6220), followed by November 2019 (E=0.5545) (Figure 4(B)). Similar peaks were also indicated by the Menhinick index whereby May 2019 (D=1.5119) and November 2019 (D=1.519) (Figure 4(C)) were recorded. Surprisingly, though larval density was not the highest during the periods of May - June 2019 and November 2019, Shannon-Weaver and Menhinick Index during these two periods were observably higher than other months. This indicates these two periods are presenting higher larval taxa occurrence during the periods.

TABLE 5. Indices of diversity, evenness, and richness at four sampling stations

Station	Total fish larvae collected	Number of family	Shannon-Weaver Index (H')	Pielou's Evenness Index (E)	Menhinick Index (D)
1	36	11	2.2249	0.9279	2.0788
2	156	18	2.5119	0.8691	1.6164
3	123	15	1.7983	0.6640	1.7321
4	87	6	0.4899	0.2734	0.6508



(A)

(B)

(C)

FIGURE 4. Indices of (A) Shannon-Weaver, (B) Pielou's Evenness and (C) Menhinick indexes at the study area among sampling months

DISCUSSION

In the 1990's, ichthyoplankton survey conducted by Liew (1992) has recorded 61 families of marine fish larvae in the seas around Malaysia. Since then, numerous works were done progressively, focusing on the assemblages of fish larvae in coastal estuarine and mangrove sites for the past two decades, especially in the west coast of Peninsular Malaysia. For instance, Ooi and Chong (2011) in Perak, Ara et al. (2011) and Arshad et al. (2012) in Johor, and Chu et al. (2019) in Selangor. However, no studies have been conducted on ichthyoplankton assemblages in the east coast of Peninsular Malaysia.

As the preliminary study, present study recorded 23 families with five main families (Gobiidae, Ambassidae, Apogonidae, Clupeidae and Mullidae) cumulatively make up of 52.24% of the total larval collected. Some infrequently sampled family rated less than 4% of total samples. Similar results pattern can be comparable in other estuarine coastal sites studies in Malaysia. For example, 19 families recorded in Matang, Perak (Ooi & Chong 2011) and Pendas, Johor (Arshad et al. 2012), 20 families in Marudu Bay, Sabah (Rezagholinejad et al. 2016), and 21 families in Klang Strait, Selangor (Chu et al. 2019).

By comparing the fish larval diversity, Sungai Terengganu estuary (Stations 3 and 4) was lower than its adjacent coastal waters (Stations 1 and 2), whereas fish larval abundance was higher inside the estuary. The high larval abundancy inside the estuary is due to the occurrence of the numerically dominant Gobiid larvae. Gobiid larvae was also the only family occurred in every sampling month, indicating the Sungai Terengganu estuary as their spawning and nursery spot. Gobiid or known as the goby fishes are commonly found in the brackish waters though they may inhabit other water bodies (Shibukawa & Ghaffar 2011). In the survey done by Liew (1992), he reported Gobiid larvae was dominant in Malaysian waters especially in the waters from east coast of Peninsular Malaysia. Meanwhile, in the west coast, Ooi and Chong (2011) reported 50.10% of their collected fish larvae were Gobiid larvae in Matang Mangrove Forest Reserve, Perak. Similar results of high abundance gobiid larvae were also reported in several tropical estuaries in Ecuador (Shervette et al. 2007), Brazil (Katsuragawa et al. 2011), and Indonesia (Muzaki, Giffari & Saptarini 2017). The dominancy of Gobiids in estuaries was probably due to their adaptive life cycle towards hydrological variation and the presence of long larval phase (Keith 2003).

Three families namely, Ambassidae, Apogonidae, and Mullidae were found at all sampling stations, suggesting larvae from these families are widely dispersed across various water bodies. Ambassidae or known as the perchlets commonly invade freshwater and brackish estuary in aggregate form (Shibukawa 2011). The high abundance of Ambassid larvae in the estuary of Sungai Terengganu was expected as the mangrove forest provide great shelter to them. Interestingly, Apogonidae which are predominantly found in coral and rocky reefs, its fish larvae occurred extensively inside the estuary. Matsunuma and Shibukawa (2011) remarked certain groups of Apogonids in Terengganu inhabit fresh and brackish water though they are mostly found in coastal waters. Additionally, with the role of estuaries as nursery grounds, it may signify the possibility of Apogonid larvae to be exploited in the river mouth. Besides, Mullidae also known as goatfishes are usually recognized as demersal fish in shallow coastal water. Naturally, majority of demersal fish produce eggs which free-floating in the water surface. Beyond hatching, their larvae undergo metamorphosis and adapt to demersal habitat upon reaching certain size. Settlement of demersal fishes mostly happened in shallower separated areas from feeding grounds of the adult to minimize cannibalism (Bergstad 2009). Bottom sediments in the coast of Terengganu compromised of sandy muds (Shazili et al. 2007). This suggested the wide dispersed of Mullid larvae in present study as Uiblein (2007) reported the behaviour shifting of Mullidae from soft to hard bottom along their growth.

Besides being important nursery and feeding areas, estuary also serve as the migration route for diadromous fishes to their spawning sites (Elliott et al. 2007). Usually, fish migration relies on the water flow. High river flows with increased nutrients and food supply during wet seasons often encourage the entrance of fish larvae into their preferred nursery sites. However, in many coastal areas, barriers were built across the mouth of estuaries, resulting a complex estuarine-lagoon system (Sanvicente-Añorve et al. 2011). Sea barriers constructed might affect the river flow, interrupting the fish migration efforts and eventually impact the fish productivity. Unfortunately, the impact of the urbanization of Kuala Terengganu towards the local ichthyoplankton assemblages were untraceable as there was no previous report to be compared.

On the aspect of this, the study on the temporal variation of ichthyoplankton assemblages become an interesting knowledge. Study on the temporal variation of the fish larvae occurrence can be a quick tool for understanding the dynamics of fish assemblage and reproduction within the studied environment (Gogola et al. 2012). It was also observed a significant temporal difference in fish larval community between sampling months from present study. Similar findings were reported in other spatial-temporal variation focused studies whereby the assemblage of fish larvae vary significantly among months and seasons, affected by the abiotic conditions like water flow and temperature (Reynalte-Tataje et al. 2012), and biotic limits such as the zooplankton biomass (Zerrato & Giraldo 2018) in different period. Besides, several surveys proved that fish larvae change their vertical position in water for food resources and predator prevention during a diel cycle. Studies on the diel cycle effects on fish larval communities contributed knowledge on fish larval behaviour and their life histories (Lecchini et al. 2013; Lima, Barletta & Costa 2016). Therefore, future study design should consider sampling time for diel cycle results.

In the present study, the highest larval abundance was observed during January 2020 due to the high density of Gobiidae and Ambassidae larvae. Besides, Bonecker et al. (2009) and Gomes, Campos and Bonecker (2014) reported higher density of Gobiid larvae often occurred in estuary during flood (high tide), suggesting that larvae with little swimming ability will enter estuary with the assistance of tide flow. Meanwhile, Milton (2010) reported diadromous fishes like Ambassidae, Clupeidae and Gobiidae normally migrate for spawning during wet seasons in the tropical region. This phenomenon may explain the appearance of high larval density of Gobiidae and Ambassidae fish larvae during January 2020 when Kuala Terengganu experienced the annual Northeast Monsoon from November to March that bring heavier rainfall than usual and changed the estuary of Sungai Terengganu into a freshwater regime (Law & Jong 2006; Wong et al. 2016).

Lunar phase which affects the tidal amplitude was also observed to impact the fish larval abundances. Mwaluma, Kaunda-Arara and Rasowo (2014) reported the fish larval abundance differ with the tidal amplitude whereby higher abundance will occur during spring tide. There have been theories which hypothesised that fish spawn coincidently with tidal and moon phase as a reproduction strategy. During high tide, seawater indiscriminately flushes fish larvae and juvenile from adjacent waters into estuary (Joyeux 1999; Ramos et al. 2011; Vargas et al. 2003) while larvae mainly spawned and dispersed to reduce fatality rate from predators during new moon (Dufour & Galzin 1993). In a tropical estuary located in Brazil, Ramos et al. (2011) reported that the number of species and individual of fish larvae collected were significantly higher during new moon, suggesting that higher number of fish larval migration into the mangrove was correlated with the moon phase. However, Lima et al. (2015) observed different moon phase will effectively influence different groups of fish and a survey done by Díaz-Astudillo et al. (2017) concluded that the lunar phase affects the fish larval abundance considerably, but the effects are rather species-specific.

CONCLUSION

In summary, fish larvae from 23 families were recorded from the present study whereby family Gobiidae was the most dominant family. Cluster analysis indicated the fish larval community grouped into two clusters spatially: one inside the river and one at the adjacent coastal waters. Higher fish larval density was observed in estuary of Sungai Terengganu while the fish larval diversity was recorder higher in the adjacent coastal water. Among the sampling months, the highest larval density was observed in January 2020. According to the occurrence of fish larvae across different waters, Sungai Terengganu seem to be important site as well as migratory route for several fish groups. Despite this present study is the first survey on the fish larvae occurrence in Kuala Terengganu waters, this study alone is insufficient to provide full information on fish larval diversity in Kuala Terengganu. Therefore, we anticipate there is a need to conduct further survey to aid the knowledge of fish larvae in this area, including the relationship between environment parameters and the distribution of fish larvae species.

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