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Composition and diversity of larval fish in the mangrove estuarine area of Marudu Bay, Sabah, Malaysia

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Abstract

The composition of fish larvae and their diversity in different habitats are very important for fisheries management. Larval fishes were investigated in a mangrove estuary of Marudu Bay, Sabah, Malaysia from October 2012 to September 2013 at five different sites. Monthly samples of fish larvae were collected at five sampling sites by a plankton net with a mouth opening of 40.5 cm in diameter. In total, 3879 larval fish were caught in the investigated area. The mean density of ichthyoplankton at this area was 118 larvae/100 m^3. The fish larval assemblage comprised of 20 families whereas 13 families occurred at St1, 16 at St2, 16 at St3, 12 at St4 and 16 at St5. The top major families were Sillaginidae, Engraulidae, Mugilidae and Sparidae with Sillaginidae consisted 44% of total larval composition. St3 with 143 larvae/100 m^3 had the highest density amongst the stations which was due to higher abundance of Sillaginidae. Shannon-Wiener diversity index represented significant variation during monsoon and inter-monsoon seasons, peaking in the months December-January and May-June. However, Shannon-Wiener index, evenness and family richness showed significant differences among stations and months ($p < 0.05$).

Key words

Composition, Diversity, Fish larvae, Malaysia, Marudu Bay, Sabah

Introduction

Information on the larval fish composition a spatial-temporal patterns of diversity in an area will help greatly in the management of capture fisheries in order to identify fish breeding grounds in an ecosystem (Kidwai and Amjad, 2001). According to Arshad et al. (2012), understanding factors that influence fish larvae distribution and abundance is one of the best ways to provide valuable information to fisheries managerial bodies, fisheries scientists and marine biologists in order to find ways to protect fishery resources, especially in tropical and subtropical areas. Fish larvae survival is an indicator of healthiness of fish (Deepananda and Arsecularatne, 2013). Identification of fish larvae will help to have good policies for fisheries management and also having good control on marine ecosystem (Kawaguchi, 2003). The survival of fish larvae is based on biological factors such as food availability, spawning area and predation affecting their distribution, abundance and diversity (Moser and Smith, 1993; Ooi, 2012).

Estuaries are recognised as main nursery grounds for many species of fishes but large-scale studies on spatial and temporal patterns of use are lacking (Strydom, 2014). Information on the composition and diversity of larval fish in estuarine systems is still limited in Malaysia, however a few studies have focused on fish larval recruitment in an estuary area (Ooi, 2012). Studies of the ecology of larval fishes is immensely useful to investigate the place of spawning of fish in space and time, feeding habitats of larvae, nursery habitats during larval stages, and the condition of fish larval assemblage within an estuary (Ooi and Chong, 2011). Nearshore larval fish assemblages are complex in relation to both species composition and distribution patterns (Harris et al., 1999; Hickford, 2000; Sponaugle et al., 2002; Ara et al., 2011). Many marine fish, especially larvae and juveniles, live

in seagrasses, mangroves and estuary ecosystems as nursery areas during these early life stages due to predator numbers is low and food resources is high that tends to improve survival and development (Ara et al., 2013). Environmental variation in mangrove estuary can affect on the structure of fish larvae community (Ooi, 2012).

Several studies on ichthyoplankton have been conducted in Malaysia. For example, Arshad et al. (2012) found two spawning peaks from December to January and from May to August in Pendas River estuary, Malaysia. Ooi and Chong (2011) reported at least 19 families of fish larvae in the waters of Matang mangrove area and between 15-17 families were caught from the mangrove ecosystem and offshore waters, respectively. However, similar studies have not been conducted in the estuarine ecosystems of Eastern Malaysia. Therefore, the principal aim of the study was to determine the diversity, abundance and distribution of fish larvae in the estuarine ecosystem of Marudu Bay, Sabah, Malaysia.

Materials and Methods

Study sites : The present study was conducted in the waters of Marudu Bay, Sabah, Malaysia (Fig. 1). Five stations were selected for sampling: St1 (N 06º 36.169; E 116º 46.400), St2 (N 06º 36.651; E 116º 48.895), St3 (N 06º 36.700; E 116º 47.775), St4 (N 06º 36.751; E 116º 47.816) and St5 (N 06º 37.502; E 116º 47.775). Global positioning system (GPS) were used for recording those stations which were positioned in outer side of mouth of river in Marudu Bay. All sampling sites situated at a distance of 1 km away from each other (Fig. 1).

Habitat characteristics : Environmental variables (Table 1) were analyzed for the assumptions of normality. Parametric tests were used to all the variables and found to be normally distributed. After confirming homogeneity of variance, an analysis of variance (ANOVA) indicated significant ($p < 0.05$) variations in the environmental parameters among the five stations except for dissolved oxygen (DO) and pH.

Field sampling : All monthly sampling from October 2012 till September 2013 were done during the daytime and high tide. A plankton net with 40.5 cm mouth diameter were used to sample fish larvae (Fig. 2) that was towed for 20 min at each station. The samples were preserved in 5% formalin solution after each tow and immediately brought to the laboratory for further analysis. In situ water parameters such as dissolved oxygen (DO) (mg/L), temperature (^{0}C), salinity (ppt), conductivity (mS/cm) and pH were examined during each sampling time by using an environmental monitoring system (YSI 556 MPS).

Sample processing and identification : Fish larvae were sorted and removed from the zooplankton using a Nikon dissection microscope and they were preserved in 5% formalin. Identification of different larval fishes to the family level was done according to literature Russell (1976); Kawaguchi (2003); and Leis and Carson-Ewart, 2000. Numbers of larvae in each family were counted and then the larval abundance in each sample were reached to a density per 100 m^3 based on the flow meter reading.

Data and statistical analysis : In order to calculate diversity of fish larvae assemblage Shannon-Wiener index (Shannon and Weaver, 1963) was used, species richness was calculated according to Margalef (1958) and Evenness (J) was calculated by Pielou, (1966). Between station variations in dissolved oxygen, temperature, salinity, pH, conductivity, density and diversity of larval fishes were analyzed by one-way analysis of variance (ANOVA) at 0.05 significance levels. Physical and biological data were tested for normality and homogeneity of variance and the whole testing and measurements were done with using SPSS software version 19 and PRIMER (Plymouth Routines Multivariate Ecological Research) (Clarke and Warwick, 1994).

Results and Discussion

Fish larval composition and temporal abundance : In total, 3879 larval fish were caught in the investigated area. The fish larval assemblage comprised of 20 families. The mean density of ichthyoplankton at this area was 118 larvae/100 m^3. Sillaginidae larvae with 44% contribution was the family which had the highest abundance that is followed by Engraulidae (14%), Mugilidae (12%) and Sparidae (10%). Of the total larvae catch, 3.63% were unidentified (Table 2).

Four dominant families (Sillaginidae, Engraulidae, Mugilidae and Sparidae) were observed consistently throughout the year in the investigated area (Fig. 3-4). Sillaginidae were observed on a monthly bases in October (Fig. 4), particularly during the inter-monsoon season and their breeding time. The second most abundant family was the Engraulidae and peaked in abundance during November, coinciding with the northeast monsoon (wet season).

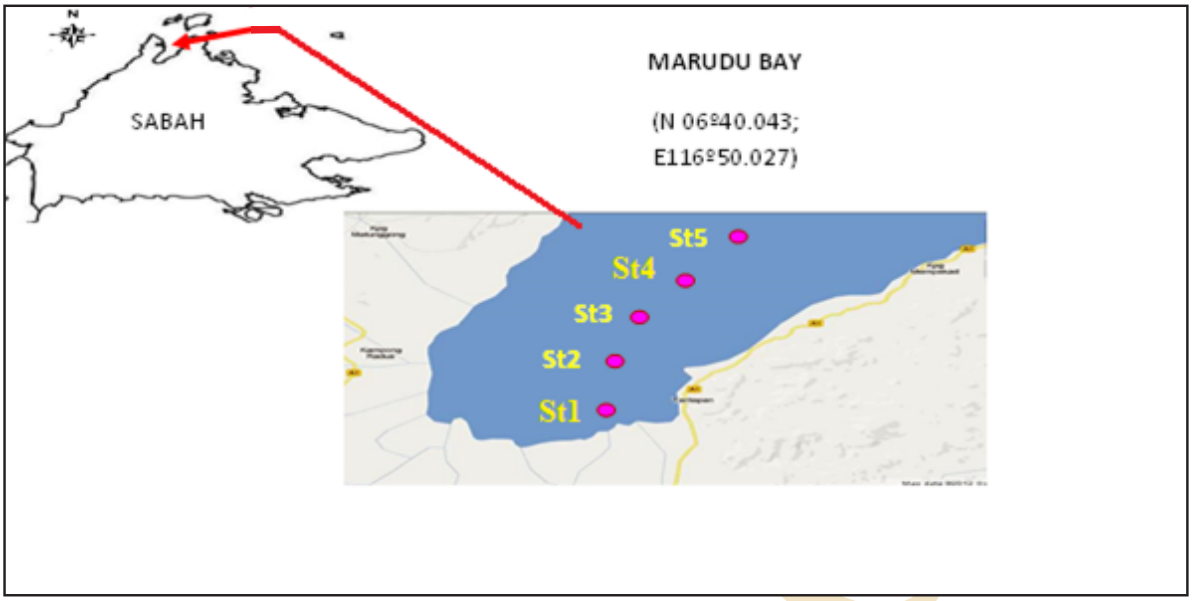

Fig. 1 : Sampling area in the waters of Marudu Bay, Sabah, Malaysia

Fig. 2 : Plankton net (Mesh size 350 µm, mouth diameter 0.405 m and length 1.70 m) was used to catch fish larvae in the waters of Marudu Bay, Sabah, Malaysia

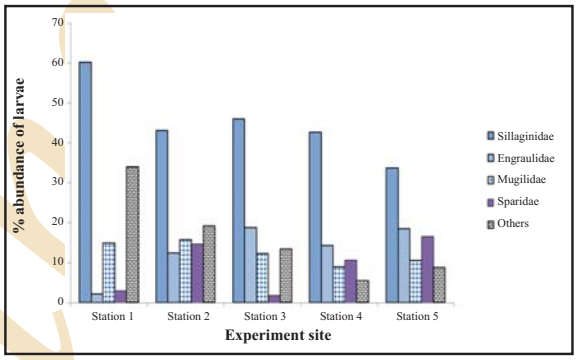

Fig. 3 : Spatial variation of top four families in the study areas of Marudu Bay, Sabah, Malaysia

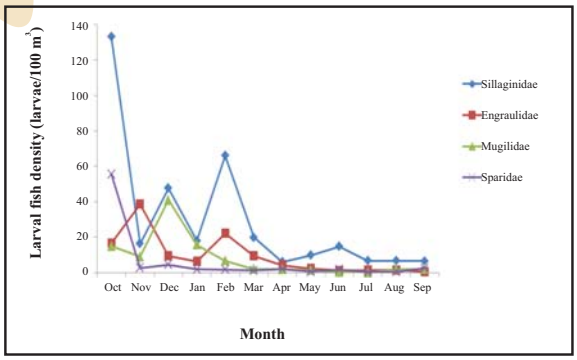

Fig. 4 : Temporal variation of top four families in the study areas of Marudu Bay, Sabah, Malaysia

Table 1 : Physico-chemical water characteristics of different sampling stations in the mangrove estuary of Marudu Bay (Mean ± SD)

Parameters	St-1	St-2	St-3	St-4	St-5	P
Temp. (^{0}C)	30.64 ± 0.22	30.51 ± 0.27	30.25± 0.41	29.80± 0.33	29.50± 0.23	**0.049***
DO (mg l^{-1})	6.79 ± 0.47	6.74 ± 0.38	6.82 ± 0.38	6.93 ± 0.41	6.99 ± 0.60	**0.995**^{NS}
Salinity (ppt)	24.43 ± 1.38	26.46 ± 0.85	28.74 ±0.66	27.56 ±1.20	28.08 ±1.12	**0.054***
pH	7.64 ± 0.07	7.68 ± 0.10	7.59 ± 0.10	7.47 ± 0.10	7.52 ± 0.13	**0.545**^{NS}
Con. (mS cm^{-1})	41.00±1.66	44.79±1.13	47.63 ±1.05	45.10 ±1.64	45.95 ±1.65	**0.034***

For each environmental variable, means with the same superscripted letter are not significantly different. *The mean difference is significant at 5% level; NS, not significant at 5% level.

Table 2 : Composition of fish larval density among the different sampling stations

Family	Mean density (Larvae/100 m^3)					Mean total (%)	Body length (mm) Mean±SE	Range
	St1	St2	St3	St4	St5			
Blenniidae	1.36	1.04	1.04	0.50	0.42	0.72	2.31± 0.10	2.10- 2.54
Bothidae	-	0.14	-	-	0.13	0.05	-	-
Carangidae	0.51	0.31	1.34	2.64	2.23	0.01	3.07±0.19	2.54-3.50
Centriscidae	-	-	-	-	0.13	0.03	-	-
Clupeidae	1.68	0.45	1.49	3.14	1.12	1.29	4.44±0.20	3.84-5.38
Cynoglossidae	-	0.45	0.75	-	0.70	0.34	7.57±1.83	3.70-11.00
Engraulidae	2.03	14.35	26.98	16.21	23.44	14.31	4.72±0.10	3.22-6.30
Gobiidae	2.7	3.28	4.03	3.47	5.73	3.27	2.00±0.08	1.42-2.56
Mugilidae	14.03	18.25	17.75	10.26	13.26	12.40	2.62±0.04	2.12-3.52
Mullidae	1.01	1.2	1.49	4.78	1.81	1.70	2.55±0.06	2.22-2.84
Pegasidae	-	-	0.14	-	-	0.03	-	-
Platycephalidae	4.56	2.39	4.47	2.48	3.90	2.99	2.43±0.07	2.60-3.28
Pomacentridae	-	0.14	0.75	0.50	0.84	0.39	2.51±0.07	2.27-2.67
Scatophagidae	-	2.10		-	0.13	0.39	8.81±0.51	5.30-10.2
Sciaenidae	0.67	0.90	2.24	3.63	5.31	2.19	2.12±0.07	1.74-2.50
Scombridae	-	0.31	-	-	-	0.05	-	-
Sillaginidae	56.78	49.79	65.90	48.28	42.41	44.01	2.45±0.05	2.40-2.50
Sparidae	2.88	17.04	2.68	12.07	20.93	9.59	3.98±0.06	2.10-5.52
Syngnathidae	0.16	-	0.30	-	-	0.08	4.55±0.11	3.14-5.84
Terapontidae	2.03	-	6.12	-	-	1.37	11.15±0.15	11.00-11.3
unidentified	3.89	3.28	5.96	5.12	3.48	3.63	2.66±0.06	2.30-3.20
Total number	558	772	962	684	903	-		
Total family	13	16	16	12	16	-		
Total density/100 m^3	94.29	115.42	143.43	113.07	125.96	118.43		

Larval fish diversity : The highest mean diversity index value (1.41) was found at St5 and lowest (1.04) was appeared at St1 (Fig. 5b). The highest mean evenness (0.82) was found at St4 and St5 and the lowest (0.70) was at St1 (Fig. 5c). Family richness shown the highest mean (1.49) at St3 while in St 1 was found with lowest mean (1.10) (Fig. 5d). Shannon Wiener Index, evenness and Family richness showed significant differences ($p < 0.05$) among the five stations (Fig. 5a-d).

The highest mean density of fish larvae at 294/100 m^3 was recorded in December (wet season) (Fig. 6a). Temporal variations in larval density varied significantly ($p < 0.05$) among the different months. The Shannon-Wiener Index indicated one peak in December-January (wet season) (Fig. 6b). The Evenness Index clearly showed two important peaks, (April and August-September) (Fig. 6c). Family richness also showed the highest peak in June (Fig. 6d).

In total, larvae belonging to 20 fish families were observed in Marudu Bay mangrove estuarine, Sabah, Malaysia. Same results were also reported by Ooi and Chong (2011), who found 19 families including Blenniidae, Carangidae, Clupeidae, Cynoglossidae, Engraulidae, Gobiidae, Mullidae, Mugilidae, Scatophagidae, Syngnathidae and Terapontidae in the Matang mangrove estuary, Malaysia. Ara et al. (2013) identified a total of 24 families, which were sampled in the seagrass-mangrove

ecosystem of Gelang Patah, Johor Strait, Malaysia. Eleven common families such as Blenniidae, Carangidae, Clupeidae, Cynoglossidae, Engraulidae, Gobiidae, Mullidae, Scatophagidae, Sillaginidae, Syngnathidae and Terapontidae occurred in this study are same with the exploration of Ara et al. (2013). Larval fish abundance has been influenced by food availability and fish larvae distribution (Deepananda and Arsecularatne, 2013). Moreover, this study approved that the estuarine ecosystems are the main spawning area for aquatic organism.

In a previous study it was found that abundance of Sillaginidae was at most during May (Ara et al., 2013). The second highest family was Engraulidae and the highest peak abundance was observed in November (Fig. 4), during the time that this family may have their highest spawning activities. Two species of Engraulidae were reported from the Matang mangrove of Malaysia (Ooi and Chong, 2011).

The spatial patterns of larval fish abundance and distribution are related to their reproductive strategies such as location and spawning of the adults (Ara et al., 2013). Adequate food and less predation pressure are two main elements effecting the abundance of larval fish (Moser and Smith, 1993). Temporal changes in the species composition, diversity and abundance are also important for larval fish assemblage in estuaries (Ooi, 2012). Other parameters which can affect larval fish abundance in estuaries are food resources accessibility, currents, protection from predators and chemical and physical factors, which may also make the estuary a suitable nursery area for many fishes (Leis, 1991).

Information on fish eggs and larvae is very useful in fisheries biology regarding their reproductive period (Miller and Kendall, 2009). On the basis of the egg and larval occurrence of a particular species, it is possible to determine the probable spawning time of the species (Miller and Kendall, 2009). Community of fish larvae in the Marudu Bay

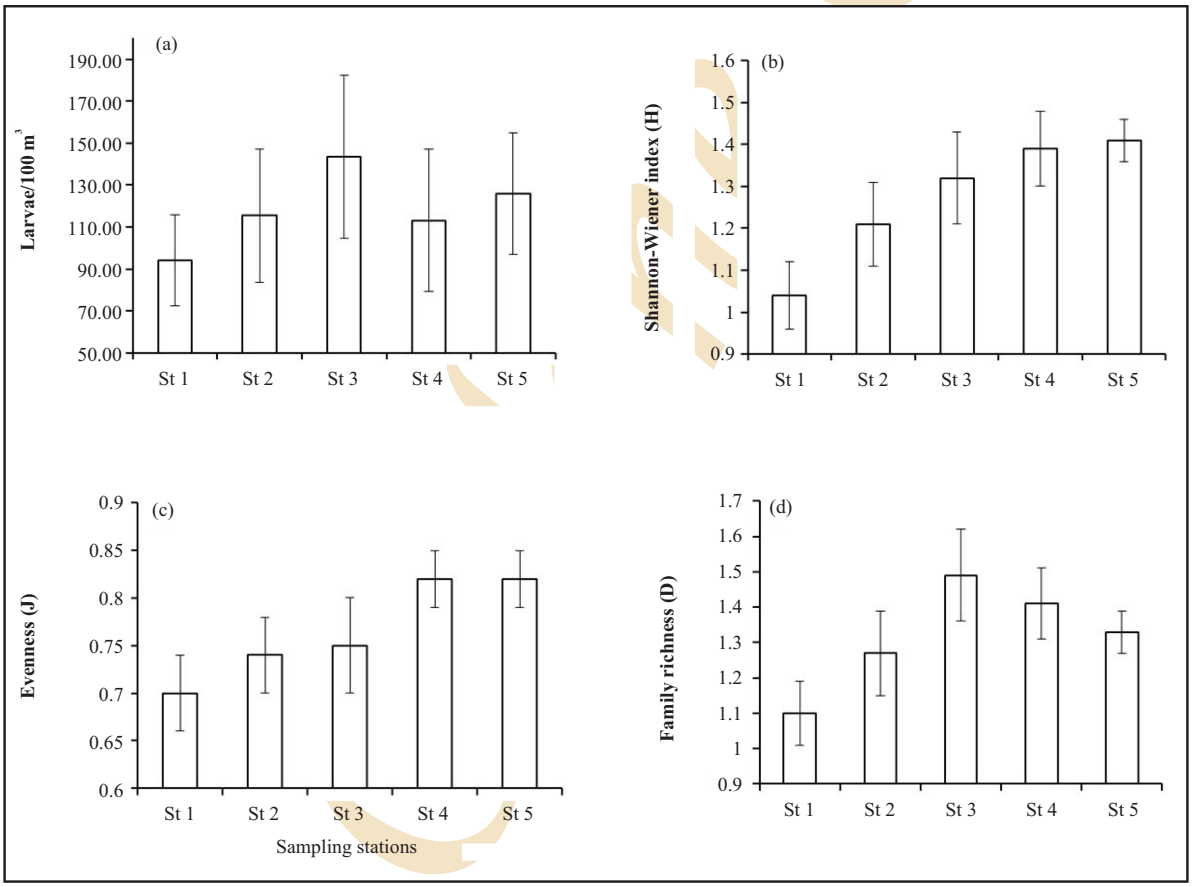

Fig. 5 : Spatial variations in a) Fish larval diversity (Larvae/100 m^3), b) Shannon-Wiener Index (H) of diversity, c) Evenness (J) and d) Family richness (D) for fish larvae assemblages in Marudu Bay, Sabah, Malaysia; Values are mean + SE derived from 5 sampling stations

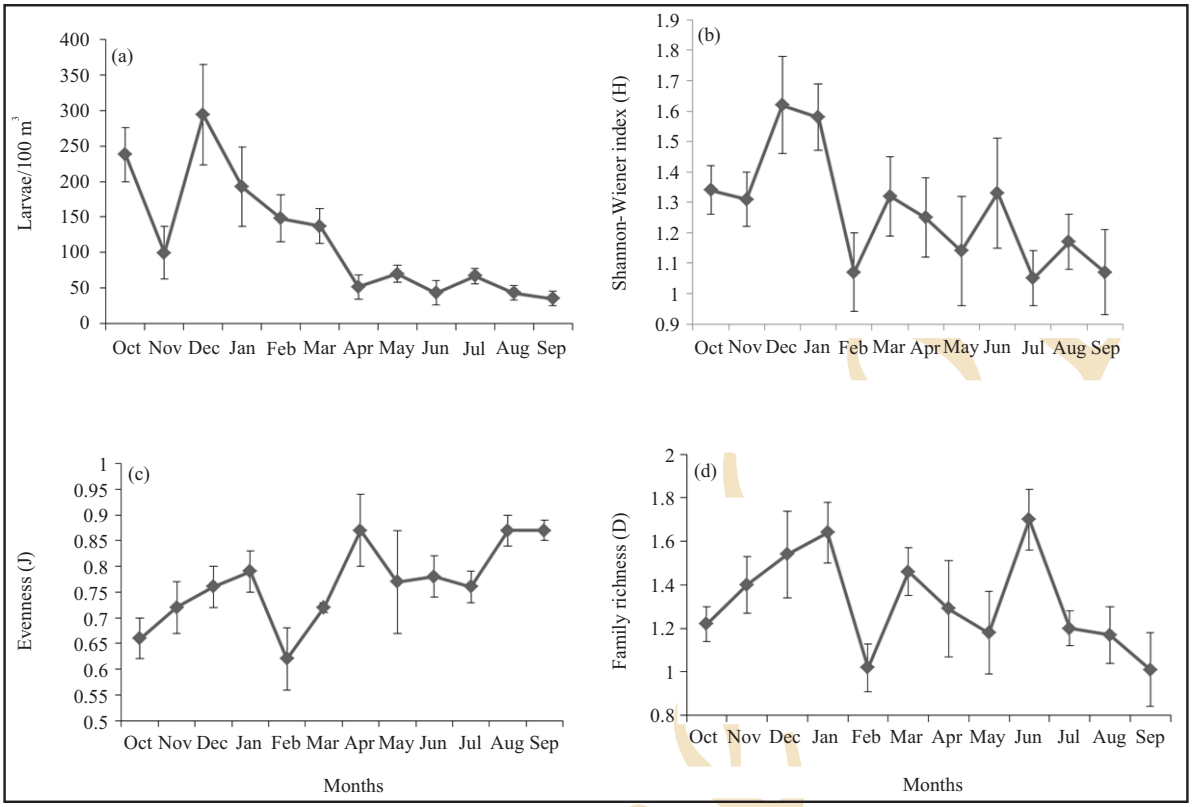

Fig. 6 : Temporal variations in a) Fish larval diversity (Larvae/100 m^3), b) Shannon-Wiener Index (H) of diversity, c) Evenness (J) and d) Family richness (D) for fish larvae assemblages in Marudu Bay, Sabah, Malaysia; Values are mean + SE derived from 12 months cruises

estuary is basically same with those estuarine fishes found by Amin et al. (2014), except for five families. This is due to larvae migrating to the estuary because predator numbers is low and food resources is high. Considering that status of estuarine and marine is gradually shifting in Marudu Bay, then a suitable categorization is highly difficult. Fish larvae in Marudu Bay can be classified into three different group. The first group are Estuarine group which are located in mangrove estuary for spawning and feeding, for example Syngnathidae and Gobiidae. The second group are Marine euryhaline group, they spawn in the sea and their larvae use mangrove estuary as nursery habitat; which includes two categories, those who enter at larvae stage, for example Terapontidae, Carangidae and Engraulidae, and those who enter at juveniles stage, for example Mugilidae. The third group are Stenohaline group, they spawn in the offshore waters but their larvae use the mangrove estuary only at the dry season period, for example Soleidae and Cynoglossidae.

It is known that in tropical areas, monsoon winds are the key elements in existing of various kinds of monsoon seasons, with any kind has different time period and characteristic (Poovichiranon and Satapoomin, 1994; Suryana, 1997). Based on Malaysian Meteorological Department (2012), there are four major monsoon season in Malaysia, from May to September is the Southwest monsoon time (dry season), from November to March is Northeast monsoon (wet season) and there are two inter-monsoonal season which has short duration.

In summary, the seasonal (temporal) and sites (spatial) diversity are two main factors influencing the fish community at tropical areas (Whitfield, 1999; Blaber, 2000). The present work evident that the temporal patterns of larval abundance was significantly higher during the wet season due to availability of huge amount of food resources such as zooplankton and crustacean larvae which motivate lots of fish migrate to the estuarine area for spawning which is supported by Boonruang and Janekarn (1985); Robertson *et al.* (1988).

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