

The influence of environmental parameters on fish larval distribution and abundance in the mangrove estuarine area of Marudu bay, Sabah, Malaysia

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Abstract

The aim of this study was to estimate the influence of selected environmental parameters on the fish larval distribution and abundance between October 2012 and September 2013 in the Mangrove estuarine area of Marudu bay, Sabah, Malaysia. Fish larvae samples were collected monthly using plankton net of 350 μm of mesh size with a mouth opening of 40.5 cm in diameter through 20 min surface tows. Five different stations were chosen in this study. In total 3,879 larvae, belonging to 20 families were recorded, with a mean abundance of 118 larvae per 100 m^3 . Among 20 families, top four families such as Sillaginidae (44%), Engraulidae (14%), Mugilidae (12%) and Sparidae (10%) occurred consistently around the year in the study areas. Sillaginidae was the most abundant larval fish families. *In situ* environmental parameters such as water temperature, dissolved oxygen (DO), salinity, pH and conductivity were recorded during the sampling times. Significant variations were found in the environmental parameters among the five stations except DO and pH ($p < 0.05$). It is revealed that mainly four families (centriscidae, Engraulidae, Mugilidae, and Sillaginidae) were significantly influenced by the abiotic factors. Of the environmental parameters recorded, salinity appeared to be the main factor affecting the distribution and abundance of Mugilidae families. Overall, regression analysis test indicated a weak overall correlation between larval assemblage and environmental parameters in the estuary of Marudu Bay.

Keywords: Fish larval, Environmental parameters, Mangrove estuarine, Marudu Bay, Malaysia

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Introduction

Marudu bay is located at Northern part of Sabah, Malaysia which is largely fringed with mangroves, making it abundant with numerous types of commercially important aquatic species (Azim *et al.*, 2015). Mangrove estuarine areas are uniquely interesting for many environmentalists as they face continuous and dramatic fluctuations of various environmental parameters due to the input of freshwater and marine water at various time scales, human activities and major climatic disturbances (Blaber, 2000). Most estuary-dependent marine fishes enter these systems during the postflexion stage of their larval phase (Whitfield, 1999; Ooi and Chong, 2011). Some species remain in these nursery estuaries until they are sexually mature (Elliott and Hemingway, 2008). Mangrove estuaries are ecosystems described by environmental fluctuations and directly will have an important influence on the structure of the larval fish assemblages (Feller and Sitnik, 1996; Lee, 1999; Ooi and Chong, 2011). Successful recruitment and retention of fish larvae in estuaries which function as nursery areas are strategies adopted by the early life stages of many fish species (Boehlert and Mundy, 1988; Islam and Tanaka, 2006).

According to Arshad *et al.* (2012) a great understanding of fish larvae is often the best technique to provide information of major value to fisheries management, fisheries science and

marine biologists. Fish larvae can be a useful sign on the condition and health of an aquatic environment (Deepananda and Arsecularatne, 2013). The distribution of fish larvae in estuaries is dependent on a number of factors; including habitat condition, salinity, water temperature, turbidity, seasonality (Whitfield, 1999). The environmental parameters and fish larvae assemblage are directly affected by several elements which may have impact on the growth, food resources, survival, abundance and distribution of the taxa (Pombo *et al.*, 2005). Identification of significant associations between fish fauna and environmental condition is the first step towards incorporating habitat information into fish abundance (Perry *et al.*, 1994; Pombo *et al.*, 2005).

Although the species composition, distribution and seasonal variation of larval fishes of the mangrove estuarine area have been well documented, but there is no previous work has been done in the waters of Marudu Bay. There is only some information on adult fish and juveniles rather than larval stage. The importance of mangrove estuarine as nursery and feeding ground for many marine fishes are well researched in tropical areas (Ara *et al.*, 2013). Therefore, the present study was undertaken to improve the knowledge of the fish larval assemblage changes influencing by different habitats and abiotic factors in the mangrove estuarine area of Marudu bay, Sabah, Malaysia.

Materials and methods

Study site and sampling

The study was conducted at Marudu Bay in the coastal waters of Kota Marudu, Sabah, East Malaysia (Fig. 1). The sampling activities were carried out during daylight when tides were high, one time each month from October 2012 to September 2013. The coastline of Kota Marudu is short (70 km) compared to the other districts in Sabah, with only 4 km along the mainland, 33 km along lagoons and 33 km along islands. The stations for this study were located just outside a river mouth of Bandau River in Marudu Bay with coordinates for latitude and longitude for each station was recorded by using a Global Positioning System (GPS). There were five sampling stations (St-1 - N 06° 36.169' E 116° 46.400', St-2 - N 06° 36.651' E 116° 48.895', St-3 - N 06° 36.700' E 116° 47.775', St-4 - N 06° 36.751' E 116° 47.816' and St-5 - N 06° 37.502' E 116° 47.775') for the study. St-1 was the nearest station to the river mouth while

St-5 was the farthest. The distance interval between each sampling station was about 1 kilometer. The plankton net was towed from the subsurface for 20 min. *In situ* water parameters such as Temperature (°C), dissolved oxygen (mg/L), salinity (ppt), pH and conductivity (mS/cm) were recorded during every sampling time by using an environmental monitoring system (YSI 556 MPS).

Sample processing

In the laboratory, fish larvae were sorted and immediately preserved in 5% formalin. Larvae were identified to the family level using the appropriate literature (Russell, 1976; Okiyama, 1988; Leis and Carson-Ewart, 2000; Ghaffar *et al.*, 2010). Numerical estimation of larval abundance of different families were counted under a dissecting microscope from the sample. The raw catch data of larvae from each collection were standardized to number per 100 m³ based on flow meter readings.

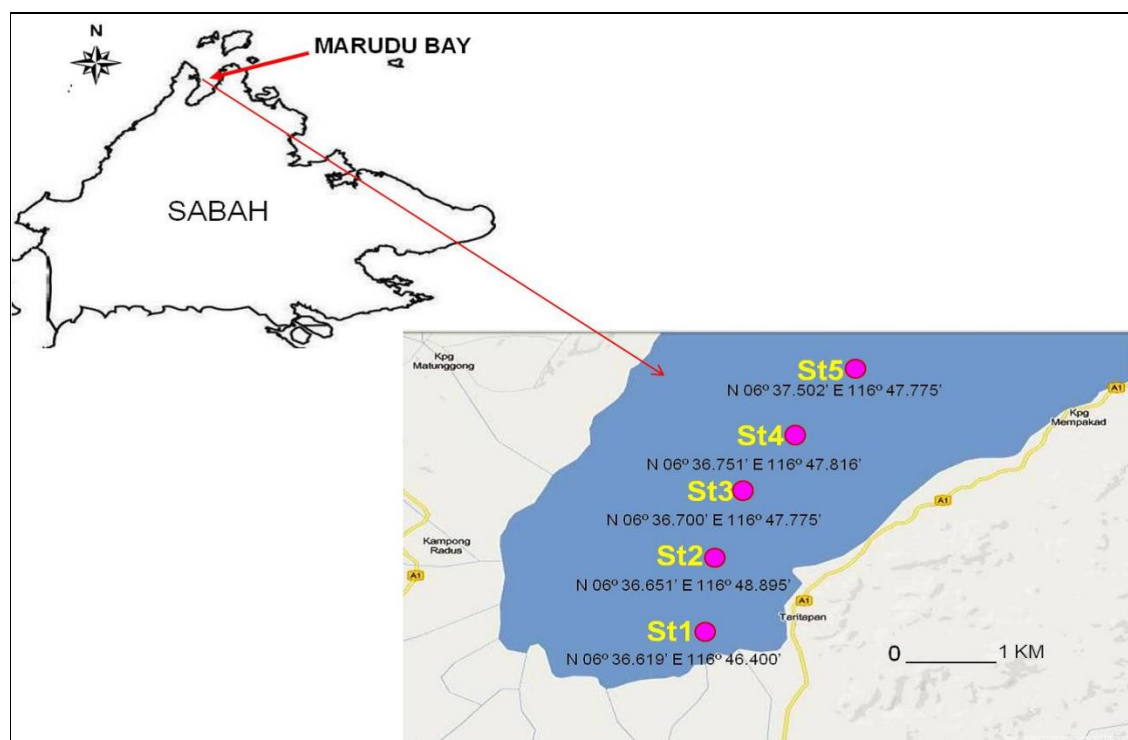


Figure 1: Geographical location of the sampling sites in the waters of Marudu bay, Sabah, Malaysia.

Data analysis

Between-station variations in temperature, dissolved oxygen, salinity, pH, conductivity were analyzed by one way analysis of variance (ANOVA). Pearson's correlation coefficients and multiple regressions between fish larvae families and abiotic factors were done using SPSS version 19.

Results

Environmental parameters

The annual means variation and F-values of each environmental parameter at the different five stations of the estuarine area of Marudu Bay are presented in Table 1. Mean temperature at St-1 was significantly higher than

other stations. Water temperature less than 30 °C were recorded at St-4 and 5 (Table 1). The average of dissolved oxygen increased slightly from St-3 to St-5 (Table 1). As predicted, mean salinity was more marked at St-3 where sampling was done near to the Sea. A higher fluctuation of pH was observed at St-2 within the estuary. The highest and lowest mean of conductivity was recorded at St-3 and St-1, respectively. However, analysis of one-way ANOVA indicated a significant ($p < 0.05$) variations were found in the environmental parameters among the five stations except DO and pH (Table 1).

Table 1: Annual mean variation+SE and F-values (derived from analysis of variance) of each parameter at the five different stations.

| Parameters | St-1 | St-2 | St-3 | St-4 | St-5 | P |
|------------------------------|--------------------------|---------------------------|---------------------------|---------------------------|--------------------------|--------|
| *Temp. (°C) | 30.64 ^a ±0.22 | 30.51 ^a ±0.27 | 30.25 ^{ab} ±0.41 | 29.8 ^{ab} ±0.33 | 29.5 ^b ±0.23 | 0.049* |
| DO (mgL ⁻¹) | 6.79±0.47 | 6.74±0.38 | 6.82±0.38 | 6.93±0.41 | 6.99±0.60 | 0.995 |
| *Salinity (ppt) | 24.43 ^b ±1.38 | 26.46 ^{ab} ±0.85 | 28.74 ^a ±0.66 | 27.56 ^{ab} ±1.20 | 28.08 ^a ±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 |
| *Con. (mS cm ⁻¹) | 41 ^b ±1.66 | 44.79 ^{ab} ±1.13 | 47.63 ^a ±1.05 | 45.1 ^{ab} ±1.64 | 45.95 ^a ±1.65 | 0.034* |

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

Composition of larval fish community

In total 3,879 larvae belonging to 20 families were recorded (Table 2). Sillaginidae was the most abundant family which contributed 44% of total fish abundant which was followed by

Engraulidae (14%), Mugilidae (12%) and Sparidae (10%). Five families such as Centriscidae, Pegasidae, Scombridae, Bothidae and Syngnathidae were less common in the present study (Table 2).

Table 2: Composition and abundance (expressed as the mean total of larvae/100 m³) of larval fishes in the mangrove estuarine area of Marudu Bay, Sabah, Malaysia.

| Family | Genus | Total larvae | Mean total (larvae/100 m ³) | Percentage (%) |
|---------------------|----------------------|--------------|---|----------------|
| Blenniidae | | 28 | 5.60 | 0.72 |
| Bothidae | <i>Asterohombus</i> | 2 | 0.40 | 0.05 |
| Carangidae | | 46 | 9.20 | 0.01 |
| Centriscidae | | 1 | 0.20 | 0.03 |
| Clupeidae | | 50 | 10 | 1.29 |
| Cynoglossidae | <i>Cynoglossus</i> | 13 | 2.60 | 0.34 |
| Engraulidae | | 555 | 111 | 14.31 |
| Gobiidae | | 127 | 25.40 | 3.27 |
| Mugilidae | | 481 | 96.20 | 12.40 |
| Mullidae | | 66 | 13.20 | 1.70 |
| Pegasidae | <i>Pegasus</i> | 1 | 0.20 | 0.03 |
| Platycephalidae | | 116 | 23.20 | 2.99 |
| Pomacentridae | | 15 | 3.75 | 0.39 |
| Scatophagidae | <i>Scatophagus</i> | 15 | 3 | 0.39 |
| Sciaenidae | | 85 | 17 | 2.19 |
| Scombridae | | 2 | 0.40 | 0.05 |
| Sillaginidae | | 1707 | 341 | 44.01 |
| Sparidae | <i>Acanthopagrus</i> | 372 | 74.40 | 9.59 |
| Syngnathidae | | 3 | 0.60 | 0.08 |
| Terapontidae | | 53 | 10.60 | 1.37 |
| unidentified | | 141 | 28.20 | 3.63 |
| Total larvae | | 3879 | 775.8 | 118.43 |

Influence of abiotic factors on larval abundance

The abundance of 20 families was found to be positively or negatively correlated with the water parameters which are presented in Table 3. It is found that five families (Engraulidae, Gobiidae, Mugilidae, Sparidae and Sillaginidae) were negatively and significantly correlated with temperature ($p<0.01$). Sillaginidae ($r=0.38$) showed significant ($p<0.01$) positive correlation with salinity while it was negatively and significantly correlated with Centriscidae ($p<0.01$). It was found that the five families (Engraulidae, Gobiidae, Mugilidae, Sparidae and Scatophagidae) were significantly correlated with salinity

($p<0.05$) (Table 3). Centriscidae and Mugilidae were significantly correlated with dissolved oxygen ($p<0.01$). However it was negatively correlated with Clupeidae ($p<0.05$). Positive and highly significant correlations were found between pH and four families that included Clupeidae ($r=0.34$, $p<0.01$), Gobiidae ($r=0.41$, $p<0.01$), Mugilidae ($r=0.67$, $p<0.01$) and Sillaginidae ($r=0.49$, $p<0.01$). It was also shown that pH had a positive and significant correlation ($p<0.05$) with four families (Platycephalidae, Engraulidae, Sparidae and Syngnathidae). Conductivity showed a negative and significant correlation with only Centriscidae ($p<0.01$) (Table 3).

Table 3: Correlation coefficient (r) between abiotic and biotic factors in the mangrove estuarine area of Marudu Bay, Sabah, Malaysia.

| Family | Temperature (°C) | Salinity (ppt) | Do (mgL ⁻¹) | pH | Conductivity (mS cm ⁻¹) |
|-----------------|------------------|----------------|-------------------------|--------|-------------------------------------|
| Blennidae | 0.16 | -0.12 | 0.03 | 0.07 | -0.01 |
| Bothidae | -0.03 | -0.09 | 0.14 | -0.13 | -0.01 |
| Carangidae | 0.03 | -0.09 | 0.06 | 0.13 | -0.08 |
| Centriscidae | -0.02 | -0.35** | 0.47** | -0.08 | -0.37** |
| Clupeidae | -0.18 | 0.07 | -0.28* | 0.34** | -0.11 |
| Cynoglossidae | -0.16 | 0.16 | -0.25 | 0.22 | 0.14 |
| Engraulidae | -0.39** | 0.26* | 0.09 | 0.28* | 0.17 |
| Gobiidae | -0.36** | 0.33* | -0.26* | 0.41** | 0.16 |
| Mugilidae | -0.39** | 0.26* | -0.36** | 0.67** | 0.03 |
| Mullidae | -0.16 | 0.15 | -0.20 | 0.32* | 0.01 |
| Pegasidae | -0.02 | -0.05 | 0.20 | -0.17 | -0.11 |
| Platycephalidae | -0.15 | 0.18 | -0.08 | 0.27* | 0.02 |
| Pomacentridae | -0.22 | 0.23 | -0.07 | 0.08 | 0.12 |
| Scatophagidae | 0.23 | -0.26* | -0.02 | -0.05 | -0.19 |
| Sciaenidae | -0.14 | -0.12 | 0.12 | 0.07 | -0.21 |
| Scombridae | -0.20 | 0.16 | -0.12 | 0.21 | 0.10 |
| Sillaginidae | -0.45** | 0.38** | -0.22 | 0.49** | 0.17 |
| Sparidae | -0.33** | 0.28* | -0.20 | 0.33* | 0.17 |

Table 3 continued:

| | | | | | |
|--------------|-------|------|-------|-------|------|
| Syngnathidae | -0.06 | 0.11 | -0.17 | 0.28* | 0.07 |
| Terapontidae | -0.21 | 0.23 | -0.18 | 0.23 | 0.10 |

* Significant at 0.05 level, ** Significant at 0.01 level

A multiple regression of 20 families with abiotic factors (temperature, salinity, dissolved oxygen, pH and conductivity) was done to observe more specific correlations between the abundance of fish larvae with the water parameters (Table 4). The multiple regression coefficients (R^2) between water parameters and abundance of larval fish families ranged from 0.04 to 0.52 (Table 4). The highest and most significant regression coefficient ($R^2=0.52$, $p<0.05$) was found in Mugilidae which showed 52% abundance of Mugilidae were influenced by water parameters remaining 48% by other factors. Salinity was the main factor in Mugilidae larvae density. The second

highest regression coefficient ($R^2=0.37$, $p<0.05$) was observed in Sillaginidae that indicated 37% abundance of Sillaginidae were directly related with water parameters and 63% for other factors. The second highest regression coefficient were found in fish larval families of Centriscidae and Engraulidae by ($R^2=0.32$, $p<0.05$) and ($R^2=0.27$, $p<0.05$), respectively.

Analyses of individuals families and their associated environmental variables indicated that salinity had a significant effect ($p<0.05$) on larval fish density in the mangrove estuarine area of Marudu Bay (Table 4). pH also had a significant ($p<0.05$) effect on catches in the mangrove estuarine area of Marudu Bay.

Table 4: Multiple regression equation of 20 families with abiotic factors in the mangrove estuarine area of Marudu Bay, Sabah, Malaysia.

| Multiple regression equations | R^2 | P |
|--|-------|------|
| Platycephalidae Y= - 33.93 + 0.54Tem + 0.65Sal + 0.26Do + 2.19pH - 0.37Cond | 0.15 | 0.11 |
| Sciaenidae Y= 10.65 - 0.38Tem + 0.01Sal + 0.22Do + 0.68pH - 0.10Cond | 0.09 | 0.37 |
| Blennidae Y= - 4.17 + 0.03Tem - 0.14Sal - 0.01Do + 0.53pH + 0.08 Cond | 0.07 | 0.52 |
| Carangidae Y= - 8.02 + 0.00Tem - 0.09Sal + 0.12Do + 1.26pH + 0.02Cond | 0.04 | 0.80 |
| Centriscidae Y= 0.55 - 0.02Tem - 0.01Sal + 0.04Do + 0.03pH - 0.00Cond | 0.32 | 0.00 |
| Clupeidae Y= - 9.69 + 0.07Tem + 0.24Sal - 0.30Do + 1.93pH - 0.24Cond | 0.20 | 0.03 |
| Cynoglossidae Y= 1.89 - 0.10Tem - 0.05Sal - 0.08Do + 0.24pH + 0.03Cond | 0.11 | 0.29 |

Table 4 continued:

| | | | |
|---------------|--|------|------|
| Engraulidae | $Y = 28.48 - 5.72\text{Tem} - 0.34\text{Sal} + 3.26\text{Do} + 14.13\text{pH} + 0.73\text{Cond}$ | 0.27 | 0.00 |
| Gobiidae | $Y = -16.11 - 0.98\text{Tem} + 0.45\text{Sal} - 0.19\text{Do} + 5.83\text{pH} - 0.16\text{Cond}$ | 0.26 | 0.01 |
| Mugilidae | $Y = -94.89 - 1.42\text{Tem} + 0.89\text{Sal} - 0.77\text{Do} + 21.03\text{pH} - 0.72\text{Cond}$ | 0.52 | 0.00 |
| Mullidae | $Y = -22.57 + 0.18\text{Tem} + 0.32\text{Sal} - 0.11\text{Do} + 2.59\text{pH} - 0.21\text{Cond}$ | 0.14 | 0.16 |
| Sparidae | $Y = 21.55 - 4.59\text{Tem} + 0.02\text{Sal} - 0.49\text{Do} + 14.46\text{pH} + 0.36\text{Cond}$ | 0.18 | 0.05 |
| Pegasidae | $Y = 0.11 + 0.01\text{Tem} + 0.02\text{Sal} + 0.02\text{Do} - 0.06\text{pH} - 0.01\text{cond}$ | 0.10 | 0.35 |
| Pomacentridae | $Y = 1.191 - 0.07\text{Tem} + 0.11\text{Sal} + 0.03\text{Do} - 0.03\text{pH} - 0.04\text{cond}$ | 0.08 | 0.47 |
| Scatophagidae | $Y = -1.18 + 0.14\text{Tem} - 0.08\text{Sal} - 0.11\text{Do} + 0.00\text{pH} + 0.00\text{Cond}$ | 0.10 | 0.34 |
| Scombridae | $Y = 0.19 - 0.04\text{Tem} - 0.00\text{Sal} - 0.00\text{Do} + 0.12\text{pH} + 0.01\text{Cond}$ | 0.07 | 0.52 |
| Sillaginidae | $Y = -114.84 - 7.86\text{Tem} + 3.56\text{Sal} + 1.35\text{Do} + 44.17\text{pH} - 1.34\text{Cond}$ | 0.37 | 0.00 |
| Bothidae | $Y = 1.75 - 0.05\text{Tem} - 0.03\text{Sal} + 0.01\text{Do} - 0.05\text{pH} + 0.02\text{Cond}$ | 0.08 | 0.51 |
| Syngnathidae | $Y = -1.44 + 0.01\text{Tem} + 0.00\text{Sal} - 0.01\text{Do} + 0.16\text{pH} + 0.00\text{cond}$ | 0.08 | 0.44 |
| Terapontidae | $Y = -14.62 - 0.04\text{Tem} + 0.46\text{Sal} - 0.11\text{Do} + 1.92\text{pH} - 0.21\text{Cond}$ | 0.11 | 0.29 |

Discussion

Estuaries are ecosystems characterized by environmental fluctuations (Whitfield, 1990). The changes in salinity and other water parameters such as temperature, pH, dissolved oxygen and conductivity occur due to the effects of tides and mixing of marine and fresh water (Marshall and Elliott, 1998). There are still few studies why many fish species and larvae are attracted to mangrove habitats (Ara *et al.*, 2013). The main

environmental factors which could influence the growth rate include salinity, temperature and food availability (Ooi and Chong, 2011; Sponaugle *et al.*, 2006; Admassu and Ahlgren, 2000).

The number of Ichthyoplankton families in the mangrove estuarine area of Marudu Bay was 20 but four families, Sillaginidae, Engraulidae, Mugilidae and Sparidae made up 80.3% of the total larval abundance. This showed that diversity of larval fishes

was uneven. Some rarely caught families such as Centriscidae, Pegasidae, Scombridae, Bothidae and Syngnathidae accounted for less than 1% of the total larvae. Little diversity of larval fishes has been similarity reported in other estuarine around the world. For example, 19 families were identified in the Matang estuaries, Malaysia (Ooi and Chong, 2011), 26 families in Sabah and Sarawak estuaries, Malaysia (Blaber *et al.*, 1997), 19 families in Pendas river mangrove estuary, Malaysia and 25 families in North Brazilian mangrove creeks (Barletta-Bergan *et al.*, 2002). In general, the number of larval fish families between these studies at different system varied greatly. This may be due to differences in sampling time, sampling method and habitat heterogeneity. Furthermore, each estuarine system may have a different abiotic environment which contributed to the different families.

The influence of water temperature and other parameters including salinity, pH, dissolved oxygen and conductivity were directly different among the 20 families in the estuarine area of Murudu Bay, Sabah, Malaysia. In KwaZulu-Natal, Harris and Cyrus (1995) noticed that the larval fish assemblages were correlated with the environmental factors such as temperature, salinity, and turbidity at the time of recruitment. In Taiwan estuaries, the abundance of *Acanthopagrus schlegelii* larvae was positively correlated with salinity and dissolved oxygen and negatively

correlated with water temperature (Huang and Chiu, 1998). Salinity is well known to affect the development and stress level of marine fishes (Chesalina *et al.*, 2013). The mean salinity inside the estuarine area of Marudu Bay fluctuated between 24.4‰ and 28‰. These were related to the increasing salinity from upstream stations to offshore stations in the estuarine area of Marudu Bay (5 km from river mouth). Ooi and Chong, (2011) also reported that salinity showed high correlation on abundance of fish larvae during the study.

The correlation coefficients between the tested water parameters and fish larvae were not similar for individual species in the estuarine area of Marudu Bay. The families, Engraulidae, Gobiidae, Mugilidae, Sparidae and Sillaginidae tended to stay at higher temperature, salinity, dissolved oxygen and pH. However, the mainly four families, Centriscidae, Engraulidae, Mugilidae and Sillaginidae were significantly ($p < 0.05$) influenced by abiotic factors. The present study also shows the higher and significant regression coefficient ($p < 0.05$) for Mugilidae where larval fishes showed preference for higher salinity. Even though salinity have been shown to be important factor in attracting larval fishes into the estuarine area of Marudu Bay, some studies do not agree (Ooi and Chong, 2011). However, the result of this study likely indicates that habitat structure was more important in

determining larval abundance compared to water quality at the tested sites.

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