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DIVERSITY OF BIVALVES IN MANGROVE FOREST, TOK BALI KELANTAN, MALAYSIA

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ABSTRACT

A study on the diversity and some ecological aspects that related to the abundance of infaunal bivalve species was done at Tok Bali mangrove, Kelantan, Malaysia. Samples and data collection was conducted during three different seasonal periods, on dry season (July), pre-monsoon (September) and monsoon (December) in the year 2005. Sampling stations were chosen in four mangrove forests which were encompassed with *Rhizophora* spp., *Avicennia* spp., *Nypa fruticans* and Mixed Mangrove. A collection of bivalve samples and sediment samples were done within 0.25 m^2 quadrates and measurement of physico-chemical parameters were conducted using Hydrolab Quanta. Temperature, salinity and pH showed the normal mangrove value and decreased during monsoon, while dissolved oxygen show increasing during monsoon. Mean of grain size (ø) value ranged from 1.9 to 2.66 indicated that the sediment is fine sand. Mean TOM ranged from 0.67-1.45 g/g. A total of five (5) species of infaunal bivalves were observed, which were *Polymesoda expansa, Marcia japonica, Gari ambigua*, *Pillsbryoconcha exilis* and *Donax faba.* Diversity index H' ranges from 0.72-1.27 and evenness index E' ranged from 0.53-0.95 and richness index varied from 0.42-0.78. ANOVA tests showed that there were no significant differences for all biodiversity indices during dry, pre-monsoon and monsoon season (P>0.05). The results showed the low biodiversity of infaunal bivalves in the mangroves of Tok Bali. They could be more affected by the spatial factors rather than the monsoon. Long-term data collection is suggested to determine the seasonal pattern of their biodiversity and contribution to the mangrove ecosystem in the area.

KEYWORDS

Bivalves, diversity, mangroves, Tok Bali, Kelantan.

1. INTRODUCTION

Bivalve mollusk constituted a large part of the biomass of macroinvetebrates in the mangrove. Several species of bivalve that are noted can be found in the mangrove environment of Peninsular Malaysia, are *Geloina coaxans, Geloina ceylonica, Grassostrea cuculata, Ostea* spp. and *Phascolosoma lurco.* Alongi believed that benthic studies are greatly needed in the tropics so as to provide some basic data for comparison to be made for any critical disorders that may arise in the future [1]. The recent study was done in the Economic Exclusive Zone (EEZ) Sarawak [2]. Depth, sediment grain size, salinity and predation density could be the factors in controlling the population density of macrobenthos. Among the factors, sediment size and predator density being the most important factors influence the macrobenthos density. In bivalves, this could be due to their responses to burrowing activity whenever there are changes in Geo-environmental condition [3]. Many studies have gained insight into the physical factors that determine the geographical distribution of benthic macrofauna on tidal flats. On an estuary-wide scale, such patterns are related to the salinity gradient, and to variations in bathymetry, hydrodynamics and sediment characteristics [4].

Most bivalves are suspension feeders that do not extend above the mean high-water neap tide level in vertical distribution. Concerning bivalve biomass and abundance at Obidos Lagoon, Portugal, it was observed that the suspensivorous group appears in the less organic and more productive sediments; the detritivorous group is clearly associated with less productive and more organic bottoms, and the third group seems to be independent of these factors [5].

The aim of this study was to estimate the diversity of bivalves in the mangroves in Tok Bali, Pasir Putih Kelantan. The mangroves were exposed to the tidal cycle of the South China Sea and also received freshwater from the Semarak River. It is expected that the abundance and diversity to be influenced by the environmental factors.

2. METHODOLOGY

2.1 Study Area

Kelantan is a state located on the East Coast of Peninsular Malaysia bordering Thailand. Situated between latitude of 04° 35.00' E to 06°28.00'N and longitude 101°20.00'E to 102°40.00'E. The study area is a mangrove forest located in Tok Bali, Kelantan. It is a part of delta of Semerak River. Mangrove forest distribution mainly found at the estuary and along the riverbank until 4.2 km from the river mouth. The areas are frequently inundated by high tides. The study areas consist of old mangrove and new forming mangrove area. The new forming mangrove area is due to the raising of the bridge and the water breaker at the estuarine mouth [6].

Stations for sample collection were marked according to mangrove zonation (Figure 1). Four (4) transects were established at 4 different mangrove types which are *Nypa fruticans, Avicennia* spp., *Rhizophora* spp. and Mixed Mangrove. Stations were fixed followed the GPS (Global Positioning System) as shown in Table 1.

Table 1: Summary of sampling station and the GPS

Station	GPS
Station 1(*Nypa fruticans*)	N 05° 51.507', E 102° 30.28'
Station 2 *(Avicennia* spp.*)*	N 05° 51.22', E 102° 30.473'
Station 3 (Mixed Mangrove)	N 05° 51.656', E 102° 30.908'
Station 4 (*Rhizophora* spp.)	N 05° 51.737, E 102° 30.809'

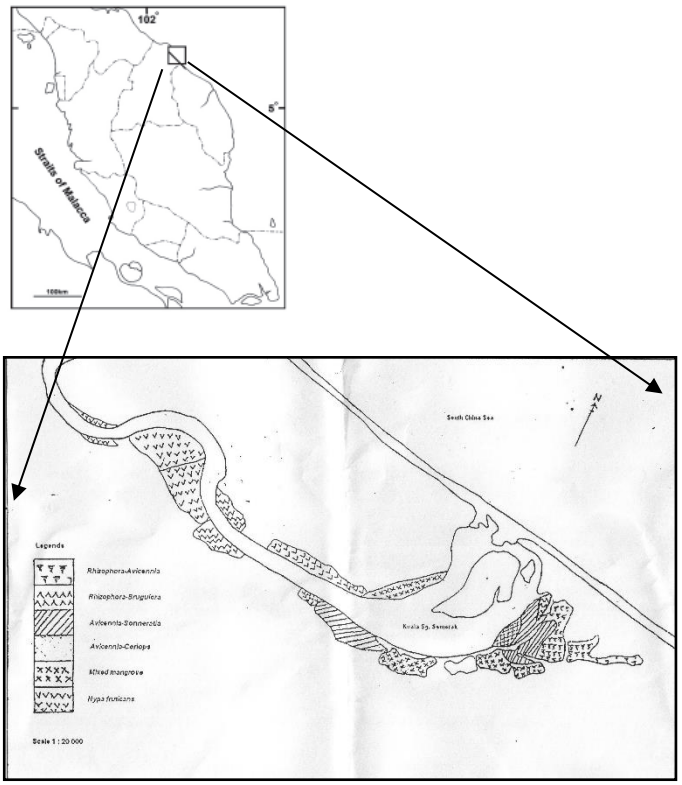

Figure 1: Map of mangrove forest area at Kg.Tok Bali, Kelantan.

2.2 Field sampling

Three (3) sampling sessions were carried out in July, September and December. July represented dry season, September represented pre-monsoon season while December can be categorized as a monsoon. Sampling was done during these different seasons to compare if the monsoon has a significant effect on environmental changing in mangrove area or on the diversity and abundance of bivalves.

2.2.1 Bivalve sample collection

At each station, transect was dropped along the tidal level, three quadrates (0.25 m^2) were built at three different tidal levels. Using hand scoop, six centimeters depth sediment was scrapped and the sediment were meshed using 500 μm sieve. Samples of bivalve retained on the sieve were transferred into a labeled plastic bag. The samples were preserved in five (5) % formalin and bring back to the laboratory for identification process.

2.2.2 Sediment sample collection

In order to run a grain size analysis and total organic matter analysis, 200 grams of sediment were scrapped using hand scoop at each quadrat. The sediment was taken to the lab and was put in the refrigerator below freeze temperature for laboratory analysis. The sediment samples were tested for total organic matter content and grain size analysis.

2.2.3 Physico-chemical parameters measurement

At each quadrates we dig holes to let the interstitial water to be contained to the hole. The water was then measured *in-situ* using the Hyrolab Quanta for temperature, salinity, dissolved oxygen and pH.

2.3 Laboratory Analysis

2.3.1 Sorting and identification

Sorting and identification was done in the laboratory using a dissecting microscope and a compound microscope. The species of bivalves found were determined to the species and every sample was counted and recorded. Identification of bivalves was done according to Nielsen [7].

2.3.2 Total organic matter analysis

Crucible jars were put into the furnace for three to four hours at 450°C and let it cool down in desiccators for 20 minutes to obtain constant weight. Then the constant weight of one gram sediment was measured and transferred into crucible jars and heated in the oven at 60°C to dry the sample. The samples were cooled down in the desiccators around 20 minutes, then the constant weight was taken. These steps will be repeated until constant weight was obtained. Then the samples transfer into furnace at 450°C preheating for two hours in order to destroy organic materials. The sediment, then transferred to desiccators for readings. The constant weight of sediment samples and the empty crucible jar were taken. Finally, percentage of total organic matter was determined by using formula:

$$\text{Total organic matter} = \frac{\text{sample weight before ashes - sample weight after ashes}}{\text{sample weight before ashes}}$$

2.3.3 Grain size analysis

The sediment was left in open space to undergo air-dried sediment. Then, using the 13 different size sieves range from 4000μm to 63μm, for accurate work use, the sediment was sorted. The sieves nested in order, the coarsest on the top, and the finest on the bottom. 100 grams of dried sediment were poured into the top sieve, cover, and the time is set for ten minutes. Upon completion of the sieving, the contents of each sieve are weighed and recorded. The data were used to plot the percentage of cumulative weight against the phi value. From the graph phi size for 10, 16, 25, 50, 84 and 90 were determined and later the mean, median, skewness, sorting and kurtosis were calculated. From the mean value, the sediment type is identified according to Udden-Wentworth (1922) size class scale.

2.4 Data Analyses

The actual numbers for each species counted were converted to standardize mean density for one meter square in order to obtain the species abundance and relative abundance. Then the data were applied in the PAST (Paleontelogical Statistic) free software to obtain species diversity index value. Species diversity of each sample was calculated using the Shannon–Wiener index (H') :

$$H' = -\sum_{i=1}^{s} \frac{Ni}{N} \log_2\left(\frac{Ni}{N}\right)$$

Where S = the number of species in the sample, N = the total number of individual, and Ni = the number of individual in the ith species (i = 1 to S).

The Evenness index is calculated using the formula:

$$J' = \frac{H'}{D_{\max}}$$

J = evenness value, *H'* = Shannon-Weiner diversity index, *Dmax* = maximum index diversity value.

One way ANOVA test was used for the analysis of differences in bivalve density, physico-chemical factors and sediment characteristics among the stations and also among different seasonal periods. In order to determine which factors have a significant effect on bivalve's densities, Pearson-Rank correlation test was applied using SPSS version 11.0.

3. RESULTS

3.1 Physico-chemical factors

For the purpose of studying ecologically significant of bivalve, four physico-chemical parameters were measured during all the three sampling sessions. The parameters were temperature (ºC), dissolved oxygen (mg/L), salinity (ppt) and pH. The results of these factors were presented in different figures. Table 2 below show the overall results of physico-chemical factor during all sampling sessions.

Table 2: Mean value of physico-chemical parameters at Tok Bali mangrove forest, Kelantan

	Salinity	Temperature	DO	pH
	(ppt)	(°C)	mg/L	
DRY SEASON				
Station 1	20.48	30.74	1.98	6.77
Station 2	19.72	30.97	2.11	7.08
Station 3	16.62	31.27	1.81	7.45
Station 4	21.25	31.73	2.00	7.41
PRE-MONSOON				
Station 1	20.83	30.83	1.29	6.67
Station 2	22.13	30.80	1.64	6.64
Station 3	12.93	30.63	2.17	6.63
Station 4	15.84	30.57	1.98	6.88
MONSOON				
Station 1	8.26	26.72	2.24	6.52
Station 2	5.22	27.42	3.34	6.71
Station 3	2.44	27.69	2.70	6.73
Station 4	5.06	27.36	3.41	6.82

The maximum temperature for overall observation is 31.73 ºC that recorded in dry season. Meanwhile the minimum temperature is 26.72 ºC that occurs during monsoon. During the dry season, the average temperature reading was 31.18 ºC, decreased to 30.71 ºC during pre-monsoon and 27.3 ºC during monsoon. The maximum average reading of dissolved oxygen was 3.41 mg/L and the minimum value was 1.29 mg/L. The highest dissolved oxygen was recorded at Station 2 (*Avicennia* spp.) during the monsoon.

The average of salinity during dry period was 19.52 ppt, 17.94 during pre-monsoon and decreased to 5.52 ppt during monsoon. The maximum salinity reading occurs in July where the reading is 25.74 ppt. The salinity was recorded at low tidal quadrate at Station 4 (*Rhizophora* spp.). The lowest salinity was 1.54 ppt during monsoon.

The maximum pH value was 7.45 recorded at Station 3 during a dry sampling session. Meanwhile the minimum value is 6.26 occurs at Station 1 during the monsoon. During the dry season, the average pH value was 6.77 units, 6.67 units during pre-monsoon and 6.52 units during monsoon.

3.2 Sediment characteristics

3.2.1 Grain size analysis

Grain-size data is shown in phi (ø) value. Figure 2 shows the average of mean phi (ø) value for each station during dry, pre-monsoon and monsoon sampling sessions. Mean phi (ø) value ranges from 1.9 to 2.66. The averages mean phi (ø) value during the dry season was 2.59; 2.17 during pre-monsoon and 2.18 during the monsoon.

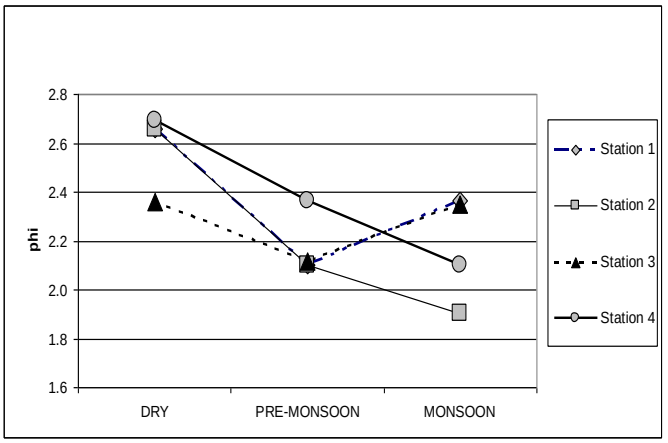

Figure 2: Grain size (mean $(\tilde{x})$ phi) at Tok Bali mangrove forest during all seasons

3.2.2 Total Organic Matter (TOM)

The average for TOM percentage during a dry sampling session was 1.42 g/g, meanwhile during pre-monsoon was 1.45 g/g and during monsoon the average decreased to 0.667 g/g. Overall, the percentage of TOM is highest during pre-monsoon. The percentages of TOM at all stations were low and show decreasing pattern during the monsoon sampling session (Figure 3).

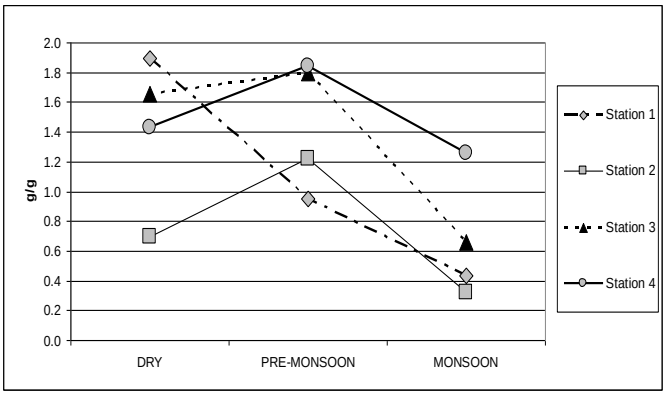

Figure 3: TOM (g/g) at Tok Bali mangrove forest during all seasons

3.2.3 Species Abundance and Composition of Infaunal Bivalves at Tok Bali Mangrove Forest, Kelantan

A total of five families with five species were observed at the study area. The families and species of observed infaunal bivalve at Tok Bali mangrove were listed in Table 3.

Table 3: Family of infaunal bivalves and the representative species from Tok Bali mangrove forest, Kelantan

Family	Species
Corbiculidae	*Polymesoda expansa* (MOUSSON, 1849)
Donacidae	*Donax faba* (GMELIN, 1791)
Unionidae	*Pilsbryoconcha exilis* (LEA, 1839)
Psammobiidae	Gari ambigua (REEVE, 1857)
Veneridae	*Marcia japonica* (GMELIN, 1791)

3.2.4 Diversity, Richness and Evenness Index

3.2.4.1 Station 1 (Nypa fruticans)

Bivalve species observed at Station 1(*Nypa fruticans*) are *Polymesoda expansa, Gari ambigua, Marcia japonica* and *Pilsbryoconcha exilis*. The mean species diversity index H at Station 1 range from 0.9 to 1.34. The highest diversity index H' value occurred during the monsoon period. Table 4 shows the diversity index H', evenness index J and richness index S at Station 1 during dry, pre-monsoon and monsoon seasonal period.

Table 4: Diversity indices at Station 1

	DRY	PRE MONSOON	MONSOON
Diversity index Shannon H'	0.90	0.93	1.34
Evenness index E'	0.82	0.85	0.95
Richness index Margalef	0.46	0.42	0.68

The value of richness index ranged from 0.42 to 0.68. While the evenness index ranged from 0.82 to 0.95. The ANOVA test showed that all these index values do not show significant differences between different seasonal periods (P>0.05).

3.2.4.2 Station 2 (Avicennia spp.)

A total of five (5) bivalve species were observed at station 2 (*Avicennia* spp.). These species are *Polymesoda expansa, Marcia japonica, Donax faba, Gari ambigua* and *Pilsbryochoncha exilis.* Table 5 shows the value of species diversity index H', evenness index J and richness index S for station 2 during July, September and December sampling session. From the table, the highest diversity index H' value is 1.27 occur during the dry season while the lowest diversity index H' value is 0.74 during the monsoon sampling session.

Table 5: Diversity indices at Station 2 during all seasons

	DRY	PRE MONSOON	MONSOON
Diversity index Shannon H'	1.27	0.91	0.74
Evenness index E'	0.71	0.62	0.53
Richness index Margalef	0.69	0.47	0.48

The highest value of evenness index E' was shown during the dry season (0.71) and the lowest one was during the monsoon (0.53). For richness index the highest value occurred during dry season (0.69) and the lowest is 0.47 during pre-monsoon.

The ANOVA test shows that the diversity index H', evenness index E' and richness index Margaleff at this station do not show significant differences during different seasonal period.

3.2.4.3 Station 3 (Mixed Mangrove)

Polymesoda expansa, Marcia japonica, Donax faba, Gari ambigua and *Pilsbryochoncha exilis* were present at Station 3. Table 6 shows the value of species diversity index H', evenness index J and richness index S for station 3 during dry, pre-monsoon and monsoon sampling session. Mean diversity index H' value ranged from 0.99 to 1.25. The mean diversity index was lowest during the monsoon season (December) and highest during the dry season (July).

The values of richness index values range from 0.37 to 0.78. The highest value occurred during the dry season while the lowest one occurred during pre-monsoon.

Table 6: Diversity indices at Station 3

	DRY	PRE MONSOON	MONSOON
Diversity index Shannon H'	1.25	1.04	0.99
Evenness index E'	0.70	0.94	0.90
Richness index Margalef	0.78	0.37	0.43

The ANOVA test shows that the diversity index H', evenness index E' and richness index Margaleff at this station do not show significant differences during different seasonal period.

3.2.4.4 Station 4 (Rhizophora spp.)

Only four (4) species presented in Station 4, that were *Polymesoda expansa, Marcia japonica, Gari ambigua* and *Pilsbryochoncha exilis.* Table 7 below shows the value of species diversity index H', evenness index E' and richness index S for station 4 during dry, pre-monsoon and monsoon periods.

Table 7: Diversity indices at Station 4 during all seasons

	DRY	PRE MONSOON	MONSOON
Diversity index Shannon H'	0.72	1.06	1.01
Evenness index E'	0.69	0.96	0.92
Richness index Margalef	0.48	0.52	0.58

Species diversity index values at this station range from 0.72 to 1.06. At this station diversity index value is lowest during dry period and highest during pre-monsoon.

While the evenness index E' ranges from 0.69 to 0.96. This index also shows the highest value during pre-monsoon and lowest during dry periods. Richness index value shows increasing from July to December. The highest value is 0.58 at during monsoon while the lowest value for richness index is 0.48 during the dry season.

The ANOVA test shows that the diversity index H', evenness index E' and richness index Margaleff at this station do not show significant differences during different seasonal period.

4. DISCUSSION

4.1 Physico-chemical Factors

Temperature, dissolved oxygen and salinity seem to get influenced significantly by the monsoons. Dissolved oxygen increased during the monsoon period. Inversely, temperature and salinity show decreasing during monsoon (December). The reason of this decreasing pattern might be because of the influence of freshwater runoff from the river and high rainfall density during monsoon [8]. High density of freshwater runoff from upstream river diluted the salinity of mangrove water and flush off the organic matter that accumulated in mangrove area to the sea. Low decomposition activity influenced the increasing of dissolved oxygen level.

Comparison between different sampling stations shows that salinity does not differ significantly. But the observation indicated that salinity at low tide level, normally in the water is always higher than salinity reading at upper tidal level. At lower tidal level, the area received direct influenced from the saline sea water all the time compared to the upper tidal level that only received salt water during high tide.

pH readings do not show any significant different neither among stations nor among different sampling sessions (ANOVA test, P>0.05). The average of pH readings ranged from 6.52 to 6.77 shows that the water in this study area is slightly acidic. However, Pearson-Rank correlation test indicated that none of these physico– chemical factors significantly correlated with the abundance of infaunal bivalve species.

Table 8: Comparison of physico-chemical parameters at Terengganu River Estuary and present study

Season	Salinity (ppt)	Temperature (°C)	pH	
Dry	19.52	31.18	7.18	** present study
	16.18	29.53	6.64	Terengganu river estuary
Monsoon	5.25	27.3	6.69	** present study
	9.14	28.07	6.19	Terengganu river estuary

Table 8 shows the comparison of data obtained in this present study of data reported earlier that study the physico-chemical of the Terengganu river estuary [9]. Table 8 shows that all parameters in this study during dry season were higher than the data obtained at the Terengganu river estuary. The reason might because of the location of Tok Bali mangrove forest is seaward compared to the sampling site of the previous study that covered a wider area from the river mouth to upstream area. Chong noted in the construction of the Tok Bali channel-jetty that reduced the coverage of its fringing mangroves and modified the river flow in the area [10].

4.2 Sediment Characteristics

Table 7: Comparison of TOM and mean phi value between the present study and study at Setiu lagoon

Season	TOM (g/g)	Mean (ø)	
Dry	0.037 - 0.04	3.7 - 7.63	*present study
	0.7 - 1.89	2.02 - 2.69	Setiu lagoon
Monsoon	0.012 - 0.015	4.06 - 7.33	*present study
	1.257 - 0.32	1.90 - 2.37	Setiu lagoon

A studied the benthos community in the Setiu lagoon aquaculture area on August and November 2002 [11]. Table 7 shows that TOM in this present study was lower than TOM at Setiu lagoon. Compare to the lagoon, mangrove is highly productive area, 86% of net productivity is recycled, though a substantial component is exported to the adjacent sub littoral area [12]. However, in this present study, TOM does not show any significant correlation with the density of infaunal bivalve in this area.

The only factor that significantly correlated with the density of infaunal bivalve species in the present study was a mean phi (ø) value that representing the grain size and used to determine the sediment type. Compared to the study at Setiu lagoon, mean phi (ø) value at this present study is low, means that the grain size was coarser. Sediment type at Tok Bali mangrove forest can be classified as fine sand, with the average mean phi (ø) value of 2.26. The formation of this mangrove area was induced by the raising of water breaker and the bridge at the river mouth of Sungai Semerak. The two components slow down the water flow and increased the sedimentation process within the area [13]. The same condition of the sediment was reported in Sungai Pulai [14].

4.3 Diversity, Evenness and Richness index

High values of H would be representative of more diverse communities and if the species are evenly distributed then the H value would be high. Thus, the H value allows us to know not only the number of species but how the abundance of the species is distributed among all the species in the community.

Overall, diversity index value of this study area is ranging from 0.72 to 1.34. The index shows that species diversity in this study area can be considered as low with only four families of bivalves represented by three species. Furthermore, the number was very much low if compared to the reports from Setiu lagoon [15,16]. ANOVA tests show that diversity, evenness and richness does not have any significant difference either compared among different station or among different season. This present study indicated that all species presented in all mangrove areas and does not show any discreet distribution or clustering pattern. The highest value of diversity index H' was recorded at station 1 *(Nypa fruticans)* that can be considered as polluted by the aquaculture activities, indicated that infaunal bivalve has the ability to tolerate polluted environment. The pollution might affect the density of these species, but not the occurrences of various species in such place [17, 18]. This suggested that infaunal bivalve can be used as bioindicator of contaminant levels in this area. They also can provide an indication of long-term effects of the pollution on the ecosystem and possible effects on other taxa [19].

5. CONCLUSION

Five (5) species of bivalve were found in Tok Bali mangrove forest. These species are *Polymesoda expansa, Marcia japonica, Donax faba, Gari ambigua* and *Pilsbryochoncha exilis.* The result might not represent the real diversity, value because this study involving small sample size compared to the size of Tok Bali mangrove area. Further study should be done in order to obtain more detail data on bivalve species in this study area.

These bivalves have shown their abilities to survive in unstable environments. It is suggested that further study should be done to evaluate if this species could be used as a bioindicator of the availability of contaminants to animals and organism at higher trophic levels and of baseline levels within the system.

The low biodiversity of infaunal bivalves in the mangroves of Tok Bali could be due to other spatial factors rather than the monsoon. Long-term data collection is suggested to determine the seasonal pattern of their biodiversity and contribution to the mangrove ecosystem in the area.

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