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POLYCHAETOUS ANNELID COMMUNITY STRUCTURE IN RELATION TO SOFT BOTTOM SEDIMENT CHARACTERISTICS IN CONTINENTAL SHELF OF THE SOUTHERN SOUTH CHINA SEA

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Abstract: Polychaetes are ubiquitous and dominant benthic fauna in the marine environment. Research on polychaete ecology has been done worldwide, however, in Malaysia, study on polychaete communities from soft bottom habitats in the continental shelf of the southern South China Sea has not been widely explored. Thus, this study embarks to determine the relationship between polychaete community structures with sediment parameters. The sampling was conducted in April and July 2011 at 43 sampling stations covered offshore areas of Pekan-Dungun, Kuala Terengganu and Kudat-Balambangan Island, southern South China Sea. Sediment sample for polychaete determination, Particle Size Analysis (PSA) and Total Organic Carbon (TOC) were taken using Smith McIntyre grab (0.1 m^2). Sediments for polychaetes were sieved through a set of wire mesh sieve (5.0, 3.0 and 0.5 mm), fixed with 10% buffered formalin and preserved in 70% ethanol prior to identification and counting. Sediment for TOC and PSA were undergo analysis in the laboratory. A total of 12,323 individuals of polychaetes was recorded and classified into 47 families. The mean total density of polychaetes at Kudat-Balambangan Island (663 ± 213 individual/m^2) and Pekan-Dungun (603 ± 214 individual/m^2) ($p > 0.05$) was significantly higher compared to offshore Kuala Terengganu (414 ± 162 individual/m^2) ($p < 0.05$). Family Spionidae was dominant at all sampling areas. The mean value of diversity (4.1 to 5.6) differs significantly ($p < 0.05$) among areas. However, the evenness index (0.73 to 0.92) did not differ significantly ($p > 0.05$). High density of polychaetes was found at silty-clay, followed by silty-clay-loam and silt-loam sediment textures. This study concluded that the sediment characteristics are among significant factors contribute to the abundance of polychaete community structure in the soft bottom habitat of southern SCS.

KEYWORDS: Community ecology, macrobenthos, Malaysia, offshore, polychaete

Introduction

Polychaetes are multi-segmented worms which are the largest class classified under Phylum Annelida. They have huge morphological diversity, often brightly coloured and the sizes can be up to several meters length (Bartolomaeus *et al.,* 2005; Eklöf, 2010). Polychaetes present in various marine habitats (Frid, 2011) ranging from estuaries and inshore waters to the open sea (Ajmal-Khan & Murugesan, 2005; Rouse & Pleijel, 2006), which are very rarely found in freshwater and almost absent from terrestrial habitats (Rouse & Pleijel, 2001). Currently more than 20,000 of polychaete species have been described worldwide (Read & Fauchald, 2018) where the majority in benthic habitat. Polychaetes often contribute more to the total macrobenthic animals concerning abundance, biomass, number of species and individual (Day, 1967a; 1967b; Ajmal-Khan & Murugesan, 2005; Sivadas *et al.,* 2010). Despite playing an important role in ecological aspect and economic values, polychaetes are also excellent bio-indicator in the marine environment (Sivadas *et al.,* 2010; Andrade & Renaud, 2011; Saleh, 2012). It is because they have limited movement, highly diverse range of feeding and reproductive strategies as well as ability to respond to different disturbances (Piamthipmanus, 1999; Trong *et al.,* 2000; Ibrahim *et al.,* 2006; Metcalfe & Glasby, 2008).

The soft bottom environment contains patches of different types of sediment. Hence, organisms at the bottom tend to occur in distinct clumps or patches (Castro & Huber, 2008). As a type of infauna, polychaetes are very selective to where they live. Therefore, changes in sediment texture and organic carbon could lead to the changes of polychaete abundance, distribution and composition. That is because any disturbances at the soft sediment can damage the existing fauna and render the habitat available for new colonisation and succession of species (Quadros *et al.,* 2009).

South China Sea (SCS) is a semi-enclosed body of water and has been categorised as one of large marine ecosystem because of its high biodiversity (Liu, 2013). It lies within the Tropic of Cancer and has a complicated geological structure which is diversified bottom geomorphology (Liu, 2013) including the Sunda shelf, a shallow continental shelf (Akhir, 2014). Recently, a total of 1,219 polychaete species has been identified in the SCS (Glasby *et al.,* 2016). Al-Hakim and Glasby (2004) believed that the majority of polychaetes of the SCS belongs to the Indo-Malayan subregion of the Indo-West Pacific province. Malaysia is located in the southern region of SCS with intensive explorations of natural gas and petroleum within Malaysia Exclusive Economic Zone (EEZ) (Rosli *et al.,* 2016).

The taxonomical and ecological studies of offshore polychaetes in Malaysia waters are less documented compared to adjacent countries such as Indonesia, Singapore and Thailand (Salazar-Vallejo *et al.,* 2014). Possible cause for insufficient biological data is previous studies were carried out for Environmental Impact Assessment (EIA) which have never been published for commercial or security reasons (Mandal & Harkantra, 2013). Furthermore, most of the studies on polychaete communities in Malaysia were carried out in the west coast of Peninsular Malaysia (Ong, 1995; Gholizadeh *et al.,* 2012; Idris & Arshad, 2013). Although those studies has increased the number of identified species and they expected that the polychaete species in Malaysia will increase from time to time, the data at the offshore area are still lacking. The example of offshore research on macrobenthos in general were done by Southeast Asian Fisheries Development Center (SEAFDEC) Expeditions from 1997 until 2000 (Phiamthipmanus, 1998; 1999; Yasin & Razak, 1999; Trong *et al.,* 2000).

Knowing the importance of polychaetes in the southern SCS, Rosli *et al.* (2016) carried out the work but the study only focuses on the diversity of polychaetes in the continental shelf area without discussing about the sediment parameters. Thus, the ecological study of polychaete involving their relationship with sediment parameters is needed for a better understanding of polychaete community in the southern SCS, particularly in Malaysian waters. This study may provide baseline information for investigations on any environmental changes that may arise in the future in relation with the oil and gas exploration at this area. Therefore, the main objective of this study is to determine the relationship between polychaetes community structures and sediment parameters in continental shelf of southern SCS.

Materials and Methods

Sample Collection

Samplings were conducted in April 2011 (Pekan-Dungun & Kudat-Balambangan Island) on board tug ship FOS LEO (785 gross tonnages) and in July 2011 (Kuala Terengganu) on Sealink VANESSA 7 (494 gross tonnages) for a one-off sampling in the Malaysia EEZ. Overall, there were 43 sampling stations with respective number of stations were 19, 11 and 13 for the offshore areas of Pekan-Dungun, Kuala Terengganu and Kudat-Balambangan Island (Figure 1) (Rosli *et al.,* 2016). The nearest sampling station was 13 km and the farthest station was about 180 km from the coastline with water depth of all stations ranged from 25 to 73 m. The selection of these areas were made considering these areas are experiencing oil and gas exploration activities (e.g. Bertam, Terap

& Cempelut oil discoveries), thus significantly influenced by anthropogenic activities.

At each sampling station, sediment samples for polychaetes, Particle Size Analysis (PSA) and Total Organic Carbon (TOC) analysis were taken using Smith McIntyre grab (0.1 m^2). Five replicates (n = 5) of sediment for polychaete determination was sieved through a set of wire mesh sieves (5.0, 3.0 & 0.5 mm). Polychaetes that retained on the sieve were collected, fixed with 10% buffered formalin and were brought back to the laboratory for further analysis (Eleftheriou & Moore, 2005; Ibrahim *et al.,* 2006).

Approximately 500 g (wet weight) of sediments (n = 3) for PSA were sampled using seawater-rinsed plastic spoons from the surface of the grab and placed in the labelled polyethylene bag prior to storage in a container. Samples for TOC were scooped from the surface of the sediment in the grab using a cleaned stainless steel metal spatula (~2 kg wet weight) (n = 3), wrapped with hexane-cleaned aluminium foil and sealed in a plastic bag. The sealed packs were then transferred into a labelled polyethylene bag and stored at –20°C on board for further analysis (Rosli, 2015).

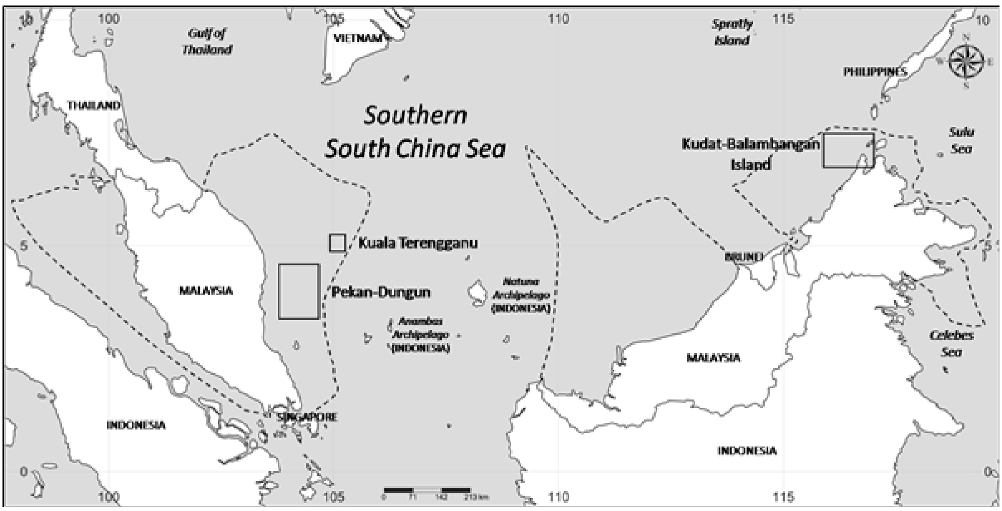

Figure 1: Map of sampling areas off the Pekan-Dungun, Kuala Terengganu and Kudat Balambangan Island (square), surrounding countries within southern South China Sea area and the border of Malaysia Exclusive Economic Zone (EEZ) (dotted line) (modified from Shorthouse, 2010).

Sample analysis

In laboratory, polychaete samples were gently rinsed with freshwater onto a 0.5 mm mesh sieve to remove the excessive formalin (Danovaro, 2010). All materials retained on the sieve were transferred into a labelled petri dish and observed systematically under the stereo microscope (Olympus SZX7). Polychaetes were counted and identified to the possible taxa. The identification of polychaetes was based on the morphological features under the stereo (Olympus SZX7) and compound microscopes (Leica DME) (Eleftheriou & Moore, 2005; Danovaro, 2010). Identified polychaetes were placed in the separated labelled container containing 70% ethanol and deposited at the South China Sea Repository and Reference Centre, Institute of Oceanography and Environment (INOS), Universiti Malaysia Terengganu. The species validity of the taxa was confirmed with reference to the World Register of Marine Species (WoRMS), on its occurrence, spelling, records and authors (Idris & Arshad, 2013). Families were arranged following Rouse and Pleijel (2006) while genera were arranged alphabetically within each family.

Sandy sediment samples for PSA were oven-dried at 60°C for 48 hours to a constant weight (Bachok *et al.,* 2006) and dry-sieved (Buchanan, 1984) through a series of sieves with different mesh sizes (2, 1, 0.5, 0.25, 0.125 & 0.063 mm) by a mechanical shaker. Fractions retained on each sieve were weighed and recorded. Samples of muddy sediment were air-dried, then placed in a 50 ml beaker. 10 ml distilled water was added before heated on a hot plate (100°C) for 15 minutes. A few drops of hydrochloric acid (HCl) were added to digest the entire carbonate fragments. Then, a few drops of hydrogen peroxide (H_2O_2) were added into the samples for organic digestion until no bubble appeared. This step was repeated until all the reactions inside the beaker completed. After the sample had cooled down (room temperature), Calgon 20% solution was added into the beaker and left for 24 hours to avoid agglutination of the sample. The grain size distribution was determined through laser diffraction of Malvern Mastersizer Particle Size Analyzer MS2000.

Analysis of TOC content was carried out using the Walkey and Black titration method (Morris & Singh, 1980). Approximately 1 g of freeze-dried sediment sample was transferred in a 500 ml Erlenmeyer flask. The non-carbonic and carbonate content in the sample was digested using sulfuric and phosphoric acids. The diphylamine indicator was added into the mixture and shaken. The sample was titrated with ferrous sulfate solution until the colour changed to light green. The quantity (ml) of ferrous sulfate used in titration was recorded.

Data Analysis

Density of polychaetes at each station (n = 5) was expressed in density as a total number of individual(s) per meter square (No. of individual/m^2). The mean density at each station was determined by averaging the five replicates of the sample. The abundance of major taxonomic groups and each species were also determined. The diversity of polychaetes species at each area was described by a diversity index of Shannon-Weiner, H' (Shannon & Weaver, 1949) and the evenness of polychaetes community was represented by Pielou's evenness index, J' (Pielou, 1966).

The sand, silt and clay fractions for PSA were expressed in percentages of dry weight using grade nomenclature of the Wentworth scale (Buchanan, 1984). The sediment characteristics from each area were characterised for its % content of sand, silt, clay and expressed in the form of a triangular graph according to USDA (1987) classification.

The percentage of TOC in the samples was calculated using the following formula:

$$\% \text{ TOC} = \frac{(\text{B-S}) \times \text{M} \times 0.003 \times 100}{\text{W} \times 0.77}$$

where B is the volume of Fe^{2+} solution used to titrate blank (mL); S is the volume of Fe^{2+} solution used to titrate sample (mL); M is molarity of Fe^{2+}; 0.003 is milliequivalent weight; and w is sample weight (g).

One-way analysis of variance (ANOVA) was performed using SPSS (Statistic Package for Social Science) version 11.5 software to determine the significant differences on the mean of biological and sediment parameters (e.g. Density, species number, diversity, evenness, TOC & PSA) among sampling areas. A criterion of $p < 0.05$ was used to determine statistical significance.

Results

The mean total density of polychaetes at the southern SCS is shown in Figure 2. Kudat-Balambangan Island (663 ± 213 individual/m2) and Pekan-Dungun (603 ± 214 individual/m2) had a significantly higher total density compared to offshore of Kuala Terengganu (414 ± 162 individual/m^2) ($p < 0.05$). Overall, 47 families were recorded (Table 1) and a total of 12,323 individuals of polychaetes was identified (Table 2). Family Spionidae had the highest density recorded (1,520.3 ± 431.7 individual/m^2), followed by Nephtyidae (664.3 ± 518 individual/m^2), Paraonidae (572.1 ± 63 individual/m^2) and Capitellidae (536.5 ± 37.7 individual/m^2). The lowest density was Acoetidae (<1 individual/m^2).

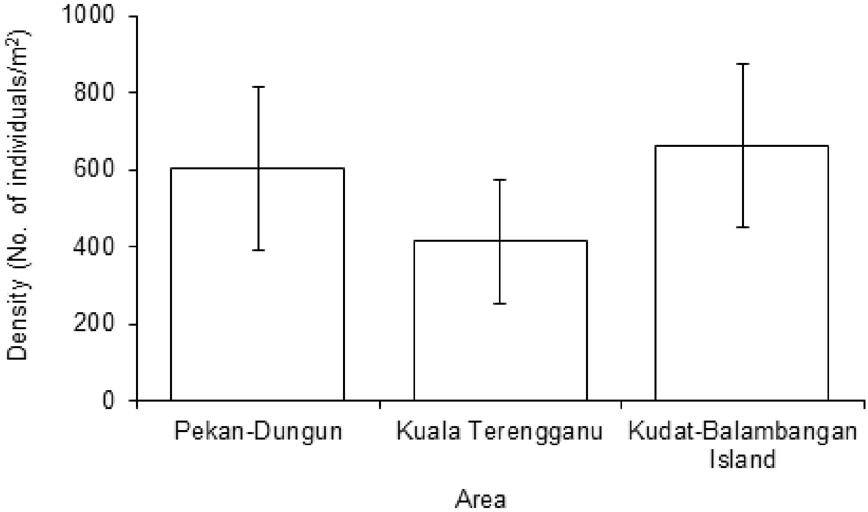

Figure 2: Mean total density of polychaetes at southern South China Sea (mean±SD). Area: Pekan-Dungun, *n* = 19; Kuala Terengganu, *n* = 11; Kudat-Balambangan Island, *n* = 13.

Table 1: Mean density (individuals/m^2) (mean ± SD) of polychaete families found in the southern South China Sea.

Subclass/ Order	Family	Pekan-Dungun	Kuala Terengganu	Kudat-Balambangan Island	Total
ERRANTIA					
Amphinomida	Amphinomidae	8.4 ± 2.8	-	0.8 ± 0.4	9.2 ± 4.7
Eunicida	Dorvilleidae	8.9 ± 0.9	55.5 ± 27.1	10 ± 2.8	74.4 ± 26.6
	Eunicidae	18.9 ± 2	6.4 ± 1.1	26.2 ± 3.7	51.5 ± 10
	Lumbrineridae	173.7 ± 27.7	110.9 ± 16.3	176.2 ± 28.4	460.7 ± 37
	Oenonidae	145.8 ± 40.4	173.6 ± 55.6	192.3 ± 67.4	511.7 ± 23.4
	Onuphidae	124.2 ± 26.3	30.0 ± 6	72.3 ± 17.2	226.5 ± 47.2
Phyllodocida	Acoetidae	0.5	-	-	0.5 ± 0.3
	Alciopidae	0.5 ± 0.4	-	0.8 ± 0.5	1.3 ± 0.4
	Aphroditidae	7.9 ± 3	22.7 ± 6.7	22.3 ± 9.6	52.9 ± 8.4
	Chrysopetalidae	30 ± 11.9	-	4.6 ± 1.5	34.6 ± 16.2
	Eulepethidae	7.3 ± 6.4	0.6 ± 1	1 ± 0.9	8.9 ± 3.7
	Glyceridae	72.6 ± 15.3	30.9 ± 10.2	72.3 ± 13.9	175.8 ± 24
	Goniadidae	2.1 ± 0.3	0.9 ± 0.5	-	3.0 ± 1.1
	Hesionidae	32.1 ± 4.5	22.7 ± 3.3	14.6 ± 2.2	69.4 ± 8.8
	Iospilidae	11.6 ± 2.1	-	-	11.6 ± 6.7
	Nephtyidae	181.6 ± 58.2	202.7 ± 91.9	280 ± 120.5	664.3 ± 51.8
	Nereididae	124.7 ± 20.4	65.5 ± 11.3	88.5 ± 12.5	278.7 ± 29.9
	Paralacydoniidae	131.6	13.6	64.6	209.8 ± 59.2
	Phyllodocidae	53.2 ± 5.8	1.8 ± 0.3	13.1 ± 1.5	68.1 ± 27
	Pilargidae	28.4 ± 10.6	40.0 ± 20	68.5 ± 28.3	136.9 ± 20.6
	Polynoidae	10.5 ± 1.4	3.6 ± 0.6	21.5 ± 3.3	35.7 ± 9

Subclass/ Order	Family	Pekan-Dungun	Kuala Terengganu	Kudat-Balambangan Island	Total
	Pontodoridae	25.8	-	3.8	29.6 ± 13.9
	Sigalonidae	24.7 ± 4.6	14.5 ± 3.8	23.1 ± 3.9	62.4 ± 5.5
	Sphaerodoridae	0.5 ± 0.4	-	3.8 ± 1.6	4.4 ± 2.1
	Syllidae	200 ± 13	37.3 ± 4	134.6 ± 14.5	371.9 ± 81.9
SEDENTARIA					
	Arenicolidae	12.6 ± 2	3.6	2.3 ± 0.7	18.6 ± 5.6
	Capitellidae	175.3 ± 14.8	218.2 ± 23.5	143.1 ± 14	536.5 ± 37.7
	Cossuridae	10.5	13.6	16.2	40.3 ± 2.8
	Chaetopteridae	1.6	0.9 ± 0.5	0.8 ± 0.4	3.3 ± 0.4
	Maldanidae	88.4 ± 6	70 ± 13	27.7 ± 2.7	186.1 ± 31.1
	Opheliidae	13.2 ± 2.9	23.6 ± 5.5	50 ± 8.5	86.8 ± 19
	Orbiniidae	46.3 ± 5.3	25.5 ± 6.1	66.9 ± 11	138.7 ± 20.7
	Paraonidae	132.6 ± 22.5	181.8 ± 29.3	257.7 ± 38.2	572.1 ± 63
	Scalibregmidae	36.8 ± 8	7.3 ± 3.1	4.6 ± 1.8	48.7 ± 17.9
Sabellida	Fabriciidae	11.1 ± 3.5	-	2.3 ± 1.2	13.4 ± 5.8
	Sabellidae	196.8 ± 35.7	51.8 ± 8.4	48.5 ± 7.6	297.1 ± 84.7
	Serpulidae	4.2 ± 0.7	-	-	4.2 ± 2.4
Spionida	Spionidae	426.3 ± 37	120.9 ± 6.9	973.1 ± 97.2	1520.3 ± 431.7
	Magelonidae	20 ± 10	41.8 ± 18.9	17.7 ± 8.3	79.5 ± 13.3
	Poecilochaetidae	12.1 ± 7.1	5.5 ± 1.3	23.1 ± 16.3	40.6 ± 8.9
Terebellida	Ampharetidae	186.8 ± 21.4	47.3 ± 5.6	170 ± 19.7	404.1 ± 76.2
	Cirratulidae	137.9 ± 12.1	106.4 ± 9.4	140.8 ± 14.2	385 ± 19.1
	Flabelligeridae	7.4 ± 1.7	40 ± 7.7	14.6 ± 3.3	62 ± 17.1
	Pectinariidae	0.5 ± 0.4	-	1.5 ± 1.1	2.1 ± 0.8
	Sternaspidae	22.1 ± 14.9	70.9 ± 50.1	16.2 ± 11.4	109.2 ± 30
	Terebellidae	47.4 ± 3.6	53.6 ± 6.5	31.5 ± 3.4	132.5 ± 11.4
	Trichobranchidae	8.9 ± 3.8	153.6 ± 59.5	14.6 ± 4	177.2 ± 81.9

Table 2: List of families, polychaete taxa and mean density (individuals/m^2) (mean ± SD) found in the southern South China Sea.

Subclass/Order/ Family	Taxa	Pekan-Dungun	Kuala Terengganu	Kudat-Balambangan Island
ERRANTIA				
Amphinomida				
Amphinomidae	*Chloeia* sp.	1.1 ± 4.6	-	-
	Eurythoe sp.	0.5 ± 2.3	-	0.8 ± 2.8
	Hipponoe sp.	6.3 ± 13.8	-	-
	Pareurythoe sp.	0.5 ± 2.3	-	-
Eunicida				
Dorvilleidae	*Dorvillea* sp.	2.1 ± 5.4	-	0.8 ± 2.8
	Protodorvillea sp. 1	3.2 ± 8.2	0.9 ± 3	3.1 ± 6.3
	Protodorvillea sp. 2	1.1 ± 3.2	-	-
	Schistomeringos sp.	2.6 ± 4.5	54.5 ± 180.9	6.2 ± 9.6

Subclass/Order/ Family	Taxa	Pekan-Dungun	Kuala Terengganu	Kudat-Balambangan Island
Eunicidae	*Leodice* sp.	1.6 ± 5	-	-
	Eunice sp. 1	7.4 ± 20.8	0.9 ± 3	11.5 ± 27.6
	Eunice sp. 2	0.5 ± 2.3	-	-
	Eunice sp. 3	1.1 ± 3.2	2.7 ± 9	7.7 ± 11.7
	Eunice sp. 4	1.6 ± 5	-	-
	Eunice sp. 5	1.1 ± 4.6	-	2.3 ± 6
	Eunice sp. 6	-	-	2.3 ± 6
	Lysidice sp. 1	-	-	0.8 ± 2.8
	Lysidice sp. 2	1.6 ± 5	-	0.8 ± 2.8
	Marphysa sp. 1	3.2 ± 7.5	2.7 ± 4.7	-
	Marphysa sp. 2	1.1 ± 4.6	-	-
	Palola sp.	-	-	0.8 ± 2.8
Lumbrineridae	*Augeneria* sp. 1	2.1 ± 5.4	-	-
	Augeneria sp. 2	0.5 ± 2.3	-	-
	Lumbrineris sp. 1	86.8 ± 51.2	47.3 ± 40.3	76.2 ± 50.8
	Lumbrineris sp. 2	2.6 ± 7.3	0.9 ± 3	-
	Lumbrineris sp. 3	51.1 ± 77.5	33.6 ± 35	36.9 ± 69.7
	Lumbrineris sp. 4	2.6 ± 7.3	-	-
	Lumbrineris sp. 5	12.1 ± 15.1	0.9 ± 3	-
	Lumbrineris sp. 6	8.4 ± 25.4	17.3 ± 24.9	60.8 ± 75.3
	Lumbrineris sp. 7	0.5 ± 2.3	0.9 ± 3	-
	Lumbrineris sp. 8	1.6 ± 5	-	-
	Ninoe sp.	5.3 ± 9	10.0 ± 14.1	2.3 ± 8.3
Oenonidae	*Arabella* sp. 1	8.9 ± 14.5	-	0.8 ± 2.8
	Arabella sp. 2	1.1 ± 4.6	-	-
	Drilognathus sp.	1.6 ± 3.7	-	-
	Drilonereis sp. 1	7.4 ± 12.4	5.5 ± 12.1	-
	Drilonereis sp. 2	3.2 ± 6.7	2.7 ± 9	-
	Drilonereis sp. 3	117.9 ± 146.9	159.1 ± 69.1	190.8 ± 453.8
	Notocirrus sp.	2.6 ± 6.5	0.9 ± 3	0.8 ± 2.8
	Oenone sp.	3.2 ± 13.8	5.5 ± 12.1	-
	Diopatra sp. 1	-	1.8 ± 4	-
	Diopatra sp. 2	0.5 ± 2.3	-	-
	Hyalinoecia sp.	-	-	0.8 ± 2.8
	Nothria sp.	25.8 ± 32	19.1 ± 28.1	54.6 ± 37.6
	Onuphis sp. 1	-	-	1.5 ± 5.5
	Onuphis sp. 2	83.7 ± 264.1	4.5 ± 6.9	13.8 ± 17.6
	Onuphis sp. 3	7.4 ± 11.9	-	0.8 ± 2.8
	Onuphis sp. 4	5.8 ± 12.2	-	-
	Paradiopatra sp.	0.5 ± 2.3	4.5 ± 8.2	0.8 ± 2.8
	Unidentified onuphid	0.5 ± 2.3	-	-
Phyllodocida				
Acoetidae	*Eupanthalis* sp.	0.5 ± 2.3	-	-
Alciopidae	*Krohnia* sp.	-	-	0.8 ± 2.8
	Vanadis sp.	0.5 ± 2.3	-	-

Subclass/Order/ Family	Taxa	Pekan-Dungun	Kuala Terengganu	Kudat-Balambangan Island
Aphroditidae	*Aphrodita* sp.	6.8 ± 25.4	3.6 ± 6.7	21.5 ± 21.2
	Laetmonice sp. 1	-	16.4 ± 36.4	-
	Laetmonice sp. 2	-	1.8 ± 6	-
	Laetmonice sp. 3	0.5 ± 2.3	-	0.8 ± 2.8
	Pontogenia sp.	0.5 ± 2.3	0.9 ± 3	-
Chrysopetalidae	*Bhawania* sp.	3.2 ± 7.5	-	1.5 ± 3.8
	Paleanotus sp.	23.7 ± 62.2	-	3.1 ± 8.5
	Chrysopetalum sp.	3.2 ± 11.6	-	-
Eulepethidae	*Grubeulepis* sp.	-	1.8 ± 4	-
Glyceridae	*Glycera* sp. 1	3.7 ± 8.3	-	13.8 ± 17.6
	Glycera sp. 2	7.4 ± 11	-	1.5 ± 3.8
	Glycera sp. 3	19.5 ± 29.1	25.5 ± 27	37.7 ± 42.8
	Glycera sp. 4	1.6 ± 5	-	5.4 ± 12
	Glycera sp. 5	0.5 ± 2.3	-	-
	Glycera sp. 6	40.0 ± 49.8	5.5 ± 10.4	13.8 ± 24.7
Goniadidae	*Glycinde* sp.	0.5 ± 2.3	-	-
	Goniada sp. 1	0.5 ± 2.3	0.9 ± 3	-
	Goniada sp. 2	1.1 ± 4.6	-	-
Hesionidae	*Hesione* sp.	0.5 ± 2.3	-	-
	Leocrates sp.	1.1 ± 3.2	-	-
	Oxydromus sp. 1	0.5 ± 2.3	5.5 ± 12.1	5.4 ± 8.8
	Oxydromus sp. 2	2.1 ± 4.2	-	0.8 ± 2.8
	Podarkeopsis sp.	5.3 ± 13.1	8.2 ± 14.7	3.1 ± 4.8
	Psamathe sp.	10.0 ± 13.3	5.5 ± 8.2	0.8 ± 2.8
	Syllidia sp. 1	11.6 ± 19.2	3.6 ± 9.2	4.6 ± 8.8
	Syllidia sp. 2	1.1 ± 3.2	-	-
Iospilidae	*Iospilus* sp.	3.2 ± 6.7	-	-
	Phalacrophorus sp. 1	5.8 ± 15.4	-	-
	Phalacrophorus sp. 2	1.6 ± 5	-	-
	Phalacrophorus sp. 3	1.1 ± 4.6	-	-
Nephtyidae	*Aglaophamus* sp.	0.5 ± 2.3	-	3.1 ± 8.5
	Micronephthys sp.	52.1 ± 97.7	188.2 ± 66.5	250.0 ± 137.1
	Nephtys sp. 1	125.3 ± 74.1	14.5 ± 29.8	26.2 ± 30.7
	Nephtys sp. 2	3.7 ± 6.8	-	0.8 ± 2.8
Nereididae	*Ceratonereis* sp. 1	2.6 ± 11.5	7.3 ± 24.1	0.8 ± 2.8
	Ceratonereis sp. 2	1.1 ± 4.6	-	3.1 ± 8.5
	Dendronereis sp.	1.1 ± 4.6	-	-
	Micronereides sp.	2.1 ± 6.3	-	-
	Neanthes sp.	-	4.5 ± 15.1	-
	Nereis sp. 1	0.5 ± 2.3	10.0 ± 33.2	-
	Nereis sp. 2	18.9 ± 52.3	43.6 ± 29.8	17.7 ± 44.8
	Perinereis sp. 1	0.5 ± 2.3	-	-
	Perinereis sp. 2	1.1 ± 4.6	-	-
	Platynereis sp. 1	3.2 ± 7.5	-	-
	Platynereis sp. 2	0.5 ± 2.3	-	-
	Platynereis sp. 3	80.0 ± 52.8	-	17.7 ± 52.1

Subclass/Order/ Family	Taxa	Pekan-Dungun	Kuala Terengganu	Kudat-Balambangan Island
	Pseudonereis sp.	0.5 ± 2.3	-	-
	Unanereis sp.	8.9 ± 27.3	-	45.4 ± 50.3
	Websterinereis sp.	3.7 ± 8.3	-	3.8 ± 13.9
Paralacydoniidae	*Paralacydonia* sp.	131.6 ± 64.6	13.6 ± 12.1	64.6 ± 52.5
Phyllodocidae	*Eteone* sp.	2.1 ± 5.4	-	0.8 ± 2.8
	Lopadorrhynchus sp. 1	2.6 ± 6.5	-	-
	Lopadorrhynchus sp. 2	0.5 ± 2.3	-	0.8 ± 2.8
	Lopadorrhynchus sp. 3	22.6 ± 27	0.9 ± 3	3.1 ± 8.5
	Mystides sp.	1.1 ± 3.2	0.9 ± 3	-
	Nereiphylla sp.	0.5 ± 2.3	-	-
	Pelagobia sp.	0.5 ± 2.3	-	-
	Phyllodoce sp. 1	-	-	-
	Phyllodoce sp. 2	-	-	0.8 ± 2.8
	Phyllodoce sp. 3	1.1 ± 3.2	-	0.8 ± 2.8
	Phyllodoce sp. 4	4.7 ± 6.1	-	-
	Phyllodoce sp. 5	11.1 ± 43.4	-	5.4 ± 7.8
	Phyllodoce sp. 6	0.5 ± 2.3	-	-
	Phyllodoce sp. 7	1.1 ± 3.2	-	-
	Protomystides sp.	3.7 ± 9.6	-	1.5 ± 3.8
	Sige sp.	1.1 ± 4.6	-	-
Pilargidae	*Ancistrosyllis* sp. 1	0.5 ± 2.3	-	-
	Ancistrosyllis sp. 2	5.3 ± 16.1	-	8.5 ± 18.6
	Cabira sp.		-	0.8 ± 2.8
	Sigambra sp.	22.6 ± 62.8	40.0 ± 28.3	59.2 ± 55.1
Polynoidae	*Antinoe* sp.	1.6 ± 5	-	0.8 ± 2.8
	Drieschia sp.	-	-	1.5 ± 5.5
	Euphione sp.	-	-	0.8 ± 2.8
	Gastrolepidia sp.	0.5 ± 2.3	-	-
	Gattyana sp.	0.5 ± 2.3	-	-
	Harmothoe sp. 1	-	-	0.8 ± 2.8
	Harmothoe sp. 2	-	0.9 ± 3	-
	Harmothoe sp. 3	5.3 ± 11.2	-	10.8 ± 17.5
	Hololepidella sp.	0.5 ± 2.3	-	-
	Malmgrenia sp.	-	0.9 ± 3	-
	Paralepidonotus sp. 1	1.1 ± 4.6	-	-
	Paralepidonotus sp. 2	0.5 ± 2.3	1.8 ± 6	-
	Subadyte sp.	0.5 ± 2.3	-	6.9 ± 22.1
Pontodoridae	*Pontodora* sp.	25.8 ± 32.9	-	3.8 ± 13.9
Sigalonidae	*Sigalion* sp. 1	-	2.7 ± 4.7	3.8 ± 7.7
	Sigalion sp. 2	0.5 ± 2.3	-	-
	Sthenelais sp. 1	8.4 ± 18	10.0 ± 12.6	7.7 ± 16.9
	Sthenelais sp. 2	-	0.9 ± 3	-
	Sthenelais sp. 3	5.3 ± 15	-	2.3 ± 8.3
	Neoleanira sp.	10.5 ± 15.8	0.9 ± 3	9.2 ± 13.2
Sphaerodoridae	*Sphaerodoropsis* sp.	-	-	0.8 ± 2.8
	Sphaerodorum sp.	0.5 ± 2.3	-	3.1 ± 11.1

Subclass/Order/ Family	Taxa	Pekan-Dungun	Kuala Terengganu	Kudat-Balambangan Island
Syllidae	*Anguillosyllis* sp.	1.6 ± 5	-	-
	Branchiosyllis sp.	25.8 ± 39.3	1.8 ± 6	13.8 ± 23.6
	Brania sp. 1	1.6 ± 6.9	-	-
	Brania sp. 2	0.5 ± 2.3	-	-
	Erinaceusyllis sp.	0.5 ± 2.3	-	1.5 ± 5.5
	Eusyllis sp.	-	-	0.8 ± 2.8
	Exogone sp. 1	44.7 ± 45	9.1 ± 20.7	73.1 ± 60.5
	Exogone sp. 2	1.6 ± 5	-	-
	Exogone sp. 3	43.2 ± 89.8	-	7.7 ± 24.9
	Haplosyllis sp. 1	7.9 ± 10.8	3.6 ± 6.7	6.9 ± 15.5
	Haplosyllis sp. 2	10.5 ± 17.5	-	1.5 ± 3.8
	Myrianida sp.	1.6 ± 5	-	-
	Nudisyllis sp.	-	-	1.5 ± 5.5
	Opisthosyllis sp.	2.1 4.2	-	0.8 2.8
	Pionosyllis sp.	-	-	0.8 ± 2.8
	Proceraea sp.	0.5 ± 2.3	-	-
	Prosphaerosyllis sp.	2.6 ± 9.3	-	0.8 ± 2.8
	Saccocirrus sp.	-	-	0.8 ± 2.8
	Sphaerosyllis sp. 1	1.6 ± 5	1.8 ± 4	-
	Sphaerosyllis sp. 2	-	0.9 ± 3	-
	Sphaerosyllis sp. 3	-	0.9 ± 3	-
	Syllis sp. 1	1.6 ± 5	-	-
	Syllis sp. 2	0.5 ± 2.3	-	-
	Syllis sp. 3	22.1 ± 40.2	19.1 ± 21.7	21.5 ± 44.7
	Syllis sp. 4	25.3 ± 34.9	-	2.3 ± 8.3
	Syllis sp. 5	4.2 ± 10.7	-	-
	Trypanosyllis sp.	-	-	0.8 ± 2.8
SEDENTARIA				
Arenicolidae	*Abarenicola* sp. 1	0.5 ± 2.3	-	-
	Abarenicola sp. 2	0.5 ± 2.3	-	-
	Arenicola sp. 1	4.7 ± 12.6	1.8 ± 6	1.5 ± 3.8
	Arenicola sp. 2	2.6 ± 11.5	-	-
	Branchiomaldane sp.	4.2 ± 8.4	1.8 ± 4	0.8 ± 2.8
Capitellidae	*Anotomastus* sp.	-	25.5 ± 36.4	-
	Capitella sp.	7.9 ± 12.7	20.9 ± 29.8	15.4 ± 46.7
	Dasybranchus sp. 1	37.4 ± 36.5	51.8 ± 51	30.8 ± 41.9
	Dasybranchus sp. 2	-	0.9 ± 3	-
	Heteromastus sp. 1	2.6 ± 6.5	-	-
	Heteromastus sp. 2	4.2 ± 18.4	-	-
	Leiochrides sp.	2.1 ± 9.2	-	-
	Mediomastus sp.	1.1 ± 3.2	-	-
	Notomastus sp. 1	32.6 ± 41.2	68.2 ± 58.8	9.2 ± 18.0
	Notomastus sp. 2	35.8 ± 50.6	42.7 ± 43.8	36.9 ± 49.4
	Notomastus sp. 3	23.2 ± 36.5	1.8 ± 6	27.7 ± 22.8
	Scyphoproctus sp. 1	24.2 ± 22.4	6.4 ± 12.9	23.1 ± 23.6
	Scyphoproctus sp. 2	4.2 ± 13.9	-	-

Subclass/Order/ Family	Taxa	Pekan-Dungun	Kuala Terengganu	Kudat-Balambangan Island
Chaetopteridae	*Mesochaetopterus* sp.	0.5 ± 2.3	-	-
	Phyllochaetopterus sp.	0.5 ± 2.3	0.9 ± 3	0.8 ± 2.8
	Spiochaetopterus sp.	0.5 ± 2.3	-	-
Cossuridae	*Cossura* sp.	10.5 ± 15.4	13.6 ± 12.9	16.2 ± 15.6
Maldanidae	*Axiothella* sp.	14.2 ± 15.7	57.3 ± 65.4	7.7 ± 16.9
	Euclymene sp. 1	22.1 ± 38.8	-	3.1 ± 8.5
	Euclymene sp. 2	4.2 ± 9.6	0.9 ± 3	2.3 ± 8.3
	Euclymene sp. 3	0.5 ± 2.3	-	-
	Euclymene sp. 4	3.2 ± 10	-	-
	Euclymene sp. 5	1.1 ± 4.6	-	0.8 ± 2.8
	Gravierella sp.	1.1 ± 3.2	-	-
	Leiochone sp.	11.6 ± 17.4	3.6 ± 6.7	9.2 ± 17.1
	Macroclymene sp. 1	0.5 ± 2.3	0.9 ± 3	-
	Macroclymene sp. 2	4.2 ± 9	-	0.8 ± 2.8
	Maldane sp.	12.6 ± 17.6	-	1.5 ± 3.8
	Maldanella sp. 1	-	3.6 ± 6.7	-
	Maldanella sp. 2	0.5 ± 2.3	0.9 ± 3	2.3 ± 6
	Nicomache sp. 1	1.1 ± 4.6	-	-
	Nicomache sp. 2	3.2 ± 11.6	-	-
	Nicomache sp. 3	1.6 ± 5	-	-
	Petaloproctus sp.	2.6 ± 6.5	-	-
	Praxillella sp.	0.5 ± 2.3	-	-
	Rhodine sp.	3.7 ± 16.1	2.7 ± 6.5	-
Opheliidae	*Armandia* sp. 1	8.4 ± 17.1	16.4 ± 19.6	17.7 ± 36.8
	Armandia sp. 2	0.5 ± 2.3	3.6 ± 9.2	-
	Armandia sp. 3	0.5 ± 2.3	0.9 ± 3	14.6 ± 38.9
	Ophelia sp.	2.6 ± 6.5	0.9 ± 3	16.9 ± 31.2
	Ophelina sp.	-	0.9 ± 3	-
	Polyophthalmus sp. 1	-	0.9 ± 3	-
	Polyophthalmus sp. 2	1.1 ± 4.6	-	-
	Travisia sp.	-	-	0.8 ± 2.8
Orbiniidae	*Leitoscoloplos* sp. 1	0.5 ± 2.3	-	-
	Leitoscoloplos sp. 2	5.3 ± 11.2	-	0.8 ± 2.8
	Leitoscoloplos sp. 3	0.5 ± 2.3	-	-
	Naineris sp. 1	-	-	1.5 ± 5.5
	Naineris sp. 2	2.6 ± 9.3	-	-
	Orbinia sp.	0.5 ± 2.3	-	-
	Phylo sp.	-	-	9.2 ± 16.6
	Proscoloplos sp.	1.1 ± 4.6	-	-
	Schroederella sp. 1	20.5 ± 48.2	-	13.1 ± 15.5
	Schroederella sp. 2	0.5 ± 2.3	-	-
	Scolaricia sp. 1	3.7 ± 6.8	23.6 ± 22.5	41.5 ± 59.3
	Scolaricia sp. 2	1.6 ± 3.7	-	-
Sabellida				
Fabriciidae	*Fabricinuda* sp.	0.5 ± 2.3	-	-
	Novafabricia sp.	2.1 ± 9.2	-	-

Subclass/Order/ Family	Taxa	Pekan-Dungun	Kuala Terengganu	Kudat-Balambangan Island
	Pseudofabricola sp. 1	0.5 ± 2.3	-	-
	Pseudofabriciola sp. 2	7.9 ± 11.3	-	2.3 ± 6
Sabellidae	*Acromegalomma* sp.	6.3 ± 20.9	0.9 ± 3	-
	Amphicorina sp. 1	1.6 ± 5	-	-
	Amphicorina sp. 2	-	-	0.8 ± 2.8
	Amphiglena sp.	3.2 ± 5.8	3.6 ± 8.1	0.8 ± 2.8
	Branchiomma sp.	1.1 ± 4.6	-	-
	Chone sp. 1	12.6 ± 27.7	-	3.8 ± 6.5
	Chone sp. 2	2.6 ± 8.1	1.8 ± 4	2.3 ± 8.3
	Euchone sp.	14.2 ± 44.9	9.1 ± 19.2	9.2 ± 18.9
	Hypsicomus sp.	0.5 ± 2.3	-	-
	Jasmineira sp.	3.2 ± 11.6	0.9 ± 3	0.8 ± 2.8
	Parasabella sp.	0.5 ± 2.3	-	-
	Potamilla sp. 1	1.6 ± 5	0.9 ± 3	0.8 ± 2.8
	Potamilla sp. 2	0.5 ± 2.3	-	-
	Pseudopotamilla sp.	1.6 ± 5	-	-
	Sabella sp.	2.1 ± 5.4	0.9 ± 3	-
	Unidentified sabellid	145.3 ± 259.2	33.6 ± 27.3	30.0 ± 27.4
Serpulidae	*Filograna* sp.	0.5 ± 2.3	-	-
	Hydroides sp. 1	1.1 ± 4.6	-	-
	Hydroides sp. 2	0.5 ± 2.3	-	-
	Unidentified serpulid	2.1 ± 7.1	-	-
Spionida				
Spionidae	*Aonidella* sp.	134.2 ± 118.1	13.6 ± 19.6	448.5 ± 399.6
	Aonides sp.	-	-	17.7 ± 33.7
	Boccardia sp.	-	0.9 ± 3	-
	Dipolydora sp. 1	0.5 ± 2.3	10.0 ± 21.4	-
	Dipolydora sp. 2	0.5 ± 2.3	-	-
	Laonice sp.	8.9 ± 24	5.5 ± 6.9	2.3 ± 6
	Malacoceros sp.	44.7 ± 41	2.7 ± 9	86.9 ± 180
	Paraprionospio sp.	9.5 ± 14.3	21.8 ± 22.3	88.5 ± 50.8
	Polydora sp.	1.1 ± 3.2	3.6 ± 6.7	0.8 ± 2.8
	Prionospio sp. 1	5.3 ± 9	0.9 ± 3	2.3 ± 8.3
	Prionospio sp. 2	92.1 ± 74.4	3.6 ± 8.1	58.5 ± 121.2
	Prionospio sp. 3	90.5 ± 111.3	16.4 ± 17.5	99.2 ± 115.4
	Prionospio sp. 4	1.1 ± 4.6	1.8 ± 4	136.9 ± 289.4
	Prionospio sp. 5	33.2 ± 55.9	-	18.5 ± 32.6
	Pygospio sp.	3.2 ± 4.8	2.7 ± 9	-
	Scolelepis sp. 1	1.1 ± 3.2	1.8 ± 4	4.6 ± 11.3
	Scolelepis sp. 2	-	2.7 ± 6.5	-
	Scolelepis sp. 3	-	0.9 ± 3	-
	Scolelepis sp. 4	-	0.9 ± 3	2.3 ± 6
	Spio sp. 1	-	21.8 ± 35.7	-
	Spio sp. 2	0.5 ± 2.3	-	3.8 ± 13.9
	Spiophanes sp. 1	-	-	2.3 ± 6
	Spiophanes sp. 2	-	9.1 ± 21.2	-

Subclass/Order/ Family	Taxa	Pekan-Dungun	Kuala Terengganu	Kudat-Balambangan Island
Magelonidae	*Magelona* sp. 1	-	-	2.3 ± 6
	Magelona sp. 2	1.1 ± 4.6	6.4 ± 14.3	-
	Magelona sp. 3	18.9 ± 44.3	35.5 ± 48.7	15.4 ± 29.3
Poecilochaetidae	*Poecilochaetus* sp. 1	11.1 ± 22.6	3.6 ± 5	23.1 ± 40.3
	Poecilochaetus sp. 2	1.1 ± 3.2	1.8 ± 4	-
Terebellida				
Ampharetidae	*Ampharete* sp. 1	9.5 ± 30.1	0.9 ± 3	10.0 ± 14.7
	Ampharete sp. 2	0.5 ± 2.3	3.6 ± 6.7	-
	Ampharete sp. 3	0.5 ± 2.3	-	-
	Ampharete sp. 4	0.5 ± 2.3	0.9 ± 3	-
	Amphicteis sp. 1	44.2 ± 92.5	5.5 ± 12.1	20.0 ± 21.2
	Amphicteis sp. 2	7.9 ± 15.5	1.8 ± 6.0	-
	Glyphanostomum sp.	3.7 ± 13.8	2.7 ± 4.7	26.2 ± 37.5
	Isolda sp. 1	11.6 ± 41.1	6.4 ± 12.1	33.1 ± 37.9
	Melinna sp.	2.6 ± 8.1	-	5.4 ± 11.3
	Melinnopsides sp.	42.6 ± 102.6	-	8.5 ± 19.9
	Phyllocomus sp.	1.1 ± 3.2	5.5 ± 15.1	1.5 ± 5.5
	Unidentified ampharetid	62.1 ± 144.1	20.0 ± 39	65.4 ± 140
Cirratulidae	*Aphelochaeta* sp. 1	3.7 ± 8.3	-	18.5 ± 21.2
	Aphelochaeta sp. 2	15.3 ± 23.2	2.7 ± 6.5	15.4 ± 55.5
	Caulleriella sp.	-	0.9 ± 3	-
	Chaetozone sp.	-	0.9 ± 3	-
	Cirratulus sp. 1	11.6 ± 23.9	16.4 ± 41.5	43.1 ± 50.2
	Cirratulus sp. 2	7.9 ± 16.9	5.5 ± 8.2	11.5 ± 19.5
	Cirratulus sp. 3	26.3 ± 40.4	0.9 ± 3	9.2 ± 25
	Cirriformia sp. 1	45.3 ± 46	10.9 ± 19.2	40.0 ± 55.1
	Cirriformia sp. 2	0.5 ± 2.3	-	-
	Cirriformia sp. 3	5.3 ± 13.1	16.4 ± 34.7	0.8 ± 2.8
	Dodecaceria sp. 1	11.1 ± 30.5	-	-
	Dodecaceria sp. 2	3.7 ± 10.1	-	-
	Kirkegaardia sp.	5.8 ± 14.3	16.4 ± 17.5	2.3 ± 6
	Protocirrineris sp.	0.5 ± 2.3	32.7 ± 108.5	-
	Tharyx sp. 1	1.1 ± 4.6	-	-
	Tharyx sp. 2	-	2.7 ± 6.5	-
Flabelligeridae	*Brada* sp.	-	1.8 ± 4	-
	Diplocirrus sp.	0.5 ± 2.3	5.5 ± 8.2	10.8 ± 16.6
	Flabelligera sp.	-	3.6 ± 12.1	0.8 ± 2.8
	Pherusa sp. 1	5.3 ± 22.9	-	1.5 ± 3.8
	Pherusa sp. 2	-	25.5 ± 27.7	-
	Pherusa sp. 3	-	0.9 ± 3	-
	Pherusa sp. 4	-	0.9 ± 3	-
	Piromis sp. 1	-	1.8 ± 4	0.8 ± 2.8
	Piromis sp. 2	1.6 ± 5	-	-
	Piromis sp. 3	-	-	0.8 ± 2.8
Pectinariidae	*Pectinaria* sp.	-	-	1.5 ± 5.5
	Unidentified pectinarid	0.5 ± 2.3	-	-

Subclass/Order/ Family	Taxa	Pekan-Dungun	Kuala Terengganu	Kudat-Balambangan Island
Sternaspidae	*Sternaspis* sp.	21.6 ± 25.4	70.9 ± 29.8	16.2 ± 18
	Unidentified sternaspid	0.5 ± 2.3	-	-
Terebellidae	*Amaeana* sp.	0.5 ± 2.3	0.9 ± 3	0.8 ± 2.8
	Lanassa sp.	4.7 ± 10.2	4.5 ± 15.1	5.4 ± 13.3
	Loimia sp.	2.1 ± 4.2	-	-
	Lysilla sp. 1	1.1 ± 3.2	1.8 ± 4	-
	Lysilla sp. 2	-	0.9 ± 3	-
	Pista sp. 1	-	-	0.8 ± 2.8
	Pista sp. 2	11.1 ± 18.2	5.5 ± 12.1	13.1 ± 21.8
	Pista sp. 3	7.9 ± 13.6	1.8 ± 4	3.1 ± 8.5
	Pista sp. 4	2.6 ± 6.5	-	0.8 ± 2.8
	Polycirrus sp. 1	1.1 ± 4.6	-	-
	Polycirrus sp. 2	-	2.7 ± 6.5	4.6 ± 16.6
	Streblosoma sp. 1	1.1 ± 4.6	-	-
	Streblosoma sp. 2	4.7 ± 7	0.9 ± 3	0.8 ± 2.8
	Streblosoma sp. 3	-	1.8 ± 4	-
	Terebella sp.	0.5 ± 2.3	-	-
	Thelepus sp.	10.0 ± 18.6	5.5 ± 18.1	2.3 ± 6
	Unidentified Terebellidae	-	27.3 ± 30	-
Trichobranchidae	*Terebellides* sp. 1	-	126.4 ± 82.1	5.4 ± 11.3
	Terebellides sp. 2	7.9 ± 15.1	-	8.5 ± 21.5
	Trichobranchus sp. 1	-	22.7 ± 42	-
	Trichobranchus sp. 2	1.1 ± 4.6	4.5 ± 15.1	0.8 ± 2.8

The mean taxa numbers of polychaetes at the southern SCS were presented in Figure 3A. The number of taxa among areas was significantly different ($p < 0.05$). Offshore Pekan-Dungun had the highest value (65 taxa/station) while Kuala Terengganu was the lowest (47 taxa/station). The mean value of diversity (4.1 to 5.6) differed significantly ($p < 0.05$) among all areas (Figure 3B), however the value for evenness index (0.73 to 0.92) did not differ significantly among all areas ($p > 0.05$) (Figure 3C).

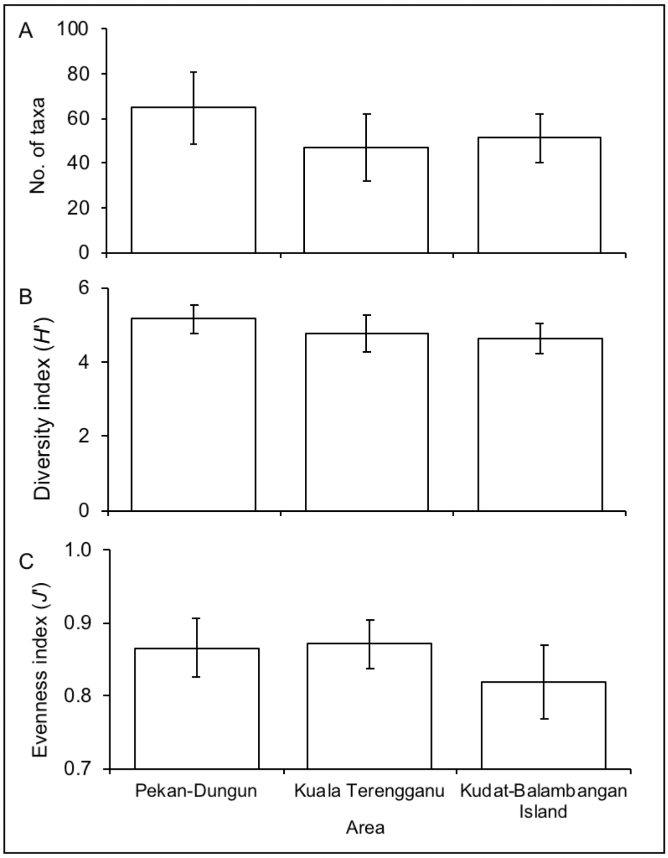

Figure 3: Total taxa number (A), Diversity index (*H'*) (B) and Evenness index (J') (C) of polychaetes at each area of the southern South China Sea (mean ± SD). Area: Pekan-Dungun, n = 19; Kuala Terengganu, n = 11; Kudat-Balambangan Island, n = 13.

Although offshore Kuala Terengganu had the lowest value for the number of species and density (individual/m^2), it had significantly higher ($p < 0.05$) percentage of sediment TOC compared to offshore Pekan-Dungun and Kudat-Balambangan Island (Figure 4).

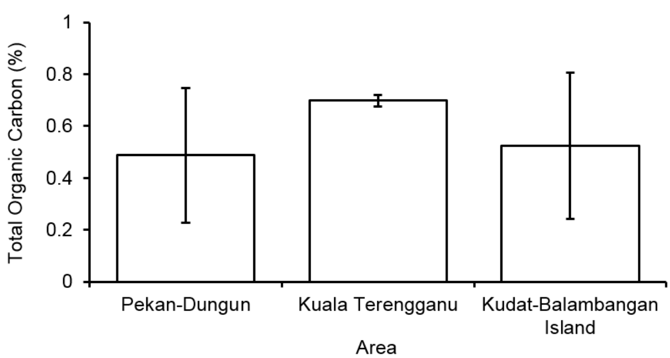

Figure 4: Percentage of Total Organic Carbon at each area of the southern South China Sea (mean ± SD). Area: Pekan-Dungun, n = 19; Kuala Terengganu, n = 11; Kudat-Balambangan Island, n = 13

Percentage of sediment particles according to sizes of offshore Pekan-Dungun, Kuala Terengganu and Kudat-Balambangan Island in the southern SCS were divided into three types; sand (0.06 – 2.0 mm), silt (0.039 – 0.063 mm) and clay (<0.0039 mm) (Figure 5). The percentage of sand was significantly lower compared to silt and clay in all areas ($p < 0.05$). The offshore area of Kudat-Balambangan Island had the highest percentage of sand (16%) and clay (40%) while Kuala Terengganu had the highest percentage of silt (74%). The sediment textures of offshore Pekan-Dungun, Kuala Terengganu and Kudat-Balambangan Island were described in details based on USDA (1987) classification (Figure 6).

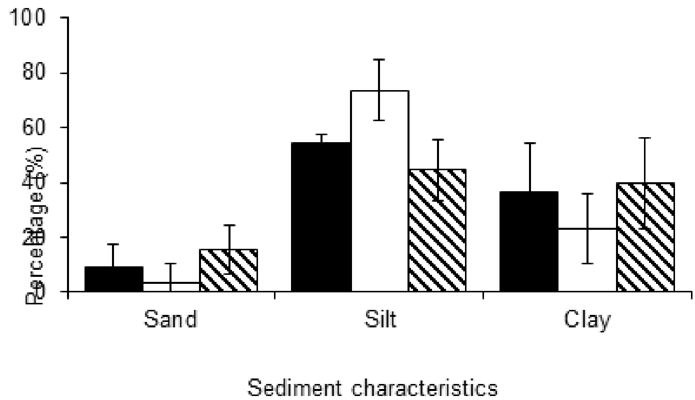

Figure 5: Percentage of sediment characteristics (sand, silt and clay) in each area of the southern South China Sea (mean ± SD). Area: Pekan-Dungun, n = 18; Kuala Terengganu, n = 11; Kudat-Balambangan Island, n = 13.

Eight types of sediment texture were determined as in Table 3. The sediment texture in the southern SCS was compounded and complicated. The compound property was the mixture of various sediment textures such as silty-clay, silty-clay-loam, silt-loam and sandy-loam. The complicated property was the patchy distribution of sediment, for example silty-clay-loam type was found at Pekan-Dungun (10 stations), Ku ala Terengganu (2 stations) and Kudat-Balambangan Island (2 stations).

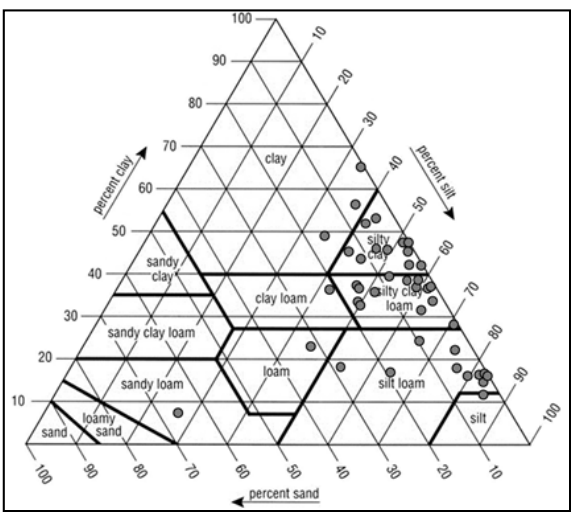

Figure 6: Sediment texture of the southern South China Sea (offshore Pekan-Dungun, Kuala Terengganu and Kudat-Balambangan Island).

Table 3: The sediment textures of southern South China Sea.

Sediment texture	No. of station
Silty-clay	**11**
Silty-clay-loam	**14**
Silt-loam	**10**
Silt	**1**
Clay	**3**
Clay-loam	**1**
Loam	**1**
Sandy-loam	**1**

Table 4 shows that silt had the lowest density of polychaetes with an average 394 individual/m^2. However, silt-loam, silty-clay and silty-clay-loam had the highest density with 1,685 individual/m^2, 1,354 individual/m^2 and 1,236 individual/m^2 respectively. The polychaetes at offshore Pekan-Dungun were found only in three types of sediment (silty-clay, silty-clay-loam and silt-loam), offshore Kuala Terengganu with four types of sediments (silty-clay, silty-clay-loam, silt-loam and silt) while the polychaetes were found in all types of sediments except silt at offshore Kudat-Balambangan Island.

Table 4: The distribution of polychaetes abundance (individual/m^2) in the group of sediment.

Group of sediment	Pekan-Dungun	Kuala Terengganu	Kudat-Balambangan Island
Silty-clay	517	306	531
Silty-clay-loam	282	564	390
Silt-loam	612	397	676
Silt	-	394	-
Clay	-	-	856
Clay-loam	-	-	524
Loam	-	-	566
Sandy-loam	-	-	624

Discussion

The abundance of polychaetes in this study was higher compared to previous studies at the southern SCS region (Table 5). The possible reason could be due to current study covered three areas of the southern SCS, which have high biodiversity, even it is only one-off sampling. Besides that, the use of different sampling gear (Smith McIntyre grab, 0.1 m^2) and different mesh sizes (0.5 mm) also contributed in better samples collection. Another reason is that, five replicates of samples were compared in present study, in contrast to with only one replicate (Piamthipmanus, 1998; Yasin & Razak, 1999) and two replicates in Piamthipmanus (1999) and Trong *et al.* (2000). Therefore, by enhancing the sampling method and effort, more polychaete samples were obtained throughout the study.

Table 5: Comparison of polychaete density (individual/m^2) with previous studies done in Malaysia and the South China Sea region.

Locality	Density (No. of ind/m^2)	References
Offshore Malaysia	573	Present study
North & South Vietnamese water	32	Trong *et al.* (2000)
East Coast of Peninsular Malaysia & Gulf of Thailand	107	Piamthipmanus (1999)
East Coast of Peninsular Malaysia & Gulf of Thailand	106	Yasin and Razak (1999)
Brunei & Malaysia (Sabah and Sarawak)	113	Piamthipmanus (1998)

Kuala Terengganu had the lowest in abundance and species number which can be due to smaller study area sampled as compared to Pekan-Dungun and Kudat-Balambangan Island (Rosli *et al.,* 2016) which were 12 times greater in the sampling area being covered. Moreover, samples collected from offshore of Kuala Terengganu, located far from the mainland of the east coast of Peninsular Malaysia; in which it received lower nutrients input from the coastal water (Shaari & Mustapha, 2017). However, the mean species number of polychaete found in this study was considered higher compared to previous studies done in the SCS (Table 6). Liu (2013) stated that the SCS has higher species richness and number compared to adjacent seas (East China Sea, Bohai Sea & the Yellow Sea). In addition, SCS had the highest identified polychaete species in the Southeast Asian region (e.g. the Andaman Sea) (Phasuk, 1992; Barrio-Froján *et al.,* 2005). Latest Malaysian polychaete checklist by Idris and Arshad (2013) and study done by Ibrahim *et al.* (2017) showed that 65 polychaetes species belonging to 31 families were recorded and the present study has increase the number of identified polychaetes.

Table 6: Comparison of polychaete density (individual/m^2) with previous studies done in Malaysia and the South China Sea region.

Locality	Number of taxa	References
Malaysia	64	Idris and Arshad (2013)
South China Sea	1,219	Glasby *et al.* (2016)
East China Sea	376	Liu (2013)
Bohai and Yellow Sea	367	Liu (2013)
China Sea	1065	Liu (2013)
The world	20,000	Read and Fauchald (2018)

Family Spionidae had highest density in this study possibly as spionids tend to live on the surface and sub-surface sediment (Bone *et al.,* 2011), which in turn can be easily collected by the grab. Spionids are also known as ubiquitous species that can be found in the soft mud, sand and mixed sediments, hence become dominant in soft bottom habitat from intertidal to abyssal depth including shallow sandy areas (Delgao-Blas & Salazar-Silva, 2011; López, 2011; Sato-Okoshi *et al.,* 2012; 2013).

Offshore of Kuala Terengganu had the highest percentage of TOC compared to the other two study areas. Highest percentage of silt also was observed in this area in contrast to the other two areas. This is because the organic carbon content at the offshore Kuala Terengganu are trapped in the silt sediments. Evans *et al.* (1990) stated that the organic content is increase as the sediment grain size decrease, whereby silt and clay contain higher organic matter compared to sand and gravel.

The diversity and distribution of polychaetes in this study is highly determined by the sediment type. The occurrence of the high number of identifying species was relatively highest in soft sediments silty-clay, silty-clay-loam and silt-loam. These indicated that the soft sediments are the preferable habitats for the growing of polychaete community. Ajmal-Khan and Murugesan (2005), Patel and Desai (2009) also supported that the polychaetes are higher in soft sediment rather than coarse sediment.

Conclusion

Southern SCS recorded with high presence of polychaete diversity and density with family Spionidae being the most abundant family. Polychaete in the southern SCS were found mainly in soft sediment (silty-clay, silty-clay-loam & silt-loam).

The information obtained from this study provides significant baseline information for sustainable marine management ecosystem of southern SCS. However, further taxonomic and ecological studies on macrobenthos in general and polychaetes in particular are needed for a better understanding of the polychaetes group in the southern SCS especially in Malaysian waters. Hence, the use of polychaetes as a potential bio-indicator for mineral resources in this region could be done widely in the future.

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