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SETTLEMENT RATE OF FOULING SERPULID *Ficopomatus* cf. *uschakovi* PILLAI, 1960 ON ARTIFICIAL STRUCTURE AT SETIU WETLANDS, TERENGGANU, MALAYSIA

(Kadar Penempatan Petumbuhan Serpulid *Ficopomatus* cf. *uschakovi* Pillai, 1960 pada Struktur Tiruan di Tanah Bencah Setiu, Terengganu, Malaysia)

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Abstract

Fouling polychaetes from genus *Ficopomatus* are known to have adverse impacts on human activities through fouling on man-made structures such as ship hulls, seawater intake pipes and aquaculture platforms. Various studies on fouling patterns of the fouling species have been done worldwide, as some of the species are estuarine invaders, which have become pests to the environment. This study was conducted to determine the spatial and temporal distribution of the *Ficopomatus* cf. *uschakovi* settlement and their relationship with environmental parameters in Setiu Wetlands. A monthly assessment was conducted at three stations for 14 months from May 2017 until July 2018. A frame consisting of three replicates of perspex plate (14 x 10 cm) was placed randomly at each station and collected for assessment every month. All *F.* cf. *uschakovi* tubes on the front and back of the plate were counted. Physico-chemical parameters collected included temperature (^{o}C), salinity (ppt), pH and dissolved oxygen (mg/L) of the water column. The results showed the larval attachments were spatially and temporally variable. A higher density of *F.* cf. *uschakovi* tubes was recorded at the station with protected area and orientation. The settlement rate of *F.* cf. *uschakovi* was low, at only 0.044 individuals.dm^{-2}/sampling month. It was further found out that the distribution and occurrence of *F.* cf. *uschakovi* tubes in Setiu Wetlands was affected by the environmental parameters, particularly, temperature, salinity and pH of the water column.

Keywords: fouling polychaete, Serpulidae, *Ficopomatus*, larval settlement, Setiu Wetlands

Abstrak

Petumbuhan poliket dari genus *Ficopomatus* diketahui memberi kesan buruk terhadap aktiviti manusia melalui petumbuhan pada struktur buatan manusia seperti badan kapal, paip pengambilan air laut dan pelantar akuakultur. Pelbagai kajian mengenai corak petumbuhan bagi spesies ini telah dilakukan di seluruh dunia, kerana sesetengah spesies adalah penceroboh muara, sehingga menjadi perosak kepada alam sekitar. Kajian ini dijalankan untuk menentukan taburan tempat dan masa bagi penempatan *Ficopomatus* cf. *uschakovi* dan hubungannya dengan parameter sekitar di Tanah Bencah Setiu. Penilaian bulanan dilakukan pada tiga stesen selama 14 bulan dari Mei 2017 hingga Julai 2018. Bingkai yang terdiri daripada tiga replikasi plat perspeks (14 x 10 cm) diletakkan secara rawak di setiap stesen dan dikumpulkan untuk penilaian setiap bulan. Kesemua tiub *F.* cf. *uschakovi* di bahagian depan dan belakang plat dikira. Parameter fiziko-kimia yang dikumpulkan ialah suhu (^{o}C), saliniti (ppt), pH dan oksigen terlarut (mg/L). Hasilnya menunjukkan penempatan larva berubah-ubah mengikut lokasi dan tempoh masa. Ketumpatan tiub *F.* cf. *uschakovi* yang tinggi dicatatkan di stesen yang berkawasan dan berorientasi terlindung. Kadar penempatan *F.* cf. *uschakovi* adalah rendah, iaitu hanya 0.044 individu.dm^{-2}/bulan pensampelan. Penemuan seterusnya mendapati bahawa taburan dan kehadiran tiub *F.* cf. *uschakovi* di Tanah Bencah Setiu dipengaruhi oleh parameter sekitar, terutamanya, suhu, kemasinan, oksigen terlarut dan pH turus air.

Kata kunci: petumbuhan poliket, Serpulidae, *Ficopomatus*, penempatan larva, Tanah Bencah Setiu

Introduction

Fouling is an undesirable accumulation of unwanted organisms (e.g., microorganisms, plants, algae and animals) on submerged structures that happens all over the world [1-3]. Several examples of fouling communities are algae, ascidians, crustaceans, hydroids, molluscs, sea anemones, sponges as well as polychaetes [4]. Fouling polychaete can be tubeworms (family Sabellidae and Serpulidae) or burrowers (family Spionidae and Terebellidae), but the most important components of the fouling polychaete community globally are the serpulids [4-7].

Serpulids are distributed globally in tropical, subtropical and temperate areas around the world, mainly in the intertidal zone whereby they can also be found attached on mangrove plants [8]. Serpulids are sessile and filter feeder polychaete that have protandric hermaphroditism, broadcast spawning and have a lifespan of one to five years [5]. Past studies had discovered that the serpulids prefer an enclosed area with turbid waters, rich in organic matter and weak water currents [9]. Besides this, temperature and salinity are factors that affect the reproduction and settlement of serpulids. Serpulids are also known as ecosystem engineers as they can; 1) improve water quality with their high rate of ingestion and particle clearance; 2) act as efficient suspension feeders as they eat suspended detritus and phytoplankton; 3) act as reef builders, where many associated organisms live together, hence causing an increase in biodiversity and abundance of the affected areas; and 4) help in bio-erosion [9, 10].

Research on fouling serpulids has been done worldwide, as some of the species are global estuarine invaders, including genus *Ficopomatus* Southern, 1921 [11]. *Ficopomatus* are euryhaline species and are the only brackish water serpulids that are classified under the subfamily Serpulinae. They are capable of building large, reef-like colonies that can have strong ecological and economic impacts [12]. For example, they can foul on man-made structures, aquaculture structures and seawater intake pipes. This fouling behaviour increases drag on the vessels, decrease structure stability and durability, thereby reducing water flow, oxygen supply, food intake and waste removal of cultured species [4, 5]. In an ecological aspect, *Ficopomatus* are capable of invading areas outside of their original geographical distribution via vessels, which contribute to the alteration of the composition and function of benthic communities [4, 9]. For instance, *Ficopomatus enigmaticus* (Fauvel, 1923) is originally described from Caen Canal (northwestern France), but was recorded worldwide in temperate and subtropical waters. However, the information about the ecological and economic effects of this genus in the world is still scarce because they are small in size and hence are often overlooked or ignored [4].

The Setiu Wetlands are in a semi-enclosed area and are complex wetlands located in the east coast of Peninsular Malaysia, within the southern South China Sea region (sSCS) [13]. The wetland belongs to the Terengganu state under the District of Setiu, covering 23,000 ha of land and 880 ha of water body [14]. It consists of nine types of interconnected ecosystems which include seas, beaches, mudflats, lagoons, estuaries, rivers, mangrove forests, islands and coastal forests [15]. Each of these are characterised by unique yet intricate physical environments that support their biological entities [14]. Cage cultures are one of the main activities in Setiu Wetlands. However, the accumulation of fouling organisms (oyster, barnacle, tubeworms, etc.) on the cage cultures is the main constraint to such activities, as it reduces the effectiveness of the cages.

In Malaysia, the fouling serpulids are not well known, and, to date there are only a few records about serpulids that occur in Malaysian waters [16]. In the Setiu Wetlands, *F.* cf. *uschakovi* can be found attached on the mangrove plants such as on the root of *Rhizophora apiculata*, on the bark of *Nypa fruticans*, on oysters clump as well as on the cage culture activities. Therefore, this study aims to determine the spatial and temporal distribution of *Ficopomatus* cf. *uschakovi* settlements and to investigate the effect of environmental parameters on their settlements in Setiu Wetlands. Hence, this study will improve on the existing fouling polychaete information and hence provide a better understanding of this group in Malaysia. The output from this study could be used as baseline data for the aquaculture industry, for future investigations on environmental changes in this area and as a reference for wetland management activities.

Materials and Methods

Study area

Monthly field sampling was conducted from May 2017 to July 2018 (14 months) during low tide, at three stations (Figure 1) which were chosen in order to represent the range of activities within the study area (Table 1). The physical water quality parameters (temperature, salinity, pH and dissolved oxygen) were measured in situ using a water quality multi-parameter instrument, either a Hydrolab Quanta (Multiprobe System) or a YSI meter.

Experimental method and sampling

A frame consisting of smooth sides of white perspex (14 x 10 cm) with three replicates (n=3) was attached randomly on a floating raft at each station and was submerged 0.2 m below the estuary surface water, following [9] slight modifications (Figure 2). Each perspex was labelled at the front (facing outside the raft) and back (facing inside the raft) sides. Each plate was photographed from the front and the back using a digital camera (Canon IXUS 175). Then, the photographed plates were removed and placed in containers filled with *in situ* water and aerated. New plates were placed and left for a month after each assessment time.

Laboratory analysis

In the laboratory, both sides (front and back) of each plate were observed. All *F.* cf. *uschakovi* tubes present were counted and preserved in 80% ethanol. The density is determined as a total number of individual(s) per decimeter^2 (No. of individuals.dm^{-2}) (1 dm = 100 cm). The settlement rate for *F.* cf. *uschakovi* was calculated using the formula based from [7]:

$$\text{Settlement rate} = \frac{\text{Mean density (Individuals.dm}^{-2}\text{)}}{\text{Total no. of sampling months}} \tag{1}$$

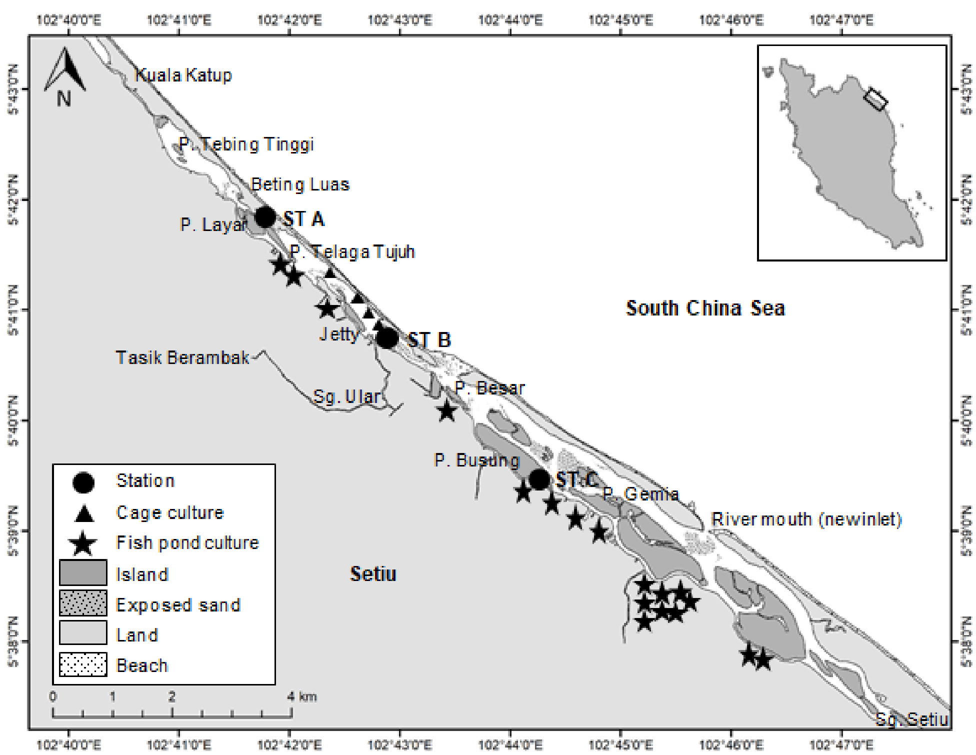

Figure 1. The locations of sampling station at Setiu Wetlands

Table 1. Description of the sampling stations

Station	Coordinate		Site Description
	Latitude (N)	Longitude (E)	
A	5°41’ 50.40”	102°41’ 42.20”	Northern part of the lagoon. Lack of human activity.
B	5°40’ 46.44”	102°42’ 50.58”	Middle part of the lagoon. Center of human activities such as boat landing, aquaculture, and seafood-based food production [13]
C	5°39’ 25.68”	102°44’ 20.70”	Southern part of the lagoon. Sheltered area with small scale fishponds and abandoned cage cultures

Statistical analyses

Calculations on significant differences in the mean of biological parameters (e.g. density of *F.* cf. *uschakovi*) and physico-chemical parameters (temperature, salinity, DO, pH) among stations and sampling periods were performed using SPSS (Statistic Package for Social Science) version 22. For the data that failed to meet the assumptions of analysis of variance (ANOVA), the Kruskal Wallis test was used. If the one-way ANOVA showed a significant result, a post hoc test was conducted for a pairwise comparison. For all tests, a criterion of $p < 0.05$ was used to determine statistical significance. The PCA analysis was conducted to determine the factor that affected the distribution of *F.* cf. *uschakovi*.

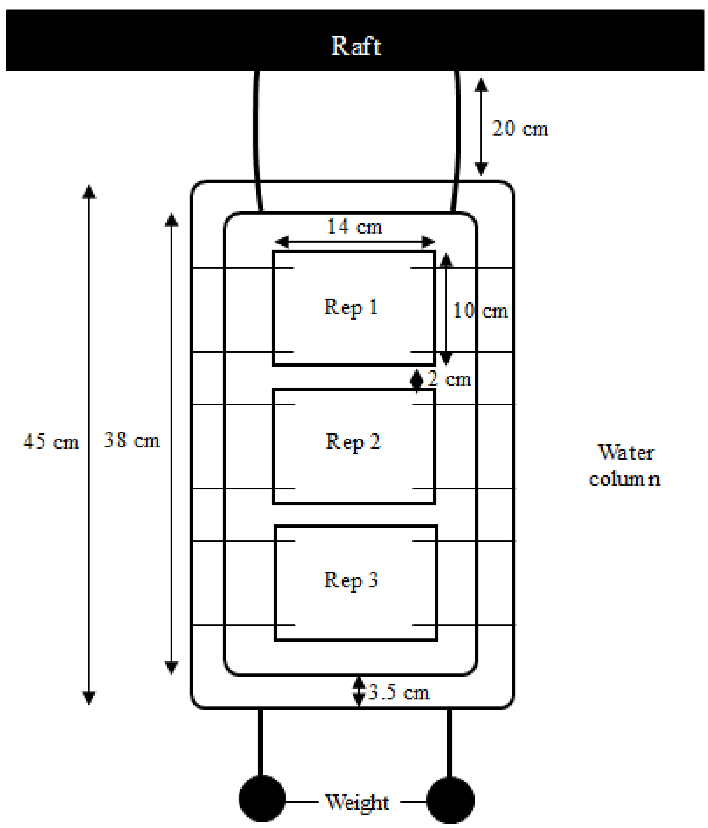

Figure 2. Diagram of a single experimental frame attached on a raft consists of 3 perspex plates

Results and Discussion

In the present study, mean temperature, salinity, DO, and pH exhibited approximately a similar pattern at all sampling stations throughout the study period (Figure 3). The Kruskal Wallis test showed that all the parameters did not differ significantly ($p > 0.05$) between sampling stations. The mean temperatures observed ranged between 28 °C and 33 °C. The range of water Salinity was between 2 ppt and 31 ppt (Figure 3). High mean salinity was recorded at ST C due to its location near the river mouth which contributes more seawater. The lowest salinity values were recorded during December 2017 (2 to 4 ppt), which was because of the influence of rainfall during the sampling activities. The salinity values saw a reduction from October until February because of the northeast monsoon that dominates the sSCS region from November to March every year, which results in strong northeasterly monsoon wind stress and heavy rainfall [17].

The mean DO concentrations ranged from 2.6 mg/L to 11.9 mg/L (Figure 3), which were lower compared to Suratman et al. [13]. This was probably due to the location of the station, which is in an area where a large scale of palm oil plantation activity takes place, upstream of the Sungai Ular (Figure 1). The use of fertilisers at this plantation increased the runoff of nutrients, thus increasing the phytoplankton growth, followed by the decomposition processes when the phytoplankton died, resulting in low DO in the water column [13, 18]. Moreover, it was probably due to the aquaculture activities in the area. A decrease of the DO concentration can also be as a result of the respiration of the farm fish and other aquatic organisms inside the caged area of the water column [19]. Besides that, low DO at ST C was probably also caused by the input of domestic wastes from the town of Penarik, located upstream of Sungai Setiu. While for pH, the values ranged between 5.6 and 8.1 (Figure 3). Generally, there was no consistent trend of high or low pH values at the different stations, with water pH being similar throughout the sampling period for all stations.

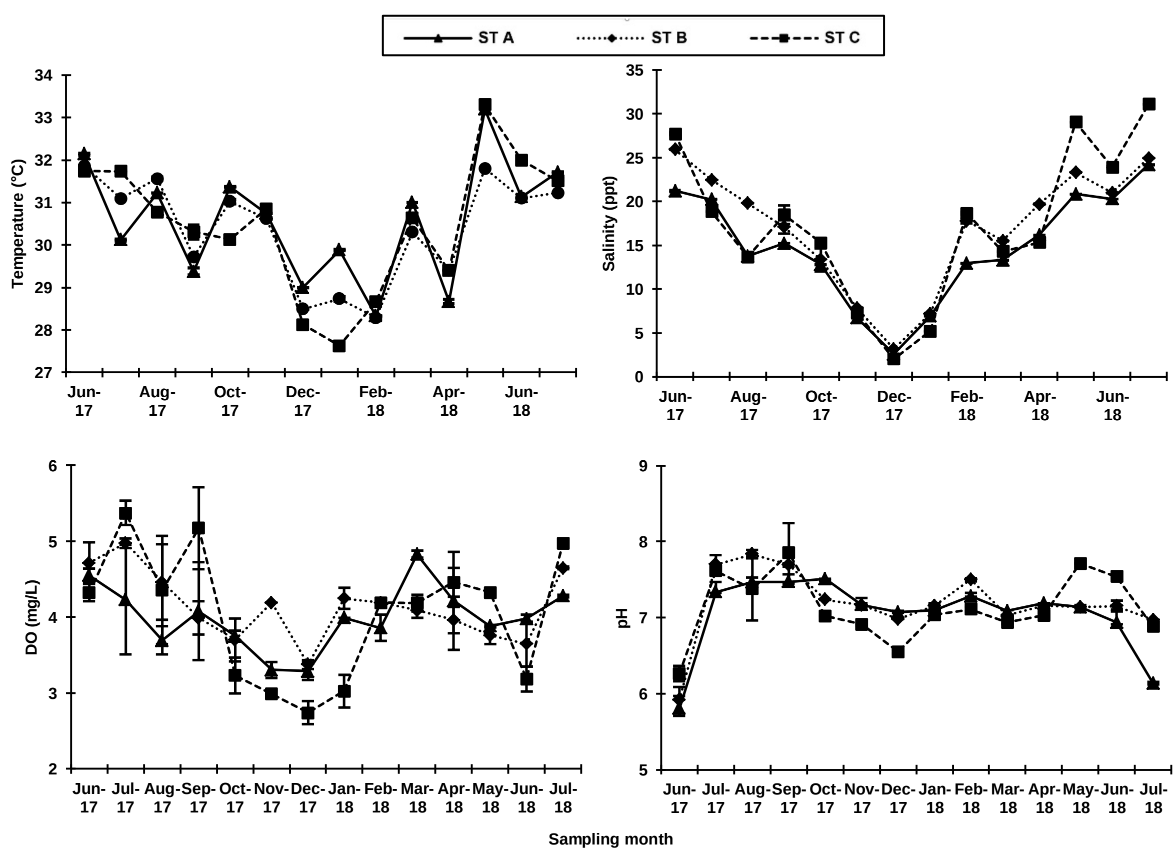

Figure 3. Variation of mean temperature, salinity, DO and pH at station A, B, and C of Setiu Wetlands

Mean density of *F.* cf. *uschakovi* tube (individuals/dm^2) attached on the plate is shown in Figure 4. The Kruskal Wallis test showed that the mean density of the front and back side of the plate did not differ significantly ($p > 0.05$) between sampling stations. A wide variation of *F.* cf. *uschakovi* density was found throughout the study period. A high density of *F.* cf. *uschakovi* tubes was recorded on the back side of the plate which was in a protected orientation compared to the front side. *F.* cf. *uschakovi* tubes were observed at all stations only in August 2017 (front), December 2017 (back) and January 2018 (back). ST C had a higher occurrence of *F.* cf. *uschakovi* tubes throughout the sampling months while ST A had the lowest occurrence. The finding shows that *F.* cf. *uschakovi* tubes preferred an area that was sheltered (ST C) and in protected orientation (back). Dittmann et al. [9] believed that salinity is one of the factors that affect the *F. enigmaticus* larval settlements. However, despite the low salinity during the monsoon (October – February), there was a high settlement of *F.* cf. *uschakovi* tubes in Setiu Wetlands. A previous study [20] showed that the current velocity in Setiu Wetlands ranges from 0.04 m sec^{-1} to 0.88 m sec^{-1} from November to February, which is very low. It might have been the reason for high settlements of *F.* cf. *uschakovi* tubes, as the tubes did not get easily detached from the plate and hence were not carried away by the currents.

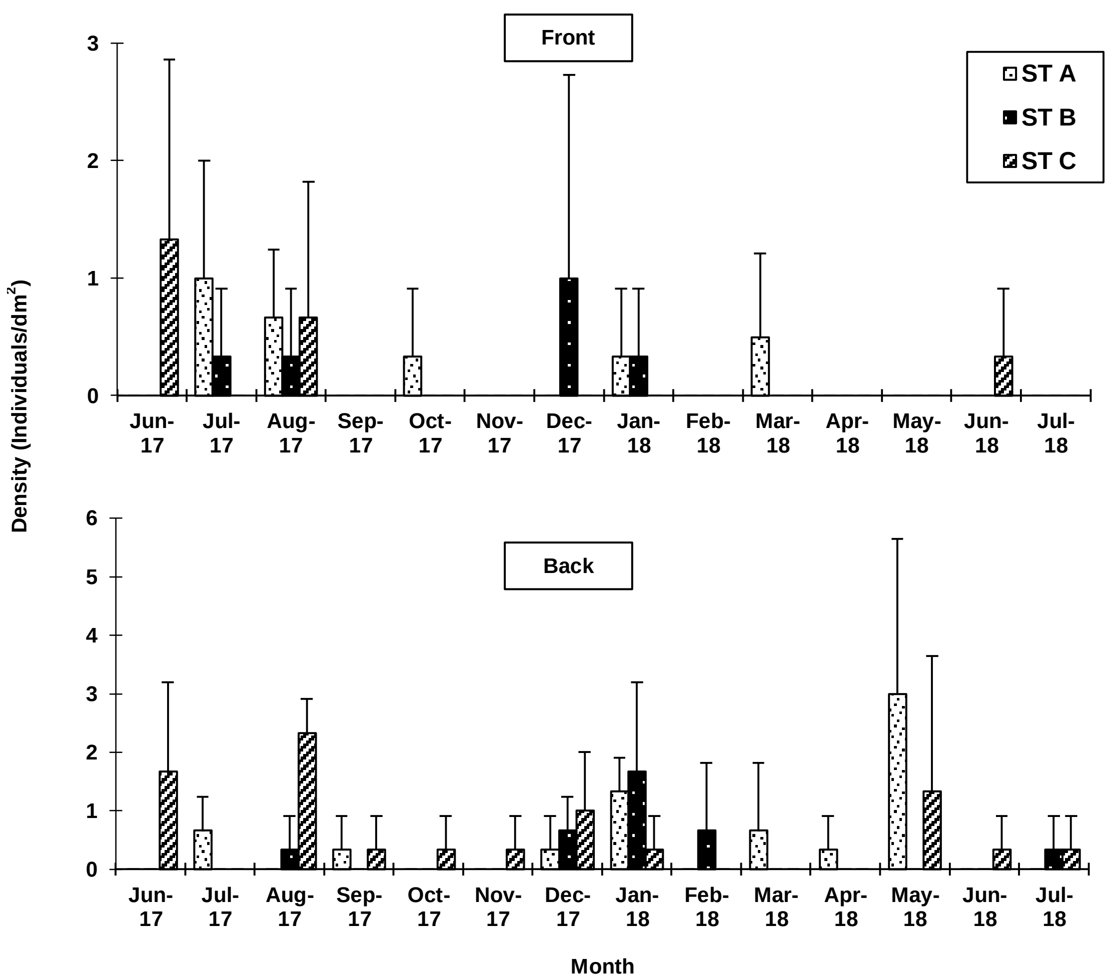

Figure 4. Colonisation pattern of *F.* cf. *uschakovi* on three perspex plates (mean ± standard deviation) submerged at station A, B and C of Setiu Wetlands

Settlement rates of *F.* cf. *uschakovi* tubes (individuals.dm^{-2}/month) at each sampling station throughout the sampling months are shown in Table 2 and Figure 5. Overall, the back side of the plate had a high settlement rate as compared to the front side, except for July 2017 (Figure 5). These results correlated with the mean density shown in Figure 4. An analysis of ST C showed that this area had the highest settlement rate of *F.* cf. *uschakovi* tubes (0.090 individuals.dm^{-2}/sampling month) for the back side of the plate compared to other stations. However, the settlement rate for the front side of the plate was almost similar for all three stations, which was within a range of 0.020 – 0.027 individuals.dm^{-2}/sampling month. This study had also found that the settlement rate of *F.* cf. *uschakovi* tubes was 0.044 individuals.dm^{-2}/sampling month, which generally considered to be low.

Table 2. Settlement rate of *F.* cf. *uschakovi* tube (individuals.dm^{-2}/sampling month) at each sampling station for 14 months from Jun 2017 until July 2018

Station	Plate Position	***F.* cf. *uschakovi* Settlement Rate (individuals.dm^{-2}/sampling month)**
A	Front	0.027
	Back	0.067
B	Front	0.020
	Back	0.037
C	Front	0.023
	Back	0.090
Mean total		0.044

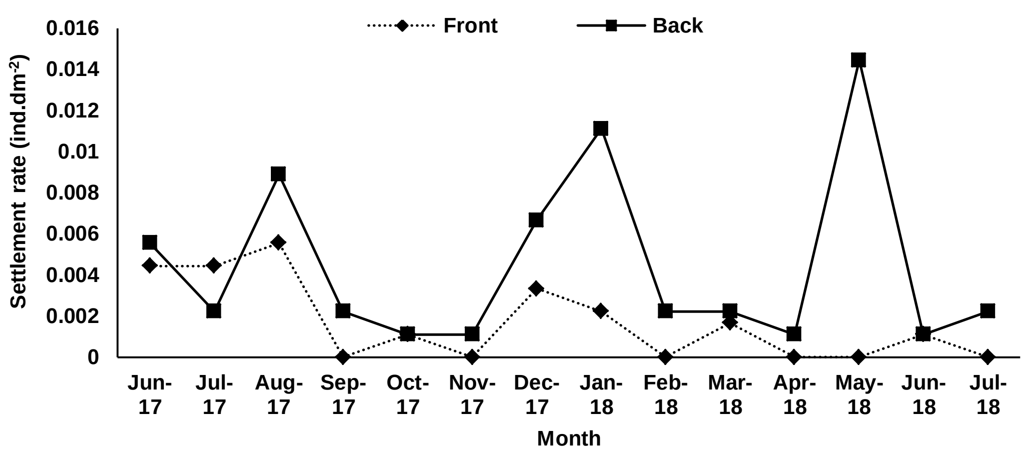

Figure 5. Settlement rate of *F.* cf. *uschakovi* tube (individuals.dm^{-2}/sampling month) on front and back of perspex plate for 14 months from Jun 2017 until July 2018

PCA analyses show that three factors can be extracted based on total eigenvalue more than 1 (Table 3), where all the factors had less than 50% of cumulative of variance (rotation sums of squared loadings). The total variance explained by the three-factor solution is 77.289%, which can be considered high. Each of the three factors explains a portion of the total variance and can be categorised as PC1 (32.829%), PC2 (23.923%) and PC3 (20.537%). Based on the rotated component matrix (Table 4, Figure 5), PC1 consists of temperature and salinity, PC2 consists of mean density (front & back), while PC3 consists of mean density (front & back) and pH. This finding shows that the distribution and settlement rate of *F.* cf. *uschakovi* tubes in Setiu Wetlands was affected by environmental parameters, particularly, the temperature, salinity and pH of the water column. Although Sateesh and Wesley [21] said that the hydrobiological parameters are not a critical factor in a tropical coast, the occurrence and breeding periods of marine organisms largely depend on environmental fluctuations, particularly those involving temperature and salinity [22].

Table 3. Summary of Principal Component Analysis (PCA)

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.673	33.454	33.454	1.641	32.829	32.829
2	1.190	23.802	57.256	1.196	23.923	56.752
3	1.002	20.033	77.289	1.027	20.537	77.289
4	0.777	15.535	92.824			
5	0.359	7.176	100.00			

Table 4. Rotated component matrix

Variables	Component		
	1	2	3
Mean Density (Front)		0.755	0.270
Mean Density (Back)		0.790	-0.224
Temperature	0.900		
pH			0.948
Salinity	0.905		

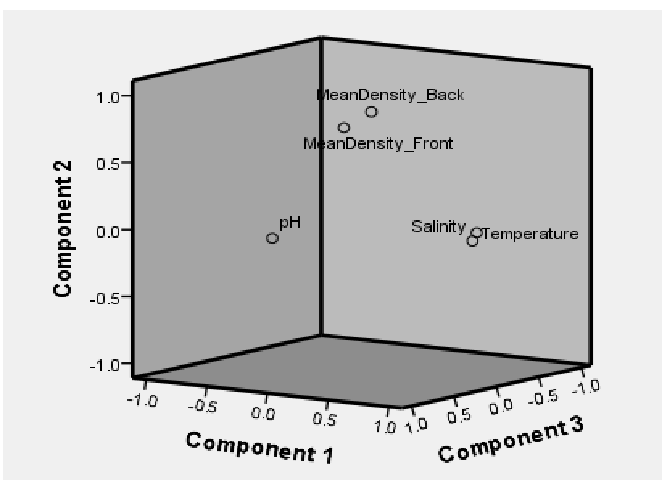

Figure 5. Component plot of five factors measured over sampling period

Conclusion

Ficopomatus cf. *uschakovi* larval attachments were found to be spatially and temporally variable. A higher density of *F.* cf. *uschakovi* tubes was recorded at the station with sheltered and in protected orientation. The settlement rate of *F.* cf. *uschakovi* was low, only 0.04 individuals.dm^{-2}/month. The distribution and settlement rate of *F.* cf.

uschakovi tubes in Setiu Wetlands was affected by environmental parameters, particularly, the temperature, salinity and pH of the water column. The information obtained from this study provides significant baseline information for sustainable wetland management ecosystem of Setiu Wetlands. However, yearly monitoring of *F.* cf. *uschakovi* distribution and settlement rate in Setiu Wetlands should be conducted. Further research on settlement cues for antifouling measures is needed for better understanding of this tubeworm in Malaysian waters.

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