The distribution and zonation of barnacles around intertidal shores of Penang Island

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Abstract. The intertidal shores around Penang Island were surveyed for the distribution of barnacles from 14th November 2011 to 31st January 2012. The sampling was done by using 20 cm x 20 cm transect to count the barnacles. Three replicates were taken for each zonation available of the intertidal areas; i.e. upper, middle, and lower zonations, at every sampling site. From the result, three species were identified, including *Euraphia withersi* and *Chthamalus malayensis* from Family Chthamalidae, and *Balanus amphitrite amphitrite* from Family Balanidae. *Chthamalus malayensis* was found to be most abundant among the three species with 44.24% of total population; and Tg. Tokong recorded the highest abundance of this species (28.22%). This was followed by *Euraphia withersi* with 38.77%; which was found to be densely populated at Gelugor (21.92%). *Balanus amphitrite amphitrite*was least abundant with only 16.99% and mostly found at Gurney Drive (26.24%).The distribution of the three species of barnacles also varied among the sampling locations. Gertak Sanggul recorded the highest relative abundance of all three species of barnacles at 18.01%; while the location with the least relative abundance of barnacles is Queensbay with 0.33%.Based on 'Non-Supervised Artificial Neural Network' (ANN), distinct zonation was observed where *Chthamalus malayensis* was more dominant on the upper zonation; *Euraphia withersi* on the middle zonation; and *Balanus amphitrite amphitrite* on the lower zonation. The interaction between barnacles with other barnacles leads to competitive exclusion and niche partitioning which created zonations among the species. Interspecies interaction that brought by predation also played a part in the distribution of barnacles. Apart from that, the distribution was affected by the sampling sites and human activities; such as embankment, land reclamation, and residential development.
Key words: barnacles, distribution, zonations, Non-supervised Artificial Neural Network.

Introduction

Barnacles are crustacean arthropods. They are exclusively marine and tend to live in shallow and tidal waters. They are sessile creatures and they attach to hard surface such as rocks, ships, pilings, and other creatures as their settlement, so they filter feed. Their distribution is influenced by a few environmental factors, which include biotic interactions – such as predation; seasonal changes in environmental conditions (Blythe, 2008). Studies done in Teluk Aling, Penangby Omar et al. (2012) have found *Chthamalus* sp. and *Balanus* sp. to be the most abundant in three of the littoral zones.Their sessile nature turns them into the most successful marine fouler (Southward, 1987), and thusa 'problem' species that cause biofouling. Biofouling is the unwanted, non-desirable attachment and growth of organisms that readily occurs on clean, submerged, unprotected man-made surfaces. The main distinction in biofouling is the adhesion of microfoulers; such as bacteria, diatoms, and microalgae etc. to the surface that cause a biofilm formation. It is then followed by the settlement of soft and hard macrofoulers, i.e. barnacles. (Callow & Fletcher, 1994).

Materials and Methods

Sampling sites

Fourteen sampling sites have been selected for this particular study (Table 1); all of them located in various intertidal areas around Penang Island. The sampling sites chosen comprise of different land use on Penang Island; which include popular beach tourist (Batu Ferringhi, Pantai Miami); industrial and manufacturing area (Seagate); reclamation area

(Gelugor); residential area (Jelutong, Muara Sungai Pinang, Tanjung Tokong); open area (Jeti Pantai Jerejak); commercial area (Queensbay, Gurney); and fishing villages (Balik Pulau, Teluk Bahang, Gertak Sanggul, Kampung Sg. Batu).

Zonation
Three transect lines were placed on the sampling sites; where the uppermost part of the intertidal area was labeled as upper zone (UZ), middle part as middle zone (MZ), and the lowest part and lower zone (LZ). Upper zone refers to the region above the highest tide level which borders on the splash zone. Middle zone refers to the region of the shore which is regularly exposed and submerged by average tides. Lower zone refers to the area which is only exposed to air at the lowest of low tides.

Sampling and Species Identification of Barnacles
The sampling was based on one-off sampling. A 20 x 20 cm transect was used to count the organisms. For each sampling site, three replicates were takenwhere the transect was placed randomly on the barnacle population substrates. Photos of the samples were taken by using a Nikon DX AF-S Nikkor 18-55mm lens camera modelfor counting. Physical measurements of light intensity and humidity were also taken. A few live samples were collected and brought back to the laboratory for identification.The specimens were fixed in 10% formalin solution in the sample bottles after being collected from the sampling sites, and later preserved in 70% ethanol solution after they were sorted out and identified. Their morphological characteristics were observed under a stereo microscope and the data for each different species was recorded and diagrams were drawn on the specific features of some of the species.

Results and Discussion
Three species were identified at 14 sampling sites around the intertidal shores on Penang Island during the sampling period, which were *Euraphia withersi* and *Chthamalus malayensis*from Family Chthamalidae, and *Balanus amphitrite amphitrite* from Family Balanidae.

Figure 1 shows the total composition of all the 3 species of barnacles according to sampling sites around the intertidal shores on Penang Island. In terms of sampling sites, Gertak Sanggul recorded the highest composition of all 3 species of barnacles at 18.01%; followed by Pantai Miami and Batu Ferringhi with 14.64% and 14.26% respectively. Tg. Tokong and Gurney Drive trailed closely, contributing 12.58% and 11.12 % of the total composition of barnacles respectively. About 6.53% of total composition of barnacles was found at Kg. Sg. Batu and 5.76% was found at Teluk Bahang. The rest of the locations contributed less than 5% to the total composition of barnacles, namely Gelugor at 4.47%; Seagate at 4.12%; Muara Sg. Pinang (Jelutong) at 2.66%; Pantai Jerejak at 2.17%; Muara Sg. Pinang (Balik Pulau) at 1.98%; and Jelutong at 1.37%. Queensbay has the least abundance of barnacles; contributed only 0.33% of the total composition of the organisms.

In Queensbay, there is an undergoing land reclamation activity occurring around the area. Most of the barnacle shells observed there were empty, broken, and covered in silts. According to Gomes-Filho et al. (2010), physio-chemical conditions, particularly deposition of silts, experienced after settlement could reduce the abundances of barnacle species as it directly interferes on the organisms' food intake and act as a physical barrier to feeding, settlement and reproduction.

Water pollution could be the negative factor in Jelutong (1.37%) and Muara Sg. Pinang (Balik Pulau) (1.98%). Pollutants from residential areas could be contributed to the marine community in Jelutong; and a study in water quality of Sungai Pinang has classified the river to be polluted (Farah et al., 1999). However, there are no known studies that support the account that water pollution deteriorates barnacle population. In fact, the bacteria in polluted water actually help the attachment of barnacle larvae from the biofilm formation (Goulder et al., 1980).

The reclamation activities in Gelugor (4.47%)has impinged on the barnacles' population residing in the area and observations indicated that the reclamation will eventually cause the barnacles to be permanently submerged. This will bring about negative effects on the population because according to Hummel et al (1986), species will die off within 6 months of being submerged permanently with salt water.

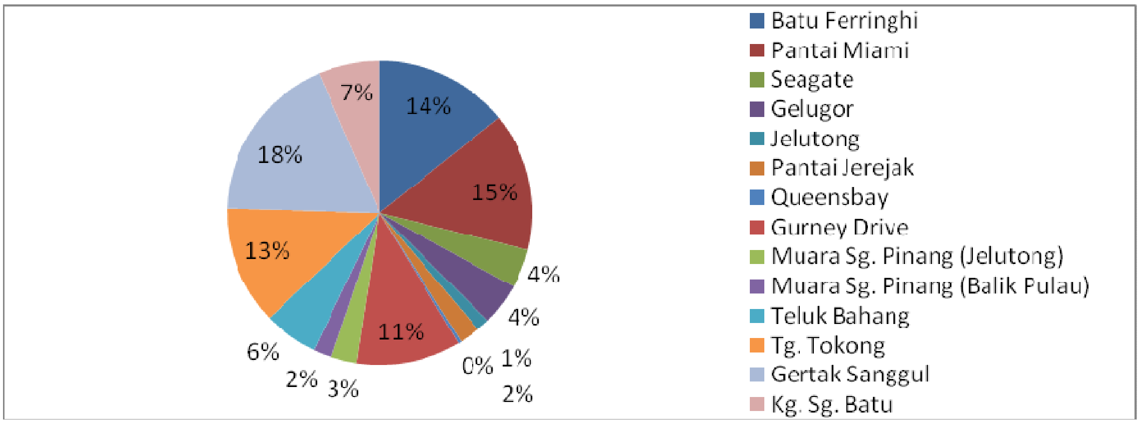

Figure 1: Relative abundance (%) of 3 species of barnacles around the intertidal shores of Penang Island

Figure 3 shows the relative abundance (%) of each species at all sampling sites in Penang Island. *C. malayensis* is the most abundant species found on the intertidal shores of Penang Island. The speciescontributed 44.24% to the total composition of barnacles as it was densely populated on the shore at Tg. Tokong (28.22%). This is followed by *E. withersi* with 38.77% of total composition; which is found to be vastly distributed at Gelugor (21.92%). Meanwhile, *B. amphitrite amphitrite* is the least abundant among the three species with 16.99% of total composition of which it was found densely on the shore at Gurney Drive (26.24%).

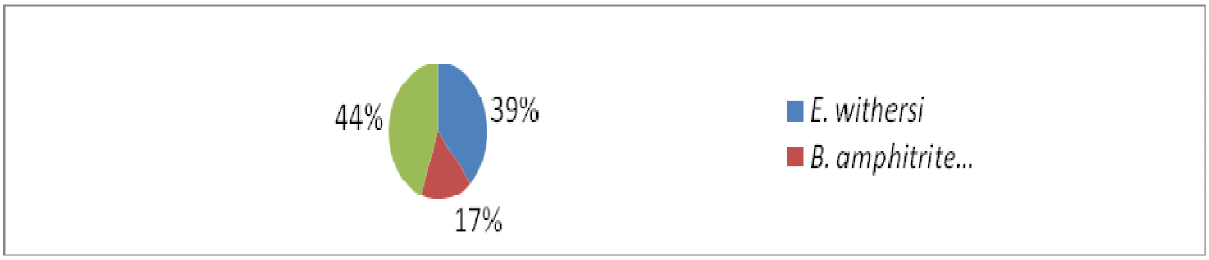

Figure 3: Relative abundance (%) of barnacle species found in sampling sites around Penang Island

The finding of this study indicated that *C. malayensis* is the most abundant species matches with the report from Tsang et al. (2008), which stated that this species population has wide distribution range in Indo-Malaysia, southern China and Taiwan regions; and was the major colonizer in Malaysia, Singapore, and India; with more than 50% coverage on the shore. Factors that contributed to their high abundance are their small body size help them to settle and survive in small-sized protective intertidal crevices; they reach reproductive maturity faster as well as has quicker generation cycle; and they are also less attractive to predators (Stanley & Newman, 1980).

According to Stephenson & Stephenson (1972), the distribution pattern of intertidal barnacles is vertically restricted; and that different factors play into the distribution of different zonation. The lower limit of the barnacle and distribution is usually set by biotic factors such as competition or predation, while the upper limit is usually determined by physical factors, such as heat and desiccation (Connell, 1961).

From the ANN analysis, there was also an overlapping distribution between *E. withersi* and *B. amphitrite amphitrite*, This overlapping may be due to competitive exclusion or niche partitioning. In ecology, the competitive exclusion principle is a proposition which states that two species that compete for the same resources cannot coexist well if other ecological factors are constant and that the species with the advantage over the other will dominate in the long term (Hardin, 1960). Stanley and Newman (1980) agreed that competitive exclusion has been the principal factor leading to the decline of the chthamaloids below the upper intertidal zone; due to the competition with balanoids.

Niche partitioning refers to the process whereby competing species are driven into different patterns of resource use or different niches by natural selection and this process also allows coexistence between the competitors as it allows the species to divide certain resources so that one species does not outcompete the other (Sahney et al, 2012); which is relevant to the overlapping found in *E. withersi* and *B. amphitrite amphitrite*.

Conclusions

Chthamalus malayensis was found to be the most dominant species among the sampling sites, followed by *Euraphia withersi* and *Balanus amphitrite amphitrite*. Gertak Sanggul recorded the highest relative abundance of barnacles and Queensbay with the least abundance. The distribution of the three identified barnacle species showed distinct zonation among the species. *Chthamalus malayensis* was found to be more densely populated on upper zonation; *Euraphia withersi* on middle zonation; and *Balanus amphitrite amphitrite* on lower zonation. There is a noticeable overlap occurring between *B. amphitrite amphitrite* and *E. withersi*.

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