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# Seasonal variation of macroinvertebrates in the estuary ecosystem: A case study of Mae Klong and Tha Chin Estuaries, the Upper Gulf of Thailand

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**Abstract** A seasonal variation of macroinvertebrates in the estuary ecosystem was reported. The results showed a basic information in natural resource management planning and benefits to local people. Macroinvertebrate variation was recorded at Mae Klong Estuary and Tha Chin Estuary in the Upper Gulf of Thailand. Four stations of two estuaries were sampled in three seasons: January 2017 (winter representative), April 2017 (summer representative) and September 2017 (rainy season representative). A total of 29 species of macroinvertebrates were recorded. Malacostraca was the dominant species number (9 species), and the highest quantity (40-54 % of all specimen). Metapenaeus was the dominant species (24 %). The density of macroinvertebrate tended to increase in the winter. Also, the density droped to the lowest during the summer. The ecological indices of macroinvertebrates in each season were not statistically significant difference ($p>0.05$). The diversity index was 1.76-1.97, the evenness index was 0.25-0.32, and the dominance index was 0.68-0.75. It is explained that in each season, some groups of macroinvertebrate were more prominent than other groups. The relationship between the average total density of macroinvertebrates and water quality factors showed a moderate level of correlation ($r = -0.622$) and a statistical significance ($p<0.05$) with temperature.

**Keywords:** Seasonal variation, Macroinvertebrate variation, Mae Klong Estuary, Tha Chin Estuary

## Introduction

An estuary is an area rich in minerals with potential for natural resources and is important in agriculture, fisheries, and water travel. Therefore, local utilization activities may affect water quality and the integrity of biological

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resources within the estuary ecosystem (Hopkinson and Smith, 2005). These result in becoming a source of degradation of the estuary ecosystem (Nixon, 1995). At the same time, the estuary has high ecological production, one of which is the macroinvertebrate, which is considered an essential component of the ecosystem and is natural food of aquatic animals that are important in the food chain. At the same time, the estuary has high ecological production, which has the potential for both primary producers and consumers. One of them is phytoplankton, which is considered an essential component of the ecosystem of water resources and is natural food at the primary level of organisms, which are important in the food chain (Battish, 1992).

Macroinvertebrate fauna is an organism that lives in general water sources, including freshwater, brackish water, and marine water. It typically lives on the underwater sediment's surface and animal adhesion to aquatic plants or underwater materials. Macroinvertebrates exhibit relatively slow movement behavior and therefore are the primary consumers. They play an important role in the transmission of energy in the food chain. Moreover, the macroinvertebrate groups are found in different environments and can be an indicator of the water resources and water quality (Sangpradub, 2001; Passago *et al*., 2018).

The research project aimed to study the change in species composition, the amount of macroinvertebrates, and water quality factors that influence macroinvertebrates in the estuary ecosystem. Moreover, It was to investigate basic information in natural resource management planning for assessing impacts that may be linked to the productivity status of water resources of nearby coastal ecosystems and result in the maximum benefit to local people.

## Materials and methods

### *Study area*

The samples from Tha Chin Estuary in Mueang District Samut Sakhon Province and Mae Klong Estuary in Muang district Samut Songkhram Province were collected (Figure 1). Samples were collected in 3 seasons, January 2018 (winter representative), April 2018 (summer representative) and September 2018 (rainy season representative). (ST.1) denoted the Tha Chin estuary, Bang Ya Phraek Subdistrict, Mueang Samut Sakhon District, Samut Sakhon Province. (ST.2) denoted the coastal area of Ban Bo Subdistrict, Mueang Samut Sakhon District, Samut Sakhon Province, (ST.3) denoted the coastal area of Bang Kaew Subdistrict, Mueang Samut Songkhram District, Samut Songkhram Province. Finally, (ST.4) denoted the Mae Klong estuary, Bang Ja Kreng Subdistrict, Mueang Samut Songkhram District, Samut Songkhram Province.

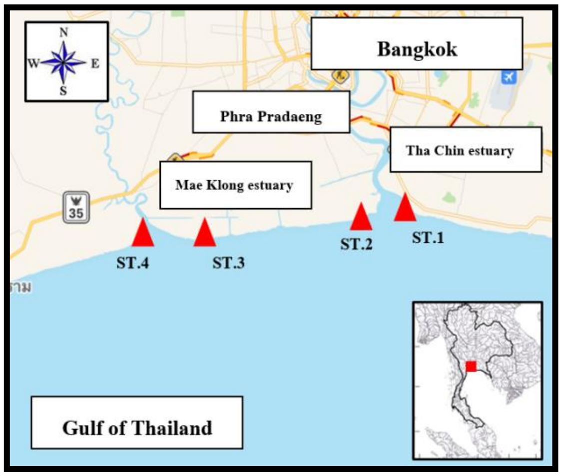


**Figure 1.** Sampling areas in the Tha Chin estuary and Mae Klong estuary

### *Water-quality sampling and analysis*

The studies of the 9 indexes of water quality in the estuary ecosystem were collected. Water samples were collected in 3 seasons for analysis of environmental condition changes all year round. All water-quality measurements were conducted according to APHA, AWWA, and WEF (2012). Five indexes of the water-quality factors were analyzed in the field, including temperature, transparency, salinity, pH and dissolved oxygen. However, other indexes were analyzed in the laboratory, including total hardness, total ammonia, orthophosphate, and BOD.

### *Total macroinvertebrate estimation*

Macroinvertebrate samples were collected by Ekman Grab and sieve 500 micron. The samples were fixed with 10% formalin for analysis at the laboratory. The samples were collected in the same location as the water quality samples. Macroinvertebrate samples were analyzed under the stereo microscope and identified with macroinvertebrate taxonomy documents.

### *Statistical analysis*

Water-quality data were analyzed using descriptive statistics. Furthermore, one-way ANOVA analysis was used to compare the differences between various factors such as water quality, density and the ecological index. Ecological structure data of macroinvertebrates including density, diversity index, evenness index, and dominant index were based on Krebs (2001).

Correlation analysis of macroinvertebrate populations and the water-quality factors were tested by the Pearson correlation (normal distribution) and the Spearman correlation (not normal distribution), at a 95-percent-confidence level.

## Results

### *Water-quality factors in study areas*

Water quality data in the 3 seasons of the study areas were analyzed (Table 1). Overall, it was found that most of the average water quality data are in the appropriate criteria for aquatic animals. The exception was for the total ammonia, which was higher than the appropriate criteria during the rainy season, indicating high levels of accumulated waste in the form of organic matter during that period. In each season, it was found that the water quality of many parameters had a statistically significant difference ($p<0.05$). The salinity in the rainy season was lower than the other seasons ($p<0.05$) and corresponded to the total hardness ($p<0.05$). The total ammonia in the rainy season was significantly higher than in other seasons ($p<0.05$). In the summer, the BOD value was significantly higher than in other seasons ($p<0.05$).

**Table 1.** Minimum-maximum, average and standard deviation of water quality factors

| Water quality factors | Season | | | p-value | Standard |
|---|---|---|---|---|---|
| | Winter | Summer | Rainy | | |
| **Water temperature ($^oC$)** | (27.1-29.1)<br>28.05±0.85 [a] | (31.2-32.7)<br>31.95±0.76 [b] | (29.1-30.3)<br>29.98±0.59 [c] | 0.000* | 25-32 |
| **Transparency (cm.)** | (25.0-45.0)<br>33.75±8.54 [a] | (25.0-35.0)<br>29.00±4.24 [a] | (25.0-35.0)<br>29.00±4.24 [a] | 0.467 | 30-60 |
| **Salinity (ppt)** | (15.4-22.0)<br>19.60±3.08 [a] | (18.3-25.0)<br>21.88±2.78 [a] | (4.2-15.4)<br>10.40±5.20 [b] | 0.005* | 8-25 |
| **Dissolved oxygen (mg/L)** | (3.8-6.7)<br>5.10±1.23 [a] | (3.4-7.2)<br>5.45±1.59 [a] | (3.6-6.7)<br>5.49±1.45 [a] | 0.916 | not less than 4 |
| **pH** | (7.7-7.8)<br>7.78±0.05 [a] | (7.6-8.3)<br>7.90±0.29 [a] | (7.3-7.6)<br>7.48±0.13 [b] | 0.028* | 6.5-8.5 |
| **Total hardness (mg/L Calcium Carbonate)** | (4,352-6,073)<br>5,167.0±706.0 [a] | (3,905-5,702)<br>5,069.5±797.0 [a] | (994-3,118)<br>2,268.5±915.8 [b] | 0.001* | - |
| **Total ammonia (mg/L nitrogen)** | (0.67-1.41)<br>0.92±0.35 [a] | (0.26-0.40)<br>0.32±0.06 [a] | (1.12-2.41)<br>1.91±0.57 [b] | 0.001* | not more than 1.0 |
| **Orthophosphate (mg/L phosphorus)** | (0.08-0.22)<br>0.12±0.07 [a] | (0.12-0.33)<br>0.20±0.10 [a] | (0.10-0.22)<br>0.16±0.05 [a] | 0.347 | not more than 0.2 |
| **BOD (mg/L)** | (1.61-2.82)<br>2.40±0.54 [a] | (4.46-5.00)<br>4.66±0.24 [b] | (1.10-2.64)<br>1.82±0.63 [a] | 0.000* | not more than 20 |

***Species composition of macroinvertebrate in study areas***

The results of the survey on species and quantity of macroinvertebrates in the estuary ecosystem were collected from 3 seasons (Table 2). All four groups of macroinvertebrates were found, namely Polychaeta, Malacostraca, Gastropoda, and Bivalvia, amounting to a total of 29 species. Polychaeta were found in 5 families namely Capitellidae, Terebellidae, Nereididae, Phytlodocidae and Glyceridae. Malacostraca were found in 9 species such as *Metapenaeus* sp., *Acetes* sp. and *Pagurus* sp. etc. Gastropoda were found in 8 species and Bivalvia were found in 7 species.

Malacostraca was the greatest species of macroinvertebrate (9 from 29), and the most numerous. The quantity of the Malacostraca was about 40-54 percent of the total amount of macroinvertebrates, with dominance genera such as *Metapenaeus* sp. and *Acetes* sp. It was inferior to Gastropoda groups, which accounted for 14-21 percent of the total amount of macroinvertebrates. Malacostraca were the predominant macroinvertebrate group in all seasons. Bivalvia found 7 species, such as *Donax* sp., *Solen* sp., *Meretrix* sp. etc, which accounted for about 5.0-30.0 percent of the total amount of macroinvertebrates.

**Table 2.** Diversity and quantity of macroinvertebrate population in the study area (average 3 seasons)

| **Species composition** | **Density of macroinvertebrate (number/m$^2$)** | | | | **Average density** | **Percent** |
|---|---|---|---|---|---|---|
| | **ST1** | **ST2** | **ST3** | **ST4** | | |
| **PHYLUM ANNELIDA** | | | | | | |
| Class Polychaeta | | | | | | |
| Order Capitellida | | | | | | |
| Family Capitellidae | 13.33 | 97.00 | 54.33 | 86.67 | 62.83 | 7.26 |
| Order Terebellida | | | | | | |
| Family Terebellidae | 0.00 | 50.00 | 97.00 | 0.00 | 36.75 | 4.25 |
| Order Phyllodocida | | | | | | |
| Family Nereididae | 20.67 | 98.67 | 96.00 | 50.00 | 66.34 | 7.66 |
| Family Phytlodocidae | 0.00 | 0.00 | 0.00 | 6.00 | 1.50 | 0.17 |
| Family Glyceridae | 0.00 | 20.67 | 0.00 | 7.33 | 7.00 | 0.81 |
| **PHYLUM ARTHROPODA** | | | | | | |
| Class Malacostraca | | | | | | |
| Order Decapoda | | | | | | |
| Family Palaemonidae | | | | | | |
| *Macrobrachium* sp. | 0.00 | 73.33 | 0.00 | 29.33 | 25.67 | 2.96 |
| Family Penaeidae | | | | | | |
| *Metapenaeus* sp. | 367.33 | 261.67 | 125.33 | 95.00 | 212.33 | 24.53 |
| Family Sergestidae | | | | | | |
| *Acetes* sp. | 0.00 | 311.00 | 157.00 | 69.00 | 134.25 | 15.51 |
| Family Grapsidae | | | | | | |
| *Sesarma* sp. | 0.00 | 17.67 | 25.00 | 22.00 | 16.17 | 1.87 |

**Table 2.** (Cont.)

| Species composition | Density of macroinvertebrate (number/m$^2$) | | | | Average density | Percent |
|---|---|---|---|---|---|---|
| | ST1 | ST2 | ST3 | ST4 | | |
| Family Ocypodidae | | | | | | |
| *Ocypode* sp. | 0.00 | 20.67 | 12.00 | 7.33 | 10.00 | 1.16 |
| *Uca* sp. | 0.00 | 0.00 | 14.67 | 0.00 | 3.67 | 0.42 |
| Family Portunidae | | | | | | |
| *Purtunus* sp. | 0.00 | 7.33 | 0.00 | 0.00 | 1.83 | 0.21 |
| *Scylla* sp. | 0.00 | 3.00 | 0.00 | 0.00 | 0.75 | 0.09 |
| Family Paguridae | | | | | | |
| *Pagurus* sp. | 0.00 | 29.33 | 3.00 | 17.67 | 12.50 | 1.44 |
| **PHYLUM MOLLUSCA** | | | | | | |
| Class Gastropoda | | | | | | |
| Order Archaeogastropoda | | | | | | |
| Family Neritidae | | | | | | |
| *Nerita* sp. | 0.00 | 22.00 | 17.67 | 54.33 | 23.50 | 2.71 |
| Order Mesogastropoda | | | | | | |
| Family Littorinidae | | | | | | |
| *Littorina* sp. | 161.33 | 17.67 | 29.33 | 22.00 | 57.58 | 6.65 |
| Family Naticidae | | | | | | |
| *Neverita* sp. | 0.00 | 0.00 | 14.67 | 0.00 | 3.67 | 0.42 |
| Family Potamididae | | | | | | |
| *Cerithidea* sp. | 44.00 | 25.00 | 29.67 | 32.33 | 32.75 | 3.78 |
| Family Cerithiidae | | | | | | |
| *Rhinoclavis* sp. | 0.00 | 14.67 | 22.33 | 9.00 | 11.50 | 1.33 |
| Family Bithyniidae | | | | | | |
| *Bithynia* sp. | 7.33 | 0.00 | 0.00 | 0.00 | 1.83 | 0.21 |
| Family Stenothyridae | | | | | | |
| *Stenothyra* sp. | 21.00 | 36.00 | 7.33 | 0.00 | 16.08 | 1.86 |
| Order Neogastropoda | | | | | | |
| Family Nassariidae | | | | | | |
| *Nassarius* sp. | 0.00 | 0.00 | 0.00 | 22.00 | 5.50 | 0.64 |
| Class Bivalvia | | | | | | |
| Order Veneroida | | | | | | |
| Family Tellinidae | | | | | | |
| *Tellina* sp. | 21.00 | 102.00 | 28.00 | 22.00 | 43.25 | 5.00 |
| Family Donacidae | | | | | | |
| *Donax* sp. | 72.00 | 25.00 | 44.00 | 14.67 | 38.92 | 4.50 |
| Family Verneridae | | | | | | |
| *Meretrix* sp. | 0.00 | 0.00 | 7.33 | 7.33 | 3.67 | 0.42 |
| Family Solenidae | | | | | | |
| *Solen* sp. | 0.00 | 0.00 | 7.33 | 7.33 | 3.67 | 0.42 |
| Order Mytilida | | | | | | |
| Family Mytilidae | | | | | | |
| *Musculus* sp. | 7.33 | 14.67 | 25.33 | 26.67 | 18.50 | 2.14 |
| *Limnoperna* sp. | 0.00 | 14.67 | 7.33 | 0.00 | 5.50 | 0.64 |
| Order Arcoida | | | | | | |
| Family Arcidae | | | | | | |
| *Anadara* sp. | 0.00 | 0.00 | 7.33 | 7.33 | 3.67 | 0.42 |

### *Changes in macroinvertebrate composition in each season*

Comparing the amount of macroinvertebrates in the study area (Table 3), it was found that in the estuary, the density of macroinvertebrate tended to increase in the winter, with an average density of 1,444.0 number/$m^2$. Also, the density of macroinvertebrate dropped to the lowest during the summer, with an average density of 533.5 number/$m^2$.

**Table 3.** Seasonal changes in macroinvertebrate composition in estuaries

| Macroinvertebrate group | Density of macroinvertebrate (number/$m^2$) | | |
|---|---|---|---|
| | Winter | Summer | Rainy |
| Polychaeta | 300.0 ±245.6 (20.78%) | 110.0 ±47.5 (20.62%) | 83.3 ±38.9 (14.45%) |
| Malacostraca | 775.5 ±468.2 (53.70%) | 242.0 ±239.0 (45.36%) | 234.0 ±169.0 (40.63%) |
| Gastropoda | 297.0 ±233.9 (20.57%) | 77.0 ±58.2 (14.43%) | 83.3 ±36.3 (14.45%) |
| Bivalvia | 71.5 ±45.4 (4.95%) | 104.5 ±79.1 (19.59%) | 175.5 ±141.8 (30.47%) |
| Total density | 1,444.0 | 533.5 | 576.0 |

### *Ecological index in each season*

In the winter, the average diversity index of macroinvertebrate was 1.84, the average evenness index was 0.25, and the dominance index was 0.75. It can be explained that in the winter, some groups of macroinvertebrate were more prominent in quantity than other groups, namely the Malacostraca group, with an average density of 775.5±468.2 number/$m^2$ (53.70% of all macroinvertebrates). During the summer and rainy season, macroinvertebrates had the same ecological index as in the winter season, indicating that in the summer, some groups of macroinvertebrates were more prominent in quantity than other macroinvertebrates. Again, this was the group of Malacostraca, with an average density of 242.0±239.0 number/$m^2$ (45.36%) in the summer and 234.0±169.0 number/$m^2$ (40.63%) in the rainy season. However, when statistically tested, the ecological index of macroinvertebrates in each season did not show a statistically significant difference ($p>0.05$) (Table 4).

**Table 4.** Changes in the ecological index of macroinvertebrates in each season

| Parameter | Ecological index | | | p-value |
|---|---|---|---|---|
| | Winter | Summer | Rainy | |
| Diversity index | 1.84±0.49 | 1.97±0.83 | 1.76±0.43 | 0.890 |
| Evenness index | 0.25±0.07 | 0.32±0.13 | 0.29±0.08 | 0.641 |
| Dominance index | 0.75±0.07 | 0.68±0.13 | 0.71±0.08 | 0.641 |

**Table 5.** Correlation coefficient (r) between water quality factors and the macroinvertebrate population

| Water quality parameters | Correlation coefficient (r) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Density of macroinvertebrate (number/m$^2$) | | | | Ecological index | | |
| | Polychaeta | Malacostraca | Gastropoda | Bivalvia | Total density | Diversity | Dominance |
| **Water temperature** | -0.474 (0.119) | -0.467 (0.126) | -0.594* (0.042) | 0.156 (0629) | -0.622* (0.031) | -0.006 (0.984) | -0.191 (0.553) |
| **Transparency** | 0.302 (0.340) | 0.508 (0.092) | 0.288 (0.365) | -0.027 (0.934) | 0.529 (0.077) | 0.110 (0.734) | -0.014 (0.965) |
| **Salinity** | 0.455 (0.137) | 0.240 (0.453) | 0.000 (0.999) | -0.490 (0.106) | 0.224 (0.485) | 0.522 (0.082) | -0.454 (0.138) |
| **Dissolved oxygen** | -0.508 (0.092) | -0.535 (0.073) | 0.202 (0.529) | -0.273 (0.391) | -0.520 (0.083) | 0.083 (0.798) | -0.257 (0.419) |
| **pH** | 0.149 (0.643) | 0.183 (0.569) | -0.097 (0.764) | -0.348 (0.268) | 0.084 (0.794) | -0.346 (0.271) | 0.376 (0.228) |
| **Total hardness** | 0.540 (0.070) | 0.297 (0.349) | 0.211 (0.510) | -0.395 (0.204) | 0.369 (0.238) | 0.511 (0.089) | -0.381 (0.222) |
| **Total ammonia** | 0.036 (0.911) | -0.016 (0.962) | -0.148 (0.646) | 0.273 (0.391) | 0.005 (0.988) | 0.019 (0.953) | -0.046 (0.887) |
| **Orthophosphate** | -0.468 (0.125) | -0.124 (0.701) | 0.042 (0.898) | -0.197 (0.539) | -0.255 (0.423) | -0.411 (0.184) | 0.358 (0.253) |
| **BOD** | -0.182 (0.571) | -0.328 (0.298) | -0.147 (0.649) | -0.196 (0.542) | -0.363 (0.246) | 0.151 (0.640) | -0.224 (0.484) |

**Remark:** * is a statistically significant difference ($p<0.05$) and parentheses are p-value.

***Relationship between water quality factors and macroinvertebrate population in estuary***

Analysis of the correlation coefficient between the average macroinvertebrate and the water quality factors showed a moderate correlation level of total density (r = -0.622) and statistical significance ($p<0.05$) with temperature. Moreover, Gastropoda showed a moderate correlation level (r = -0.594) with temperature too ($p<0.05$). However, the average density of Polychaeta, Malacostraca, and Bivalvia had no statistically significant relationship ($p>0.05$) with other water quality factors. Gastropoda related with temperature only to a moderate level of correlation (r = -0.594) and statistical significance ($p<0.05$). The relationship between the ecological indices and water quality factors showed that it had no statistically significant relationship ($p>0.05$) with other water quality factors. Therefore, it can be concluded that water temperature factors that vary in each season are related to the changes in the quantity of the macroinvertebrate population (Table 5).

## Discussion

The seasonal variation of macroinvertebrates in the estuary ecosystem, Mae Klong Estuary and Tha Chin Estuary, Upper Gulf of Thailand was reported. A total of 29 species of macroinvertebrate were recorded, whiche can be separated into 4 groups namely, Polychaeta, Malacostraca, Gastropoda and Bivalvia. Malacostraca was the dominant species number (9 species), and the highest in quantity (40-54% of all specimen). *Metapenaeus* was the most dominant species (24%). The diversity index is in the range of 1.76-1.97, and the dominance index is in the range of 0.68-0.75. It is different from the study of Puttapreecha *et al.* (2016). They found macroinvertebrates in Talet Bay, Nakhon Si Thammarat Province, were totaling 6 phylum, 248 species, with an abundance in the range of 125-4,650 number/$m^2$. The polychaetes were the most diverse (156 species), followed by crustaceans (69 species), mollusks (19 species), while the others found only 1-3. A study by To-orn (2016) studied microinvertebrates in a natural mangrove forest in the Tha Chin estuary, Samut Sakhon Province. In May 2009, 10 macroinvertebrate groups were found, including nematodes and foraminiferans, predominantly distributed and prevalent groups. Followed by polychaetes, it had a diversity index in the range of 0.22-1.29 and an evenness index of 0.55-0.62. From this study, the species number and the density of macroinvertebrates in the estuary of Tha Chin River (533.5-1,444.0 number/$m^2$) were less than the studies into this by Puttapreecha *et al.* (2016) (125-4,650 number/$m^2$) and To-orn (2016), who found 210-1,348 number/10 $cm^2$. This lower specimen may be due to the sampling area was sandy loam sediment and a wide-open space. There are rarely any mangroves where seaweed or a seagrass source cannot be found, including those affected by various industries. The mangroves' fertility can increase organic matter, which is an important food for benthic fauna and increase the density of benthic fauna (Paphavasit *et al.*, 2008). Also, when the area had a seagrass spread or seaweed, more diversity and abundance of benthic fauna was found in than other areas. When an ecosystem has a spread of seagrass or seaweed, it is a more suitable area and good refuge from predators (Pastor de Ward, 2002) and a source of food. Moreover, it can be used as a source of adhesion to sustain life (Thomsen and McGlathery, 2005). Several benthic studies showed that higher diversity and an abundance of benthic fauna in the seagrass were dispersed. For example, for the seagrass and seaweed in Satun province, the species composition, and the quantity of benthic animals were higher than in other areas (Himyi, 2009). The seabed structure and complexity is one of the factors contributing to the diversity and abundance of benthic fauna (Bostrom *et al*., 2006).

For the macroinvertebrate relationship with environmental factors, especially water quality, the study found that the density of Malacostraca and polychaetes was significantly higher. The polychaetes were negative related but not statistically significant ($p>0.05$) with water temperature and dissolved oxygen. In the study of To-orn (2016), it was found that the density of the polychaetes had a statistically negative relationship ($p<0.05$) with the water salinity and dissolved oxygen. Also, it was found that the density of polychaetes showed a statistically negative correlation ($p<0.05$) with water salinity. Environmental factors such as water quality had influenced the distribution and abundance of macroinvertebrates in mangrove forests. Other factors, such as the amount of organic matter in the soil and mangrove forests' biomass, especially the amount of plant debris, sediment, and organic matter in the soil, affected their organisms (Giere, 1993), with each macroinvertebrate species associated with different environmental factors. However, other macroinvertebrates do not have a specific relationship with anyone's environmental factors. Therefore, other environmental factors, such as biological environmental factors, regarding the sub-habitat complexity (a micro-habitat) may affect the spread of benthic fauna (Intharasook, 1999).

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