COMMUNITY STRUCTURE OF ACETES SHRIMPS IN THE GULF OF THAILAND WITH NOTES ON INFLUENCE OF PREDATORY FISH *Secutor insidiator* ON HABITAT SELECTION OF *Acetes japonicus*

Usawadee Detsri1,2*, Suree Satapoomin3 and Udomsak Darumas4

1Ecology and Biodiversity Program, School of Science, Walailak University
Nakhon Si Thammarat 80160, Thailand
2Phuket Marine Biological Center, Muang District, Phuket 83000, Thailand
3Department of Marine and Coastal Resources, Thung Song Hong Subdistrict, Lak Si District, Bangkok 10210, Thailand
4Department of Biology, School of Sciences, Walailak University, Nakhon Si Thammarat 80160, Thailand

ABSTRACT: Spatiotemporal variation of the Acetes shrimp communities at Talet Yai Bay, Nakhon Si Thammarat Province, was studied from June 2010 to May 2011. Monthly samplings, day and night, were conducted in the 5 habitat types of the bay: seagrass bed, mudflat, coarse-sand flat, mangroves, and open water. Four species of *Acetes* were recorded during the period: *A. japonicus*, *A. erythraeus*, *A. vulgaris*, and *A. indicus*. The results indicated that more Acetes shrimps were collected at night compared to daytime. Mean abundance of *Acetes* showed highly significant difference between habitats (*p* <0.01). Since few Acetes shrimps were collected in daytime, we only focused in the nighttime samples. At night, *Acetes* had highest abundance in coarse-sand flats, followed by mangroves, open water, muddy flats, and seagrass beds. In terms of temporal scale, the mean abundance of *Acetes* did not differ statistically among monsoon seasons (*p* >0.05). *Acetes japonicus* was the predominant species in all habitats. The abundance of *A. japonicus* and *A. vulgaris* was found positively related to salinity and chlorophyll-a, while *A. erythraeus* and *A. indicus* showed no relationship to any of the environmental factors.

Experiments on effect of habitat structure and light condition on habitat selection of *A. japonicas* revealed that numbers of *A. japonicus* differed significantly among habitats in daylight, but not at night. In daylight, *A. japonicus* significantly preferred bare substratum to vertically structured habitats. Effect of a predator on habitat selection of *A. japonicus* was studied using mucus of the predatory fish *Secutor insidiator*. In daylight, *A. japonicus* changed its habitat selection from a preference for bare sand in the absence of a predator to seagrass bed when mucus from the predator was present. Effect of predator detection by means of vision was demonstrated. The visual presence of a predatory fish in daylight caused a change of habitat selection from a preference for bare sand to no preference. At night, the presence of a predator either visually or by the introduction of mucus did not change the habitat selection of *A. japonicus*.

Keywords: Acetes shrimps, habitat selection, predator avoidance, *Acetes japonicus*.

INTRODUCTION

Despite low species diversity Acetes shrimps are commercially significant organisms in Asian and East African waters (Omori, 1975). They are major ingredient in the production of the shrimp paste that is an important seasoning in Thai food (Xiao and Greenwood, 1993). During their life cycles Acetes shrimps migrate between different habitats (Xiao and Greenwood, 1993). Their migration from nursery grounds to different feeding grounds may be affected by food requirements of different age classes (Levinton, 2001). They are consumed by a variety of predators, such as protozoans, ctenophores, cephalopods, fish, crocodiles, and humans (Xiao and Greenwood, 1993). The fish that are their most important predator include: Carangidae, Clupeidae, Engraulidae, Lactariidae, Polynemidae, and Sciaenidae (Xiao and Greenwood, 1993). *Secutor insidiator* Bloch, 1787 (Pugnose ponyfish) belongs to the family Leiognathidae, is carnivorous (Kwak and Klumpp, 2004), and was
reported to consume Acetes, Mysis, and Lucifer from the analysis of their stomach contents (Sebastian et al., 2011). In the nature, Acetes shrimps use tail-flip behavior to escape from the predators. They move rapidly backwards that can carry them above the water surface when they are disturbed and frightened (Xiao and Greenwood, 1993). Moreover, vision and chemoreception are important senses that determine Acetes swarming behavior related to escape from predators (Xiao and Greenwood, 1993).

Acetes shrimps belong to the suborder Dendrobranchiata in the superfamily Sergestoidea under the family Sergestidae. They are classified as holo-hyperbenthos that occur close to estuaries (Jarrin et al., 2017), so the physical complexity of habitat may influence their habitat selection. In shallow water they may be more affected by the seasonal monsoon than in deeper water. Therefore, Acetes shrimps may be spatiotemporally affected in their habitat selection by the monsoon in terms of species composition and abundance. According to the literature, Acetes shrimps are eaten by many species of predators, especially fish (Xiao and Greenwood, 1993). The habitat selection of Acetes may be affected by visual and chemical signs of the presence of their predators.

The natural population of the crustaceans that support commercial fisheries may be damaged in several ways by human activity in the process of resource exploitation and destruction of habitats (Menon and Pillai, 1996). Intensive fishing for Acetes shrimp was estimated to produce 1,000–1,500 tons throughout the year (Omori, 1975). The annual catches of Acetes in Thailand during 1969–1972 reached 67,965 tons (Omori, 1975). This suggests that the Acetes resources may have been fully exploited in the past. Illegal harvesting, agriculture, aquaculture, construction of harbors, industrialization and urbanization, land reclamation for coastal development, waste disposal and pollution, all affect natural mangrove forests and coastal habitats (Chong, 2007). Moreover, aquatic pollution can be a potential threat to crustaceans in estuarine regions that constantly receive various kinds of pesticides, industrial effluent carrying heavy metals and toxic chemicals, civic and domestic sewage, oils and oil dispersants (Menon and Pillai, 1996; Damme et al., 2008; Venturini et al., 2008).

This study aims to provide information on the species composition and abundance of Acetes shrimps, the environmental factors that affect the distribution and density of Acetes in Talet Yai Bay, Nakhon Si Thammarat Province, and also point out the importance of habitat selection in terms of the avoidance of predation of Acetes shrimps. This knowledge is necessary for the sustainable utilization of Acetes populations.

**MATERIAL AND METHODS**

1) Study sites

Talet Yai Bay is a part of Khanom Beach in Mu Ko Thaleni National Park, Nakhon Si Thammarat Province. Talet Yai Bay was chosen as the study site because it is a marine protected area under Department of Marine and Coastal Resources. In this area, only natural processes affect species distribution, seasonal abundance, and habitat selection of Acetes.

Topographically, the bay is well protected from both monsoons. During the northeast monsoon (November–January) it is protected by Tharai Island on the east, while the southwest monsoon (May–October) is absorbed by a line of mountains on the southwest (Fig. 1). The bay is quite shallow, with depth no more than 2 m. There are 5 unique habitats in the bay. Seagrass beds with four species of seagrasses: Enhalus acoroides, Thalassia hemprichii, Halophila ovalis, and Halodule uninervis, Mudflats, Coarse-sand flats, Mangroves, and Open water (Table 1).
Community structure of Acetes shrimps in the Gulf of Thailand

Figure 1. Habitat types at Talet Yai Bay.

Table 1. Habitats in Talet Yai Bay.

<table>
<thead>
<tr>
<th>Habitat types</th>
<th>Area (m²)</th>
<th>% coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seagrass bed</td>
<td>132,000</td>
<td>16.35%</td>
</tr>
<tr>
<td>Mudflat</td>
<td>193,000</td>
<td>23.85%</td>
</tr>
<tr>
<td>Coarse-sand flat</td>
<td>37,500</td>
<td>4.63%</td>
</tr>
<tr>
<td>Mangrove</td>
<td>34,000</td>
<td>4.24%</td>
</tr>
<tr>
<td>Open water</td>
<td>412,000</td>
<td>50.92%</td>
</tr>
</tbody>
</table>

2) Field sampling

The study area was divided into 113 grids, ca. 10,000 m² each (Fig. 2). In each habitat, 3 grids were randomly chosen for sampling once a month from June 2010 to May 2011. Acetes were caught using a triangular Acetes net. Dimensions of the net were 1.75 m long, 1.32 m wide, and 0.64 m high. The mesh size was 1.43 mm along the length of nets. The net was operated from a long-tailed boat, during day and night at high tide. In each grid, the net was trawled for a distance of 100 m at a speed of about 2.5 km/hr with a flow meter attached. Samples were preserved in 10% formalin, and later identified to species following Omori (1975). On each sampling occasion, environmental parameters of sea water (dissolved oxygen, water temperature, and salinity) were measured concurrently in situ, while chlorophyll-a concentration and total suspended solids were analyzed in the laboratory.
3) Laboratory experiments

3.1 Collection of animals used in experiments

_Acetes_ were collected with a push net at Talet Yai Bay, Nakhon Si Thammarat Province (Fig. 1). The collected shrimps were reared in a black plastic tank (400 liters), and fed with brine shrimp nauplii. During the rearing period, the salinity of the seawater was maintained within a range of 28–32 psu and water temperature ranged between 27–28ºC. About 50% of the sea water was renewed every second day.

3.2 Species identification

External characters can be used to identify _Acetes_ from other shrimps and to identify _Acetes_ to the species level. Other shrimps show some kind of colored bands on the antennae whereas no such bands are present on _Acetes_’ antennae. Among _Acetes_ species, _A. japonicus_ Kishinouye, 1905 has one pair of red spots on the uropod. A red spot on antero-lateral part of the sixth abdominal segment is characteristic for _A. vulgaris_ Hansen, 1919. There are two pairs of red spots on the uropod of _A. erythraeus_ Nobili 1905. Four red spots appear on the uropod of _A. indicus_ Milne Edwards, 1830. These characteristics can be seen with the naked eye. The species identification followed Chan (1998), Omori (1975), Xiao and Greenwood (1993) with subsequent examination of important body parts under the microscope.

3.3 Experiments on habitat selection by _A. japonicus_

The experimental design was modified from Meager _et al._ (2005). The experiments were conducted in a circular concrete tank (diameter 1 meter). The bottom of the tank was filled with 3 cm of washed beach sand. Seawater was filled to a depth of 15 cm in the tank. The salinity was controlled within a range of 28–32 psu and its temperature ranged between 27–28ºC.

_Acetes_ spp. were fed with brine shrimp for 1 hour in holding tanks prior to the experiments. Then specimens of _A. japonicus_ were identified and kept in aerated filtered seawater without food for 30 minutes. The density of _A. japonicus_ (100 individuals/1 m³) was close to the natural median abundance of 97 individuals/1 m³. They were released into the experimental tank and allowed to swim or remain motionless on the substratum for 5 minutes. During the investigation, aeration was not maintained in the experimental tank to avoid influence on habitat selection.
Community structure of Acetes shrimps in the Gulf of Thailand

Laboratory was divided into two light levels respectively, day and light conditions. In day time (9.30 am–18.00 pm), the light was reduced to 60% by using a black polyethylene net. At night (19.00–24.00 pm), black polyethylene net was used to shield the tank from other lighting to totally dark.

3.3.1 Habitat selection of *A. japonicus* for different levels of vertical complexity and light intensities

In each habitat, the different levels of structural complexity were indicated by ratio of surface area to volume (the measured complexity of structural followed Meager et al. (2005)). The experimental tank was divided into four equal sections representing four habitats: 1) no structure (bare sand substratum), 2) mangrove habitat had little vertical structure (*Avicennia* sp. roots; 10–12 cm in height from the substratum), 3) Rocky habitat had regular vertical structure (various size of rock were put above the sediments), and 4) seagrass habitat heterogeneous vertical structure (artificial grass 30–32 cm long and 5 mm wide were planted in sediments) (Fig. 3 and Table 2).

![Figure 3. Arrangement of four habitats in the experimental tank: Bare sand substratum, Mangrove habitat, Seagrass habitat, and Rocky habitat.](image)

<table>
<thead>
<tr>
<th>Habitat</th>
<th>SA (cm²)</th>
<th>V (cm³)</th>
<th>SA/V (cm⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare substratum</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mangrove roots</td>
<td>53</td>
<td>305</td>
<td>0.17</td>
</tr>
<tr>
<td>Rock</td>
<td>255</td>
<td>252</td>
<td>1.01</td>
</tr>
<tr>
<td>Seagrass</td>
<td>88</td>
<td>17</td>
<td>5.16</td>
</tr>
</tbody>
</table>

Table 2. Description of complexity characteristics of structure in each habitat: SA. surface area of structure in each habitat; and V. volume.
3.3.2 Habitat selection of *A. japonicus* on horizontal habitat and light intensities

Experimental tank was divided into three equal sections, each provided with one of the following substrata: 1) Bare substratum (Gypsum sheet), 2) Sand habitat, and 3) Muddy habitat (Fig. 4).

![Figure 4. Arrangement of three substrata in the experiment tank: Bare substratum, Sand habitat, and Muddy habitat.](image)

4. The influence of predator on habitat selection of *A. japonicus*

Predators of *Acetes, Secutor insidiator*, were captured by beam trawl in Talet Yai Bay, kept in a black plastic tank (400 liters), and fed with brine shrimp.

Experiments of predator detection by means of chemoreception and visual predator detection were conducted with structures similar to those used in the experiments on selection for habitat by *A. japonicas*. The different levels of structural complexity were indicated by ratio of surface area to volume (the measured complexity of structural followed Meager *et al.*, 2005). The experimental tank was divided into six equal habitat sections, randomly assigned in each with one of the following artificial habitats: 1) bare substratum, 2) mangrove (Mangrove roots), 3) seagrass, 4) rock, 5) sand, and 6) mud (Fig. 5 and Table 3).

Seawater was flushed through the fish tank for 30 minutes to transfer any mucus released by the fish into the experimental tank for predator detection by means of chemoreception experiment.

During each replicate of visual predator detection experiment, one predator was introduced into a rectangular plastic container (with approximately 6 liters) enclosure in the bottom at the center of the tank. The predator was acclimated for 30 minutes in each replicate. Aeration was maintained in the predator container only. Moreover, seawater in the enclosure was not allowed to enter the tank so that habitat selection was not influenced by fresh secretions from the predator.

In each sub-experiment, 50 individuals of *A. japonicus* were released into the experimental tank. In both light and dark conditions, the investigation was repeated five times (*n*=5) with a different set of *A. japonicus*. After 30 minutes, the partition sheet was placed in the experiment tank to separate the habitats. Numbers of *A. japonicus* in each habitat were then counted in each partition.
Figure 5. Arrangement of six substrata in the experiment tank: Bare substratum, Sand, Mud, Mangrove, Seagrass, and Rocks.

Table 3. Description of the complexity characteristics of structure in each habitat: SA surface area; V volume.

<table>
<thead>
<tr>
<th>Habitat</th>
<th>SA (cm²)</th>
<th>V (cm³)</th>
<th>SA/V (cm⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare substratum</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sand</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mud</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mangrove roots</td>
<td>51</td>
<td>125</td>
<td>0.41</td>
</tr>
<tr>
<td>Rock</td>
<td>400</td>
<td>464</td>
<td>0.86</td>
</tr>
<tr>
<td>Seagrass</td>
<td>84</td>
<td>12</td>
<td>7.00</td>
</tr>
</tbody>
</table>

5. Statistical analysis

The significance level of all statistical tests was considered to be α = 0.05 for all the statistical results above. All statistical analyses were performed using the statistical software R 2.11.1 (R Development Core Team ver. 2010).

Differences of Acetes abundance among habitats in study area was analysed. The mean abundance of Acetes species was tested for normality before analysis (Shapiro and Wilk, 1965). Because some of the variables were not normally distributed a Kruskal-Wallis analysis of variance was applied to determine the significance of Acetes species abundance between habitats. Subsequently, a Wilcoxon rank sum test was used to identify significant pairs of Acetes species abundance between habitats.

Difference in mean abundance of Acetes between the Northeast monsoon and Southwest monsoon and habitat was tested for normality. The variables were not normally distributed so Friedman’s test was used to test the differences of variables. If the variables were significant, a Wilcoxon rank sum test was used to identify significant pairs of Acetes species abundance between monsoon and habitat.

In addition, the relationship between environment factors and species composition of Acetes were defined by the co-inertia analysis.
In the experiment, differences in the average number of *A. japonicus* remaining in each habitat, both in vertical and horizontal habitat structures, light and dark phases, were tested by using a Kruskal-Wallis analysis of variance. Subsequently, a Wilcoxon rank sum test was used to identify significant pairs of *A. japonicus* abundance between habitats.

**RESULTS**

Four species of *Acetes*: *A. japonicus*, *A. erythraeus*, *A. vulgaris* and *A. indicus* were found in five habitats: seagrass beds, mudflats, coarse-sand flats, mangroves, and open water. The numbers of *Acetes* captured at night were higher than the numbers captured during daylight. At night, *Acetes* were most plentiful over coarse-sand flats and their numbers declined in mangroves, open water, muddy flats, and seagrass beds, respectively. *Acetes japonicus* was the dominant species in every habitat (Fig. 6). The mean abundance of *Acetes* did not differ statistically among monsoon season. However, their mean abundance was highest during the intermonsoon period (Fig. 7). The abundance of *A. japonicus* and *A. vulgaris* were found to be related to the salinity and the level of chlorophyll-a, but the numbers of *A. erythraeus* and *A. indicus* were not related to any of these environmental factors (Fig. 8).

In daylight *A. japonicus* selected bare sand as its habitat rather than other substrate types, but at night there was no significant difference in the selection of habitat ($x^2 = 4.28$, df = 3, $p = 0.2332$) (Table 4).

On horizontal habitat, *A. japonicus* was more abundant on muddy substratum and bare substratum than sand in light condition. At night, there was no significant difference for selection between habitats by *A. japonicus* (Table 5).

![Figure 6. Species compositions and abundances of Acetes shrimps in each habitat during night.](image-url)
Community structure of Acetes shrimps in the Gulf of Thailand

Figure 7. Acetes shrimps abundance in Talet Yai Bay.

Figure 8. Results of the co-inertia analysis of (A) Environmental variables and (B) Species composition of Acetes found in the study.
Table 4. The abundance of *A. japonicus* in each habitat under light and dark conditions. Different letters (a, b) indicate significantly different mean abundance according to the Wilcoxon rank sum test at \( p < 0.05 \).

<table>
<thead>
<tr>
<th>Habitat</th>
<th>( \bar{X} \pm SD ) Light condition</th>
<th>( \bar{X} \pm SD ) Dark condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare sand</td>
<td>51 ± 16\textsuperscript{a}</td>
<td>27 ± 10</td>
</tr>
<tr>
<td>Mangrove</td>
<td>15 ± 8\textsuperscript{b}</td>
<td>23 ± 9</td>
</tr>
<tr>
<td>Rock</td>
<td>14 ± 6\textsuperscript{b}</td>
<td>18 ± 6</td>
</tr>
<tr>
<td>Seagrass</td>
<td>17 ± 7\textsuperscript{b}</td>
<td>25 ± 8</td>
</tr>
</tbody>
</table>

Table 5. The abundance of *A. japonicus* on horizontal habitat in light and dark conditions. Different letters (a, b) indicate significantly different mean abundance according to a Wilcoxon rank sum test at \( p < 0.05 \).

<table>
<thead>
<tr>
<th>Habitat</th>
<th>( \bar{X} \pm SD ) Light condition</th>
<th>( \bar{X} \pm SD ) Dark condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare sand</td>
<td>34 ± 5\textsuperscript{a}</td>
<td>34 ± 5</td>
</tr>
<tr>
<td>Mud</td>
<td>36 ± 9\textsuperscript{a}</td>
<td>24 ± 10</td>
</tr>
<tr>
<td>Sand</td>
<td>18 ± 4\textsuperscript{b}</td>
<td>26 ± 9</td>
</tr>
</tbody>
</table>

The effects of mucus from *Acetes*’ predatory fish (*Secutor insidiator*) on the habitat selection of *A. japonicus* was striking. In daylight, *A. japonicus* changed its habitat selection from a preference for bare sand in the absence of predator mucus to seagrass bed when mucus from the predator was present. At night, in dark conditions, it seems that mangrove was preferred over others in the habitat selection of *A. japonicus* in response to the presence or absence of a predator or its mucus (Table 6).

In observations made during these experiments, *A. japonicus* was seen to be frightened when in eye to eye contact with the fish because they used tail-flip behavior to escape from the predator, but they showed no preference in subsequent habitat selection.

The visual presence of a predatory fish in daylight caused a change of habitat selection from a preference for bare sand to no preference. At night, the presence of a predator either visually or by the introduction of mucus did not change the habitat selection of *A. japonicus* (Table 7).
Community structure of Acetes shrimps in the Gulf of Thailand

Table 6. The abundance of \textit{A. japonicus} influenced by mucus of predator to select habitat in light and dark phases. Different letters (a, b) in the same column indicate significantly different mean abundance according to a Wilcoxon rank sum test at $p < 0.05$.

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Light condition $\bar{x} \pm SD$</th>
<th>Dark condition $\bar{x} \pm SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare substratum</td>
<td>36 ± 5$^a$</td>
<td>17 ± 8$^b$</td>
</tr>
<tr>
<td>Sand</td>
<td>13 ± 5$^b$</td>
<td>18 ± 8$^b$</td>
</tr>
<tr>
<td>Mud</td>
<td>14 ± 4$^b$</td>
<td>13 ± 6$^b$</td>
</tr>
<tr>
<td>Mangrove</td>
<td>6 ± 2$^c$</td>
<td>29 ± 2$^a$</td>
</tr>
<tr>
<td>Rock</td>
<td>12 ± 4$^b$</td>
<td>13 ± 6$^b$</td>
</tr>
<tr>
<td>Seagrass</td>
<td>16 ± 5$^b$</td>
<td>11 ± 7$^b$</td>
</tr>
</tbody>
</table>

Table 7. The abundance of \textit{A. japonicus} affected by detection of predator by means of vision in each habitat for light and dark conditions.

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Light condition $\bar{x} \pm SD$</th>
<th>Dark condition $\bar{x} \pm SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare substratum</td>
<td>24 ± 9</td>
<td>19 ± 10</td>
</tr>
<tr>
<td>Sand</td>
<td>9 ± 7</td>
<td>14 ± 9</td>
</tr>
<tr>
<td>Mud</td>
<td>16 ± 8</td>
<td>11 ± 3</td>
</tr>
<tr>
<td>Mangrove</td>
<td>8 ± 4</td>
<td>14 ± 4</td>
</tr>
<tr>
<td>Rock</td>
<td>21 ± 15</td>
<td>19 ± 10</td>
</tr>
<tr>
<td>Seagrass</td>
<td>15 ± 12</td>
<td>18 ± 11</td>
</tr>
</tbody>
</table>

DISCUSSION

Temporal and spatial variation of species composition and abundance of Acetes

Previously, two \textit{Acetes} species: \textit{A. japonicus} and \textit{A. erythraeus} had been reported in questionnaires and interviews along the coast of Gulf of Thailand (\textit{e.g.} Chaitiamvong and Boonyanate, 1978). This study records four species of \textit{Acetes} and their monthly abundance for a year from May 2010 to June 2011. The species composition and abundance of \textit{Acetes} in Talet Yai Bay seems to be affected by the monsoons and other environment factors.

The \textit{Acetes} harvesting seasons in different places in Thailand are synchronized with the local swarming of \textit{Acetes} (Omori, 1975). In Nakhon Si Thammarat Province (Muang, Tha Sala, Sichon and Pak Phanang Districts) the harvesting season is from January to April and the peak months are February and March (Chaitiamvong and Boonyanate, 1978). The swarming periods in these and other different localities may be similar due to similar environmental conditions such as monsoons. The same periods of high abundance are found in Samut Prakarn Province (Vongsungyang, 2007) and in Talet Yai Bay (this study).

In this study, \textit{A. japonicus} was found to be the dominant species. They were found in coarse-sand flats, mangroves, open water, muddy flats, and seagrass beds. As in the Andaman Sea, \textit{A. indicus} was generally
abundant in mangrove canals but *A. japonicus* was dominant species in seagrass beds (Pengchumrus and Upanoi, 2005).

Physical factors such as salinity and the concentration of chlorophyll-a were positively related to the abundance of *A. japonicus* and *A. vulgaris*. Acetes and mysid shrimps are known to be ontogenetically affected by salinity (Chen and Chen, 2002; Rattanachot, 2004). Measurement of chlorophyll-a concentration in the water column is an estimate of the abundance of phytoplankton, which is the major food source of *A. japonicus* (Xiao and Greenwood, 1993; Santos et al., 2003; Amani et al., 2011). Some species of Acetes show food niche separation. For example, copepods but no diatoms were found in the stomachs of *A. erythraeus* and *A. indicus* (Xiao and Greenwood, 1993).

**Habitat selection experiments with *A. japonicus***

Light intensity affected the habitat selection of *A. japonicus*. In daylight, *A. japonicus* preferred bare sand substrata to mangrove roots, rock or seagrass habitats, whereas, at night *A. japonicus* did not show any special habitat preference. *Acetes japonicus* was observed to stay very close to bare sand substrata during the daylight experiments and were difficult to see. This might be the preferred predation avoidance behavior of *A. japonicus*. In contrast, at night their semi-transparency might not be more of an advantage over bare sand substrata than in other habitats.

In another experiment, the presence of mucus from fish predators affected significantly the habitat selection of *A. japonicus* both in daylight and at night. In daylight, it selected bare substrata more than habitats with horizontal and vertical structure. However, they were likely to choose a more complex structure over a less complex structure. According to the results, the highest numbers of *A. japonicus* were recorded in the seagrass habitat that had the most complex structure. Russo (1987) suggested that more complex substrata could protect prey from predators but the results here show that at night *A. japonicus* prefers mangrove root habitats that have low vertical complexity. The effect of increasing structural complexity on the rate of predation depends on the type of predators (Savino and Stein, 1989).

*Acetes japonicus* showed no statistical difference in habitat selection either in daylight or at night in the visual presence of a predator. Juveniles of *P. merguiensis* have been found to prefer high vertical structure (mangrove debris and pneumatophores) over low vertical structure (leaf litter and bare substratum) in daylight, at night, and in the presence of predators (Meager et al., 2005) but the morphology of plants is not important for habitat selection in some marine communities (Chavanich et al., 2004).

In this study the fish predator was in a separate plastic enclosure inside the experiment tank to promote only visual and not chemosensory detection by the *A. japonicas* and they showed no preference for the selection of vertical habitats. At night in dark conditions zooplankton do not have the same necessity to escape from predators because the predators cannot see them (Levinton, 2001). There is no information in the literature about the use of shelter to avoid predation in *Acetes* (Rönnbäck et al., 1999). Acetes shrimps are holo-hyperbenthos (Jarrin et al., 2017) and their ability to deliberately find structure shelter is expected to be limited (Rönnbäck et al., 1999).

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