Feeding Ecology of Asian Green Mussel (*Perna viridis*): Influences of Sexes, Sizes, Habitats and Seasons

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ABSTRACT

This study is aimed to evaluate the impacts of sex, size, habitat and season on feeding habits and assess food selectivity of Asian green mussel (*Perna viridis*) collected monthly from three different sites in Pattani Bay, Thailand during June 2016 to May 2017. Altogether, a total of 2,627 of *P. viridis* were collected by handpicking from the wild and brought back to the laboratory for further investigation. Additional collections, one sampling occasion for each habitat, were collected during July and December 2016, and April 2017 from other three different habitats including Aceh of Indonesia, Trang and Suratthani of Thailand. It was found that *P. viridis* is omnivorous, feeding on a wide range of phytoplankton and zooplankton. Overall, *Coscinodiscus* was the major food item (38.59%), followed by green mussel larvae (22.19%) and *Pleurosigma* (12.65%). Results from ANOVA indicated that size, habitat and season highly affected both total number of food count and total number of food item fed by *P. viridis* ($P<0.01$). Result from T-test indicated a significant difference on total number of food count and total number of food item between sex ($P<0.01$). A specifc food seletion by *P. viridis* based on availability of food resources in the habitat was measured. This finding helps in understanding how *P. viridis* feeds and selects food in nature from different localities.

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P. viridis	=	*Perna viridis*
mm	=	Milimeter
spp.	=	Species
TSS	=	Total Suspended Solid
DO	=	Dissolved Oxygen
°C	=	Degree celcious
ppt	=	Part per thousand
µg	=	Microngram
mg	=	Miligram
L	=	Liter
m	=	Meter
s	=	Second
cm	=	Centimeter
km^2	=	Kilometer square
>	=	More than
<	=	Less than
mL	=	Mililiter
Bi	=	Levin's standardized index
ANOVA	=	Analysis of Variance
ANOSIM	=	Analysis of Similarity
SIMPER	=	Similarity of Percentage
±	=	Plus minnus
SD	=	Standard Deviation
SE	=	Standard Errors
Mean	=	Average
Min.	=	Minimum
Max.	=	Maximum
TA	=	Total number of food count
TI	=	Total number of food item
n.s	=	No sampling

CHAPTER I
INTRODUCTION

1.1 Background and Rationale

Bivalves are invertebrate from Phylum Molluca. In marine and freshwater environment, approximately 15,000 species of bivalves were existed (Gosling, 2004). Bivalves inhabit the tropics, as well as temperate. A number of species can survive and develop in extreme conditions.

Perna viridis is known as Asian green mussel from Phylum Mollusca, Class Bivalvia and Family Mytilidae. There are 32 genera of Mytilidae, one is genus *Perna* and one of the important species of this genus *Perna* is *P. viridis* (Gosling, 2004; Rajagopal *et al.,* 2006). It is spreaded along the Indo-Pacific territories (Soon and Ransangan, 2014), India (Rajagopal, *et al.,* 1998), Gulf of Persia to the South of Pacific and Papua New Guinea (Siddall, 1980), Hongkong (Wong and Cheung, 2001), Mexico and USA (Power *et al.,* 2004) and Thailand (Prakoon *et al.,* 2010). This mussel can be found in the warm water, which salinity varies from 0-64 ppt and temperature ranges from 6-37.5°C (de Bravo *et al.,* 1998).

Southeast Asia coastal ecosystems are known as the important habitat for fishes (Hajisamae and Yeesin, 2014). Gosling (2004) confirmed that *P. viridis* presented in all Southeast Asian countries. In Thailand, Prakoon *et al.* (2010) found *P. viridis* in six main estuaries nearby major rivers comprising Tachin, Tapi, Meklong Bangpakong, Chao Phraya River.

Commonly, *P. viridis* spat in nature settles on a fine surface. Their larvae prefer to stay at high water velocities (Rajagopal *et al.,* 2006). Mostly, they develop at the depth of less than 10 meters and their lifespan is about 3 years (Power *et al.,* 2004). Bamboo stick is usually used for *P. viridis* spat settlement (Somerfield *et al.,* 2000). Rajagopal *et al.* (1998) revealed that *P. viridis* could reach the total length of 119 mm in the first year and could reach up to 152 mm in the second year. Moreover, Rajagopal *et al.* (2006) found that the total length could reach 230 mm.

Bivalves are known as a filter suspension feeder, which feed on high biotic particles from the strained materials from water column and likely to reject the inorganic particles (Jorgensen, 1996). Different feeding selectivity of bivalve is based on different stages (Frau *et al.,* 2016). Generally, mollusks were considered an herbivorous animal. Phytoplankton was the main component of mussel's diet (Davenport *et al.,* 2011; Peharda *et al.,* 2012). They feed on phytoplankton such as diatoms, dinoflagellates and detritus (Villalejo-Fuerte *et al.,* 2005; Muñetón-Gómez *et al.,* 2010). However, phytoplankton was reported as their main food sources, some researchers reported that mussels fed also on zooplankton (Table 1.1)

1.2 Problem Statement

Study on feeding habit and selectivity of *P. viridis* had been conducted in some Asian Countries such as Hong Kong (Wong and Cheung, 2001) and Malaysia (Soon and Ransangan, 2016). In Thailand, both Andaman Sea and Gulf of Thailand, the study on feeding behavior of *P. viridis* is rarely conducted.

Food selection of mussels is an important section in feeding studies. Types of phytoplankton and zooplankton selected by mussels from the water column in natural environment are still less understood (Molina *et al.,* 2010). Thailand has been one of the major *P. viridis*) production area. In 1997, the highest production of *P. viridis* in Thailand was 51,184 tons (Somerfield *et al.,* 2000). Those areas include four provinces in the Southern part of Thailand, Suratthani, Trang and Pattani.

Chalermwat *et al.* (2008) remarked that the potential areas for *P. viridis* farming in Thailand were Pattani Province (2,000 rai*), Trang (2,500 rai) and Suratthani (4,000 rai). Food selectivity of the *P. viridis* needs to be investigated. Some parts of the Gulf of Thailand and the Andaman Sea can be considerred as suitable places for conducting research on this topic. Hence, as no study on feeding ecology of *P. viridis* in these areas before, this study was the first observation of food selectivity of *P. viridis* based on sex, size, habitat and season. Therefore, results from this study could contribute as fundamental scientific information for the development of future mussel management.

*1 rai = 0.16 hectare

Table 1.1 List of food ingested of some bivalves

Sources	Bivalve's species	Type of foods	
		Phytoplankton	Zooplankton
Lehane and Davenport (2002)	*Mytilus edulis, Cerastoderma edule* and *Aequipecten operculais*	Unexamined	Copepods, crustacean nauplii, barnacle cyprids, foraminifera and unidentified eegs.
Lehane and Davenport (2006)	*Mytilus edulis*	Unexamined	Copepods, crustacean nauplii, barnacle cyprids, amphipods, bivalve larvae, ostracods and unidentified eegs
Alvaro (2006)	*Perna canaliculus*	*Gymnodinium, Ceratium, Chaetoceros, Navicula and Nitzschia*	Copepods, cyclopoid, mysids, zoea and nauplia
Davenport *et al.* (2011)	*Pinna nobilis*	*Bacteriastrum , Chaetoceros, Ceratium Coscinodiscus , Melosira, Navicula, Nitzschia , Pleurosigma , Pseudo-nitzschia, and Thalassionema*	Copepods, copepod nauplii, gastropod and bivalve larvae, tintinnids and amphipods
Peharda *et al.* (2012)	*Ostrea edulis, Mytilus galloprovincialis, Modiolus barbatus and Arca noae*	Unexamined	Bivalve larvae, tintinnids, copepods, gastropods larvae and unidentified eegs
Soon and Ransangan (2016)	*Perna viridis*	*Coscinodiscus, Chaetocheros Prorocebtrum, Proboscia, Navicula Thallasionema, Bacteriastrum, , Pleurosigma* and *Nitzschia*	Barnacle nauplii, copepods nauplii, copepods, isopods, mussel larvae, clam and gastropods veliger, zoea

1.3 Objectives of Research

The overall objective of present study is to describe the feeding ecology of Asian green mussel (*P. viridis*). The specific objectives are described as:

1) To study impacts of sex, size, habitat and season total number of food count and total number of food item and feeding attributes *P. viridis*
2) To study the composition and abundance of plankton in the vicinity of *P. viridis* collection
3) To assess food selectivity of *P. viridis* in the study area

1.4 Expected Advantages

The overall expected is that marine fishery authority can use advantages or benefits of this study for future management. Moreover, the results of this study can be used as a reference for further research work. Overall benefits of this study can be described below:

1) The impacts of sex, size, habitat and season on feeding ecology of *P. viridis* were identified
2) The composition and abundance of plankton organisms were classified
3) Types of food selected by *P. viridis* were reported

1.5 Taxonomy

As reported by Siddall (1980), *Perna viridis* (Linnaeus, 1758) (Figure 1.1) has many synonyms including. *Mytilus viridis, M. smaragdinus, M. opalus, Chloromya viridis,* and *C. smaragdinus.* Rajagopal *et al.* (2006) reported the classification of *P. viridis* as below:

Kingdom: Animalia

Phylum: Mollusk

Class: Bivalve

Subclass: Pteriomorphia

Order: Mytiloida

Family: Mytilidae

Genus: *Perna*

Species: *Perna viridis*

Figure 1.1 Asian green mussel (*P. viridis*)

1.6 Morphology

Some of morphological characters observation can distinguish *P. viridis* (Table 1.2) (Siddall, 1980; Rajagopal *et al.,* 1998). The color is green or varies with blue and brown. In juvenile, the exterior color of *P. viridis* is green-blue. Thereafter, it will develop into brown color with patches when *P. viridis* becomes an adult (Siddall, 1980). By anatomical characteristics, *P. viridis* can be differentiated by the existence of extended sensory papillae through the side of membrane (Siddall, 1980). The exhalant inhaled and the center veneer of the inhalant opener is expanded with a darker shape than fluctuating of appraisal mantle (Figure 1.2). Furthermore, *P. viridis* can be differentiated by other genus of *Perna* by presenting 30 diploid chromosomes instead of 28 (Rajagopal *et al.,* 2006).

Table 1.2 Characteristics of *P. viridis*

Conchological features	Diagnostic characters
Shells	Thick, equivalve, inequilateral
External color of shells	Green or bluish green
Maximum size	230 mm (shell length reported)
Anterior side of the shell	Sharp and neb
Abdominal shell margin	Highly concave
Tergal ligamental margin	Curved
Mid-tergal margin	Arcuate
Coating margin color	Green yellowish or chlorine
Ventral mantle margin	Central abdominal posterior
Size of pillar sheathe	Thick and broad
Pillar antler	Small spigot on left and right side
Anterior adductor muscle	Vacant
Veining coats	Deeply impressed
Byssus mechanism	Extensive
Resilial ridge	Spotted and thick
Posterior byssal retractors	Short and swollen
Excurrent aperture opening	Broad and tapering

Source**:** Rajagopal *et al.* (2006)

1.7 Ecology

1.7.1 Locomotion

Bivalves are the most sedentary. Some marine bivalve species such as *P. viridis* bores in wood, rock, and coral and cannot leave the burrows. Some families like Pectinidae, Limidae have adaption for swimming for a short distance by ejecting water from their mantle cavity and clapping the valves. When swimming, the foot becomes wide and drowns to the bottom, and initiates to slither (Gosling, 2004).

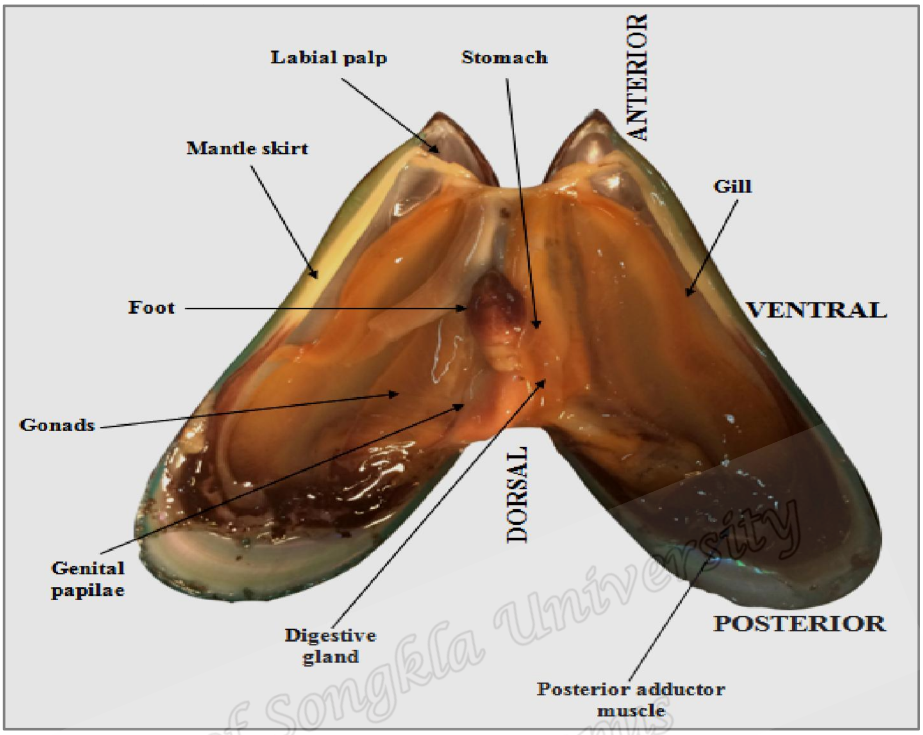


Figure 1.2 General anatomies of internal organs of *P. viridis*

1.7.2 Growth

Growth in bivalves is usually described of enhance the shell valves. In mussel, length of the shell valve is the aspect of preference (Gosling, 2004). The body of soft tissue growth is likely related to shell growth. Shell generally comes from the point of origin forwards. The growth of shell of bivalve occurs along the margins furthest from the umbones (Swennen *et al.,* 2001). Mussels can reach an average shell length of 83 mm in 1 year (Rajagopal *et al.,* 1998). The growth of *P. viridis* can be detected on shell and body growth. The growth of shell depends on food or energy consumed by *P. viridis*. While internal energy is consumed, the shell of *P. viridis* can grow up to 6-10 mm within a month (Power *et al.,* 2004).

The age of mussel can affect growth rate, the older mussels have a slow growth rate than the younger mussels because the metabolic activity of older mussels is decreased (Cheung and Shin 2005). Some environmental parameters (salinity and temperature), food availability and plankton composition influence mussel growth rate (Rajagopal *et al.,* 1998; Soon and Ransangan, 2014).

1.7.3 Reproduction

Some of the bivalve species are hermaphrodites, which both male and female can be found in the same individual, including *P. viridis* (Al-Barwani *et al.,* 2012). Some species also have the extraordinary life histories, beginning as male, passing through a hermaphrodite stage and ending up as female. Fertilization is occurred without body contact or external fertilization (Swennen *et al.,* 2001; Rajagopal *et al.,* 2006). Sex between male and female mussels is seperated and cannot be identified by the external morphology (Gosling, 2004; Rajagopal *et al.,* 2006).

Within 2-3 months old, mussels will become sexually mature when their shell length reaches 15-30 mm (Siddal, 1980). Visually, the difference between males and females can be distinguished by color of internal organs. Males show milky-white color gonads, while females reveal brick red colored gonads (Figure 1.3) (Rajagopal *et al.,* 2006; Al-Barwani *et al.,* 2012). Because of external fertilization, the life cycle of *P. viridis* start by releasing gametes into the water column and the gametes begin to assemble and establishes zygotes (Figure 4).

Figure 1.3 Morphology of *P. viridis*. Internal morphology of female (a) internal morphology of male (b)

Within 8 hours of insemination, *P. viridis* will reach a ciliate or free-swimming phase (Figure 1.4). By 8-12 hour after that, *P. viridis* will seize the veliger phase, which has a shell and ciliate membrane presence in the velum. This veliger feeds on phytoplankton and actively swims in the body water (Power *et al.,* 2004).

The spawning of aquatic animal is affected by the presence of plankton and temperature (Soon and Ransangan, 2014). However, Rajagopal *et al.* (1998) remarked that the spawning of *P. viridis* is reflected with seasonal classification of slightly temperature than food availability itself in the water column.

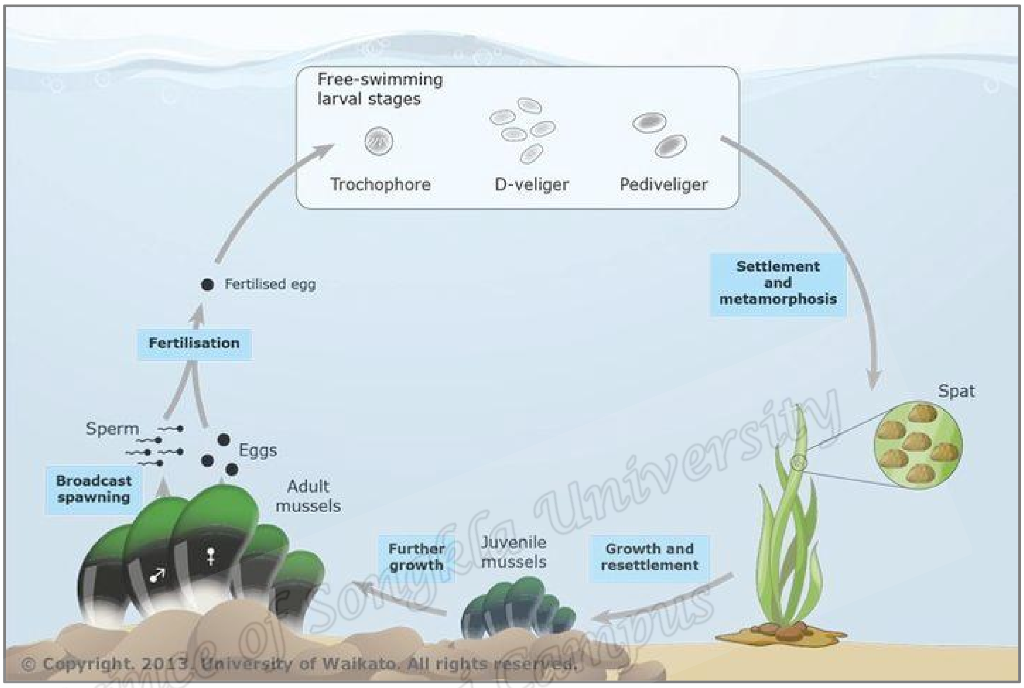


Figure 1.4 Life cycles of *P. viridis*
Source: Biotechnology Learning Hub (2013)

The difference of environmental conditions affected the different spawning time and duration. In some tropical countries (Malaysia, India and The Philippines), spawning of *P. viridis* occurs twice a year which related with monsoon season, where the peak periods is occurred during August to January and February to June in bay areas, September to January and January to April in the sea areas. While in the estuary, it only occurs one time in November to June (Kripa *et al.,* 2009).

1.7.4 Food and Feeding Mechanisms

Most of the bivalves eat and filter very small size of food particle, such as plankton and detritus out of the water with their special gills. The foods enter the mouth via the ciliated gills in a string of mucus (Swennen *et al.,* 2001) (Figure 1.5). Like other bivalves, *P. viridis* is suspension feeder, which feeds on high organic particles from seawater column and prefers to reject the inorganic particles

(Jorgensen, 1996). They feed on small particles of living organisms such as phytoplankton, zooplankton, detritus and other organic material (Gosling, 2004). Food particles are trapped in mucus strings will be converted to labial palps, which nourishment is passed to the mouth (Rajagopal *et al.,* 2006). While the foods entered through the excurrent siphon, only food with appropriately sizes, high quality and quantity of foods, high phytoplankton biomass are accepted and passed into the stomach and digested. The inorganic particles will be rejected (Dolmer, 2000; Galimany *et al.,* 2011; Wong and Cheung, 2001).

Phytoplankton was considered as the main food for bivalves (Peharda *et al.,* 2012). Soon and Ransangan (2016) found that *P. viridis* fed more phytoplankton than zooplankton. Around 85.7-98.7% of phytoplankton was found in the stomach contents. They also mentioned that *P. viridis* has an opportunistic character on doing reproduction, which taking specific food for gonad establishment. *P. viridis* feed on high quality of phytoplankton and high concentration of seston with using less energy. Some groups of phytoplankton, such as *Chaetoceros* spp. and *Bacteriastrum* spp. will be rejected. These planktons are known as poor carbohydrate, lipid and protein food (Bayne *et al.,* 1993).

Soon and Ransangan (2016) stated that research on *P. viridis* was no difference to another species of bivalve because the main food component was phytoplankton. Muñetón-Gómez *et al.* (2010) studied on ark clam, *Anadara tuberculosa,* and found that *A. tuberrculosa* fed on phytoplankton (diatoms) which counted at 91.5%. The same thing was also found by Villalejo-Fuerte *et al.* (2005), who confirmed that oyster *Hyotissa hyotis,* fed on phytoplankton especially diatoms around 86.5% in the gut. Cognie *et al.* (2001) also found that oyster *Crassostrea gigas*, fed on natural microphytobenthos (diatoms) up to 95%. The invasive mussel, *Limnoperna fortunei* feed on phytoplankton depending on size and cell shape (Frau *et al.,* 2016). The size of food does not show exactly the organism, larger food particles can be both phytoplankton and zooplankton (Troost *et al.,* 2009).

Moreover, benthic microalgae become the important food source for sub tidal bivalves. Mussels have the ability to capture both organic and inorganic particles, depend on low or high seston in the water column and their adaptive behavior. Nonetheless, mussels will select an organic particle and reject of the inorganic matter as the pseudofaeces if concentration and quality of seston are high (Jorgensen, 1996; Wong and Cheung, 2001).

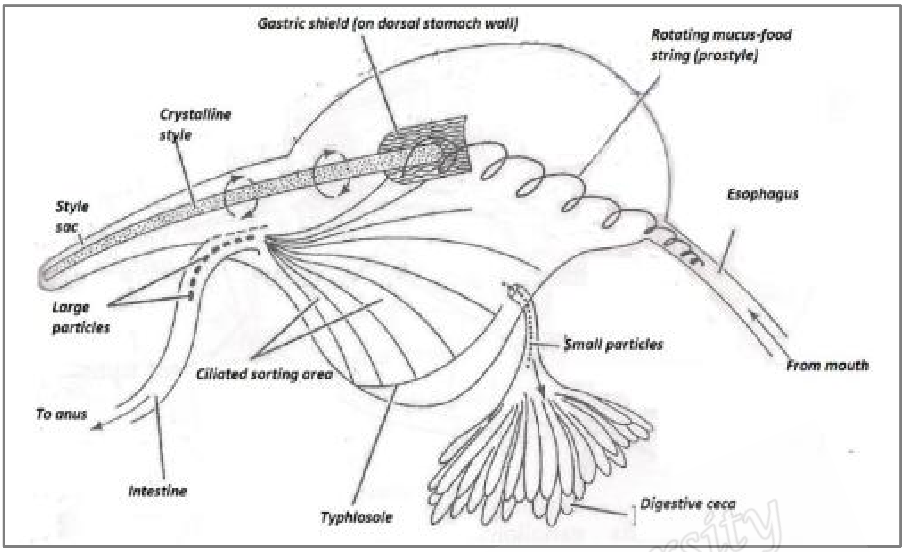


Figure 1.5 Schematic drawing of the bivalve digestive system
Source: Delahaut (2012)

However, the chances of distinguishing the food quality of plankton groups under environment conditions are still limited. Types or kind of plankton selected by mussels from water column is poorly understood. However, selectivity could be related to escape abilities and size of prey (Molina *et al.,* 2010). In relation to food and feeding competition, inhalant and exhalant might be contributed as significant factors in optimizing food intake among bivalve species (Troost *et al.,* 2009). Mussel *Mytilus galloprovincialis* is strongly respond to short-range shifts in the quality or characteristic food and relate to energy intake, growth rates and productivity (Galimany *et al.,* 2011). However, responses of variation in quantity and quality of food are not restricted to bivalve species (Wong and Cheung, 2001).

In a case of feeding response, mussels use low organic food particles as a compensational food since primary foods are not exist (Bayne *et al.,* 1993). Other interesting things of food selection are caused by habitat and size of mussel itself (Alvaro, 2006; Davenport *et al.,* 2011). Feeding behavior of mussel is linked to environmental conditions of some intertidal bottom as proper habitat or living in a slight intake habitat, even though living within a few meters of other layers (Davenport *et al.,* 2011). Startlingly, sexes of mussels play a role of ingestion food by mussel (Ashraful *et al.,* 2009). Furthermore, feeding rhythms of *P. viridis* are linked with tidal cycles, and it is controlled by variations in food availability in the seawater (Wong and Cheung, 2001). The same thing also found in other marine bivalves such as blue mussel (Rouillon *et al.,* 2005; Lehane and Davenport, 2006), giant honeycomb oyster (Villalejo-Fuerte *et al.,* 2005), New Zaeland green-lipped mussel (Alvaro, 2006), ark calm (Muñetón-Gómez *et al.,* 2010), fan mussel (Davenport *et al.,* 2011) and even in freshwater bivalves, swans mussel (Lopes-Lima *et al.,* 2014).

Phytoplankton is the first producer food in animal web chain and supplier for any aquatic ecosystem while zooplankton is the second producer in tropic level (Sharma *et al.,* 2016). Phytoplankton is an aquatic plant that photosynthesized in the existence of sunlight and nutrients such as nitrogen and phosphorus (Adesalu, 2012). There are some main factor limitations for reducing the nutrients for phytoplankton comprising nitrogen in form of ammonium ion ($NH4^{+}$), nitrite (NO2-) and phosphate (PO4-). Nitrogen (N) tends to be the limiting nutrients in marine systems. The nutrient is needed by phytoplankton to build their cell membranes and for proteins (Adesalu, 2012).

Moreover, in eastuarine or semi-enclosed bay, nutrient from open sea coastal is trasnported by wave. Because the structure and abundance of phytoplankton are usually dominated by inorganic nutrients (nitrogen and phosphorus), phytoplankton communities are susceptible to changes in their environment. Therefore, the abundance and total biomass of phytoplankton can be used as water quality indicators (Adugna and Wondie, 2016). Moreover, high values of TDS, turbidity, low DO concentration, and light attenuation or light intensity affect the nutrition in the water column, which affect also on a low density of phytoplankton (Drake *et al.,* 2010; Sharma *et al.,* 2016).

1.7.5 Predators

Crabs and octopus are main predators for *P. viridis*. Mud crab, *Scylla serrata* is regarded the main predator. Besides that, hydroids, algae, ascidians and barnacle larvae are significant pests, which patch at the shell of *P. viridis* (Rajagopal *et al.,* 2006). Predators selected their prey according to sizes. The blue crabs usually feed on the smaller prey. Moreover, Kaehler and McQuaid (1999) mentioned that animals such as cyanobacteria bored into *P. viridis* shell and could run into degradation. It will reduce the reproduction and longevity of the mussels. Jose and Deepthi (2005) reported that Pea crab, *Pinnotheres placunae* was a parasite for *P. viridis*. This crab could decrease the shell size of mussels and body weight. The damage can be observed on gill, which is crumbled.

1.8 Environmental Requirements

1.8.1 Temperature

Generally, bivalves could survive with temperature range between-3°C to 44°C. Within this range, the tolerance difference between genuses of bivalve showed their own tolerance based on temperature condition (Gosling, 2004). de Bravo *et al.* (1998) found that *P. viridis* can live at a temperature range from 6-37.5°C

P. viridis lives in a suitable range of temperature from 15-32.5°C and this species can survive at temperature of 39°C for 200 minutes. Thereafter, it will die slowly (Rajagopal *et al.,* 2006). In another case, Benson *et al.* (2001) mentioned that *P. viridis* could survive and develop in winter temperature as low as 12°C.

1.8.2 Salinity

In the open oceans, water salinity varies between 32-38 ppt, with an average of 35 ppt (Gosling, 2004). de Bravo *et al.* (1998) expressed that salinity for *P. viridis* varied between 0-64 ppt and for *P. Perna* range from 8-54 ppt. The normal fluctuation in salinity for *P. viridis* to survive in estuaries habitat is 27-33 ppt, however, it can survive in salinities as low as 20 ppt (Rajagopal *et al.,* 2006). Mostly, mussels in marine and estuarine can accept the tolerance is between 4-40 ppt. Genus *Perna* can tolerates wide salinity range for estuarine is between 27-33 ppt (Gosling, 2004).

1.8.3 pH of water

The optimum pH for *P. viridis* was from 7.6-8.2 (Soon and Ransangan, 2014). Optimum water pH for *P. viridis* was reported in ranged of 6.5-8.7 in the Gulf of Thailand and 6.98-8.63 in Pattani Bay (Khongpuang, 2011).

1.8.4 Total Suspended Solid (TSS)

Cheung and Shin (2005) mentioned that *P. viridis* could tolerate high concentrations up to 1000 mg SS/L. However, the optimum TSS for *P. viridis* is should be less than 1000 mg SS/L.

1.8.5 Chlorophyll-α

Range of suitable chlorophyll-α for *P. viridis* is from 0.6-6.5 µg/L. In the temperate area, the ideal chlorophyll-α is 4.0-8.0 µg/L. The compatible chlorophyll-α is from 2.0-3.0 µg/L in the tropical area (Soon and Ransangan, 2014).

1.8.6 Dissolved Oxygen (DO)

In Thailand, DO levels in coastal environments range from 2.57-8.67 mg/L (Khongpuang, 2011). Soon and Ransangan (2014) reported that the suitable DO for culture *P. viridis* should be higher than 8 mg/L.

1.8.7 Water Current

Water current plays an important role in food particle availability and feeding activity (Dolmer, 2000). High current may affected mussels apart from its settle (Rajagopal *et al.,* 1998). The suitable water current for *P. viridis* ranges from 0.1-0.3 m/s (Khongpuang, 2011; Soon and Ransangan, 2014).

1.8.8 Water Depth

The requirement of water depth for *P. viridis* depends on area and culture techniques. In Thailand, appropriate depth for pole culture is from 1-4 m (Khongpuang, 2011). For bottom living mussels (both in natural or culture condition), the depth >8 m is optimal depth. (Soon and Ransangan, 2014).

1.8.9 Turbidity

High turbidity caused by the presence of suspended material such as clay, sand and organic and inorganic particles. These particles would affect bivalves culture (Lovatelli, 1998). Soon and Ransangan (2014) found that the lowest turbidity was from 22-25 cm. However, for the bivalve culture, the transparency should be not less than 15 cm; it was considered as unsuitable turbidity (Lovatelli, 1998; Khongpuang, 2011).

1.8.10 Settlement

There are particular substrates in most bivalves for the suitable place for living. For mussels, settlement reflects the transient phase for mussel from larvae life until adult. *P. viridis* prefers to live on muddy sediment with high water velocity and high suspended particulate matter (Gosling, 2004; Rajagopal *et al.,* 2006).

1.9 Distribution

Asian green mussels (*Perna viridis*) (Linnaeus, 1758) appears in the tropical water of the Indo-Pacific region of Asia (Siddall, 1980) (Figure 1.6). The indigenous of *P. viridis* spreads over the Indo-Pacific to the South Pacific Islands (Siddall, 1980; Rajagopal *et al.,* 2006; Dias *et al*., 2013). *P. viridis* is spreaded throughout Southeast Asian and Indian coasts. Normally, it can be found at marine intertidal, sub tidal and estuarine areas with high salinity. It prefers to attach to the submerged rock, metal, boats, ropes, pipes PVC surface, sea grass beds and mangrove sustain roots (Siddall, 1980; Rajagopal *et al.,* 2006). Surprisingly, in 2001, non-native *P. viridis* was found in Trinity Inlet, Cairns, Queensland, Australia via ship hull biofouling (Dias *et al.,* 2013). They are introduced as juvenile free-floating mussels or introduced as adults mussels.

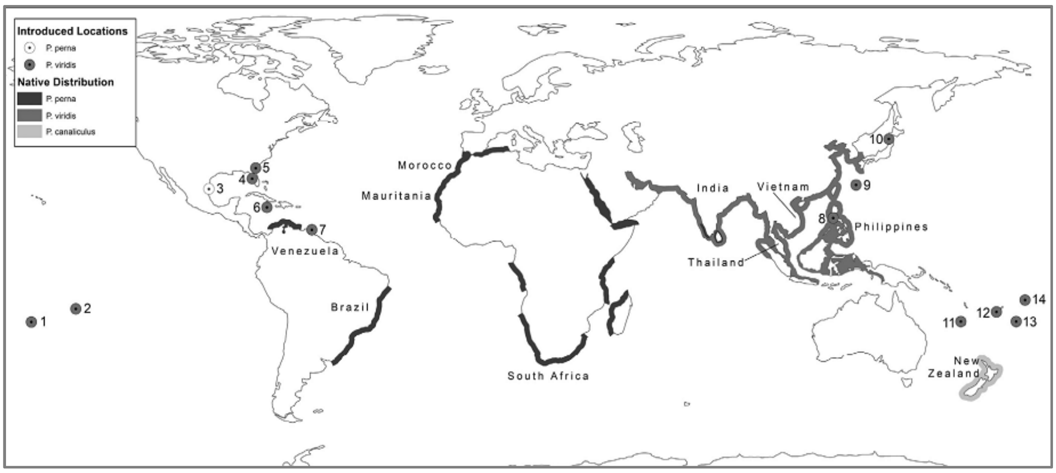


Figure 1.6 Geographic distributions of mussel species of the genus *Perna*
Source: Dias *et al.* (2013)

1.10 Culture Techniques

In Thailand, one of cultivation technique of *P. viridis* is raft culture (Figure 1.7a). Bamboo stick as the substrate for *P. viridis* patches is usually used for cultivates this technique (Somerfield *et al.,* 2000). The substrate is made from nylon rope, wrapped with mosquitoes net with diameter 3 cm (Figure 1.7b). The substrate is suspended at 50 cm depth under water surface with 30 cm rope spacing. Each substrate can load around 10-20 mussels (Figure 1.7c) (Soon and Ransangan, 2016). The raft is floated on the water surface, placed in intertidal zone or shallow water areas. The benefit of this culture technique is predator reduction, short cultivation, food (plankton) availability, low siltation, high production and low cost (Soon and Ransangan, 2014).

Figure 1.7 Mussel culture technique. Raft culture mussel (a) substrate for mussels (b) mussels in substrate (c)

CHAPTER II
METHODOLOGY

2.1 Study Sites

For the East Coast of Southern Thailand, there are three different seasons, dry or pre monsoon season is during January to April, moderate season is from May to September, and rainy or southwest monsoon season is from October to December (Chaiwanawut *et al.,* 2005). In Aceh provice, two seasons were occurred throughout year. They were dry and rainy season (Lee, 2015).

There are four study sites comprising Pattani, Trang, Suratthani and Aceh selected for this study. The first three stations are in southern of Thailand, while Aceh province is in the west of Sumatera Island, Indonesia (Figure 2.1). Those stations have different characteristics (Table 2.1)

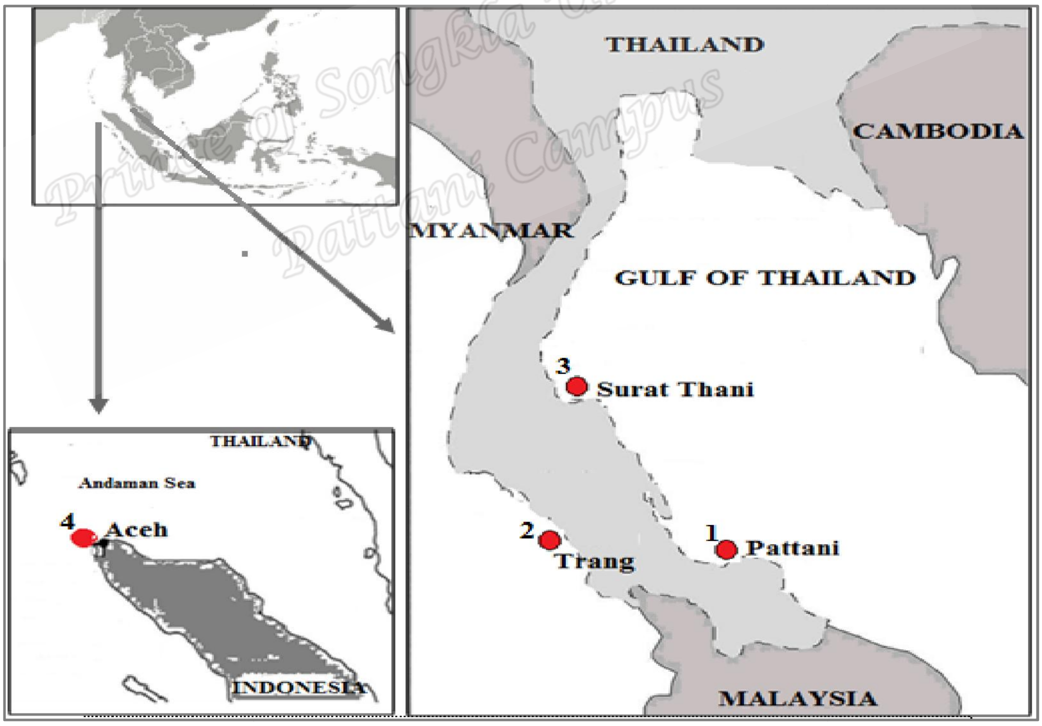


Figure 2.1 Sites selected for sampling

In Pattani Province (Figure 2.2), Pattani bay is the main sampling location. There are three substations comprising Datok (6°54'33" N, 101°19'27" E) (a), Bana (6°52'41" N, 101°17'23" E (b) and Rusamilae (6°52'42" N, 101°12'41" E) (c) substations

Table 2.1 Characteristics of study sites

Study site	Coordinates	Land use characteristics
Suratthani (Bandon Bay)	9°15'28" N, 99°29'6" E	A huge *P. viridis* farm, containing loamy soil sediment and high dissolved nutrients
Pattani (Pattani bay)	6°54'43" N, 101°17'10" E	A fishing village are, generally its sandy and muddy sediment, surrounded by mangrove area and some river banks
Trang (Kantang Coastal)	7°19'54" N, 99°29'24" E	*P. viridis* and other fishes farms, surrounded by mangrove area, intertidal mudflat zone and very low elevation gradient
Aceh (Alue Naga Beach)	5°35'46"N, 95°20'50" E	A fishing village, compose with wild *P. viridis* ecosystem, its estuarine area, sandy sediment, covered by casuarinas trees and connected to open seawater

Pattani province, the main sampling station, is characterized by tropical monsoonal climate. Pattani bay, a semi enclosed estuarine, occupies an area of 74 km^2. The bay bound with two main rivers, Pattani River and Yaring River. The average water depth is 0.8 meters with the maximum depth of 5 meter at the bay's mouth. The tidal amplitude varies from 0.9 meter at high tides and 0.4 meter at low tides. Some water parameters in Pattani bay are presented in Table 2.2.

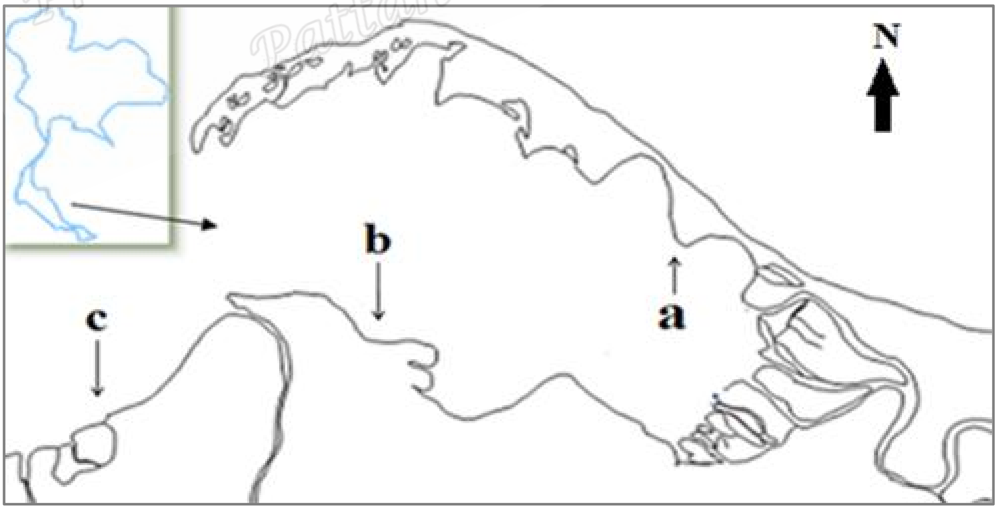


Figure 2.2 Sites sampling in Pattani bay, Thailand

The characteristics of the bay are sandy, muddy, seagrass, mangrove and shell deposited habitats. The inner bay area, (Datok and Bana) are muddy (>90% of silt and clay) and sea grass habitat (50% sea grass coverage), shell deposited and mangrove habitat, respectively. While outer bay area, Rusamilae, is sandy habitat (>40% sand composition) (Hajisamae and Yeesin, 2014).

Furthermore, the monthly rain intensity in Pattani and others Southern Thailand is shown in Table 2.5. Additionally, Khonpuang (2011) described some land use activities related to fisheries of two sites of the bay. Datok is a fishing village, shrimp farming and dried seaweeds production. Similar to Datok, Bana is also fishing villages and shrimp farming. Pattani bay connects to Pattani River at the bay opening, where both side of Pattani River is occupied by city area, industrial zones, fishing ports, infested mangrove area, government and educational organizations. Rusamilae, located in outer part of the bay, is also fishing villages.

Table 2.2 Some water parameters in Pattani bay

Parameter	Max±SD	Month	Min±SD	Month
Depth (m)	1.03±0.27	April	0.60±0.44	June
Transparency (m)	0.86±0.32	April	0.22±0.09	August
Temperature (°C)	30.20±0.26	October	29.2±0.50	December
pH	8.97±0.17	April	7.43±0.31	February
Salinity (ppt.)	31.50±2.9	April	18.10±7.50	December
DO (mg/l)	6.62±0.89	October	5.63±0.68	April
NO_2 (ppm)	0.026±0.06	August	0.001±0.003	October
NO_3 (ppm)	0.078±0.067	December	0.016±0.013	October
Total NH_3 (ppm)	0.507±0.861	February	0.034±0.052	October
PO_4 (ppm)	0.071±0.084	August	0.295±0.372	April
TTS (ppm)	279±424.5	August	0.002±0.003	June
Total phosphorus (ppm)	0.157±0.094	February	0.058±0.012	April
BOD (ppm)	4.43±0.73	December	0.29±0.44	April

Source: Khongpuang (2011)

2.2 Material and Instruments

Some materials and instruments were employed in this experiment. They are described with their functions in Table 2.3.

2.3 Experiments

The diagram (Figure 2.5, page 28) shows the detail experimental of this study.

2.3.1 Sampling Duration and Frequency

Sampling period of this study was during June 2016 to May 2017. Monthly sampling was done at main sampling site (Pattani bay) from three substations comprising Datok (Figure 2.3a) Bana (Figure 2.3b) and Rusamilae (Figure 2.3c). Datok was the *P. viridis* farming area in Pattani Bay. Some mussels were taken from Datok, set up at Bana for 2 weeks prior sampling date to mimic culture condition. Rusamilae was also farming area that established outside the bay. For additional sampling sites, Aceh, Indonesia (Figure 2.3d), Trang (Figure 2.3e) and Suratthani (Figure 2.3f) were done only one time.

Table 2.3 Materials used for experimental data

Materials/device	Function
Plankton net mesh size 60 µm	Plankton sampling
Thermometer	Measure the temperature (°C)
Refractometer	Measure the salinity (ppt)
pH meter	Measure pH
DO meter	Measure Dissolved oxygen (mg/l)
50mL bottle	Keep water sample
Glove	Collect mussels
Boat	Field data collection
Fiber box	Keep mussels sample
Ice	Keep the mussels samples
70% ethanol	Preserve the mussel stomach
5% formaline	Preserve plankton
Glass Pasteur pipette	Extract the stomach content
Sedgwick-Rafter chamber cell	Count plankton
Microscope	Identify plankton
Plankton book identification	References for plankton classification

2.3.2 Samples Collection and Preservation

The samples in this study comprise two main groups including *P. viridis* samples and plankton samples. Moreover, some water parameters including temperature, salinity, pH and DO, were collected at each station in accordance with sampling time.

2.3.2.1 Mussel Collection and Preservation

Approximately 194 of *P. viridis* were collected monthly at each substation in Pattani bay. For the additional stations (Trang, Surathani and Aceh), 100 of *P. viridis* were collected per sampling time (Table 2.4). *P. viridis* samples were collected by handpicking. Thereafter, the samples were put in the box with ice for transporting to laboratory (Lopez-Lima *et al.,* 2014). In laboratory, the sample were preserved with

5% formaldehyde for 6 hours (Alvaro, 2006), soaked with freshwater overnight, then preserved in 70% ethanol (Peharda *et al.,* 2012). Using 70% ethanol instead of formaldehyde because of formaldehyde itself, it contains a highly toxic and carcinogenic to human. This preserved *P. viridis* samples were used for stomach content analysis (more detail in **2.4**).

Table 2.4 Site, date and number of sample collection

Site	Sample size	Date of collection
Aceh	100	July 2016
Trang	100	December 2016
Suratthani	100	April 2017
Pattani:		
-Datok	868	June 2016 - May 2017
-Bana	869	June 2016 - May 2017
-Rusamilae	590	August 2016 - May 2017

2.3.2.2 Plankton Collection and Preservation

Plankton collection was done by using 60-µm phytoplankton net. The net was hauled at very low speed (< 0.75m/s or 1.5 knot), and pulled horizontally in the water column (Tranter and Fraser, 1968) for 1 minute (approximately 1,400 liters of seawater) with three replicates. Then, the concentrated plankton were kept in 50mL bottle and fill up with 5% formalin immediately to preserve samples.

2.4 Stomach Content Analysis

Prior to dissection, total lengths of preserved *P. viridis* obtained from **2.3.2.1**, (Figure 2.4a) were measured by Vernier caliper, and then opened mussel carefully by cutting the posterior adductor muscle (Figure 2.4b). The stomach content of *P. viridis* was extracted by using a glass Pasteur pipette trough a small slit in the stomach wall (Lehane and Davenport, 2002, 2006; Alvaro, 2006; Peharda *et al.,* 2012). Another method for collecting the stomach content is using a Syringe to drawn out the diet content from the stomach (Rouillon *et al.,* 2005; Lopez-Lima *et al.,* 2014) (Figure 2.4c). Extracted materials from stomach content were observed under microscope (Olympus CH30) with 4x and 40x magnification (Figure 2.4d). The number of plankton in the stomach content was counted by using Sedgwick-Rafter Cell counting (Lopez-Lima *et al.,* 2014; Soon and Ransangan, 2016).

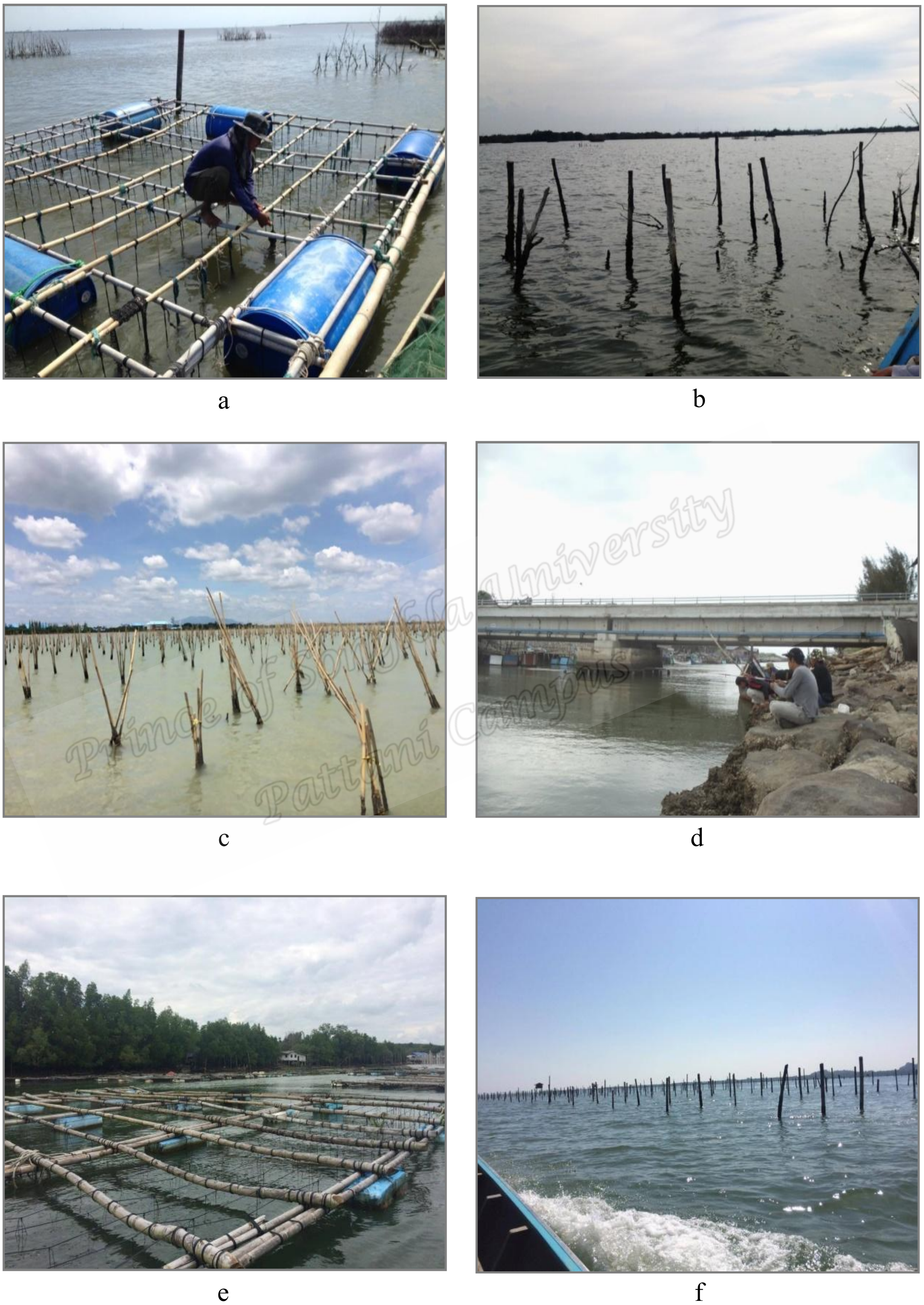


Figure 2.3 Sampling sites. Datok (a) Bana (b) Rusamilae (c) Aceh (d) Trang (e) Suratthani (f)

Table 2.5 Rain intensity in Pattani Province and others Southern Thailand

Year	Month	Monthly Rainfall (mm) in Pattani Province	Mean of monthly rainfall (mm) in Southern Thailand (East Coast)	Mean of monthly rainfall (mm) in Southern Thailand (West Coast)
	June	121.1	119.1	440.6
	July	162.4	139.5	412.6
	August	56.8	100.1	495.7
2016	September	42.9	93.8	540.4
	October	249.0	269.2	581.9
	November	224.5	162.8	226.7
	December	638.8	565.6	142.6
	January	597.9	646.1	276.9
	February	21.5	44.3	28.1
2017	March	51.1	84.9	133.4
	April	278.2	159.4	184.0
	May	126.8	178.3	447.4

Source: Thai Meteorological Department (2017)

2.5 Plankton Analysis

To identify and analyze plankton, 2 mL of the preserved sample from **2.3.2.2** was taken by glass pipette. This represents 5% of total sample in 50 mL bottle (Rouillon *et al.,* 2005; Lopez-Lima *et al.,* 2014). Counting, identifying and recording the plankton were done with the same procedure mentioned in the stomach content analysis of mussel (Lopez-Lima *et al.,* 2014; Soon and Ransangan, 2016). Afterwards, the total abundance of plankton was calculated by equation and the abundance of plankton was expressed as cell/L^{-1} (Verlencar and Desai, 2004). The formula is:

$$N = \frac{nXv}{V} X\ 1000$$

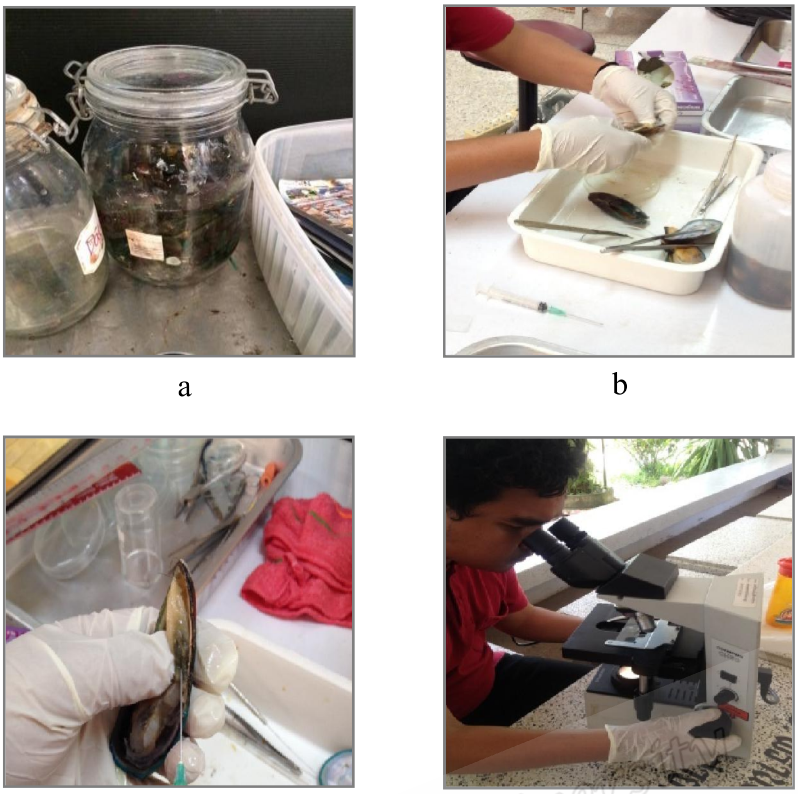
Where:

N = Total number of plankton cells per liter of water filtered

n= Average number of plankton cells in 1 mL of plankton sample

v = Volume of plankton concentrates (mL)

V = Volume of total water filtered (L)



a b c d

Figure 2.4 Stomach content analysis. Preserved samples (a) muscle cut (b) material extracted (c) diet observed (d)

2.6 Data and Statistical Analysis

Various data analysis techniques were applied to find out the ecological characteristic of the habitat and diet attributes such as food selectivity, diet breadth, and diet overlap of *P. viridis*. Specific parameters and corresponding analytical techniques are illustrated as follow:

2.6.1 Data Analysis on Diet of *P. viridis*

2.6.1.1 Diet Composition

Numerical method was applied to find the diet composition of stomach content of *P. viridis*. Thus, the value of food composition in the stomach was expressed as percentage composition (Hyslop, 1980). The formula of diet composition is :

$$P = \frac{\sum Ni}{\sum N} \, x \, 100$$

Where:

P = Numerical percentage

$\sum Ni$ = Total count of food category i

$\sum N$ = Total count of food in all categories

2.6.1.2 Ivlev's Selectivity Index

Ivlev's selectivity index is used for figure out the prey selection by predators (Jacobs 1974). In this case, it was used to compare the relative availability of food types in the environments and their relative food types in the diet of *P. viridis*. Based on Jacobs (1974), the Ivlev's selectivity index can be determined by equation:

$$E' = \frac{ri - pi}{ri + pi}$$

Where:

E' = Ivlev's selectivity index

ri = Relative abundance of prey item i in the gut content

pi = Relative abundance of the same prey item in the environment

According to Jacobs (1974), the value of Ivlev's selectivity index varies from -1 to +1. The implication of various ranges can be described as below:

1) $E' \leq 0$ = Rejection selectivity on prey
2) $E' = 0$ = Random selection on prey
3) $E' \geq 0$ = Active selection on prey

2.6.1.3 Levin's Standardized Index

Levin's standardized index or diet breadth index is used for foraging of proportion of diet of predator and number of food categories found in the stomach contents. It formulates the foragers selection with regards to the types and abundance of food they consume (Pulliam and Pyke, 2008)

Based on Labropoulou and Papadopoulou-Smith (1999), diet breadth is calculated by using Levin's standardized index. The formula for diet breadth index is:

$$Bi = \left(\frac{1}{n-1}\right)\left(\frac{1}{\sum_j P^2 ij} - 1\right)$$

Where:

Bi = Levin's standardized index for predator i

P_{ij} = Proportion of diet of predator i that is made up of food j

n = Number of food categories

Labropoulou and Papadopoulou-Smith (1999) concluded that the index of diet breadth was ranges from 0 to 1. The valuations are described as:

1) $0 > Bi \leq 0.5$ = Low values, indicating diets dominated by few prey items (specialist predators).
2) $0.5 > Bi \leq 1.0$ = Higher values, indicating generalist diets.

2.6.1.4 Diet Overlap

Diet overlap is used to calculate the proportional overlapping of food items in each stomach (Horn, 1996). Moreover, the calculation of this index is based on sum up the smaller values as the percentages of two species (Langton, 1982). For this study, diet overlap was constructed the diet overlap between the sizes of each class of *P. viridis.* The sizes of small classes (S) were <4 cm, mediums classes (M) were 4-7.9 cm and large classes (L) were >8 cm. The formula for calculation of diet overlap was taken from Morisita-Horn Index is:

$$\mathrm{CH} = \frac{2(\sum pijpik)}{\sum p2ij + \sum p2ik}$$

Where:

CH = Morisita-Horn Index of diet overlaps between two species of *i* and *k*

P_{ij} = Proportion of food *i* from the total food used by species *j*

P_{ik} = Proportion of food *i* from the total food used by species *k*

According to (Langton, 1982), the range of Morisita-Horn Index is range from 0-1, and it can be described as:

1) $0 > CH \leq 0.29$ = Low overlap
2) $0.29 > CH \leq 0.59$ = Moderate overlap
3) $0.59 > CH \leq 1.0$ = High overlap

2.6.2 Univariate and Multivariate Analyses

One-way ANOVA test was applied for testing differences in stomach content between different size, habitat and season based on total number of food count and total number of food item. The differences among the mean value were proved by Post Hoc Tukey test. Sex impact was tested by T-test. Prior to analyses, raw data was transformed by using square root transformation to reduce the skewness.

To examine the differences in plankton among mussels size classes, a cluster analysis with complete linkage was applied with Bray-Curtis similarity, prior the data were transformed by square root transformation (Rouillon *et al.,* 2005; Peharda *et al.,* 2012; Soon and Ransangan, 2016). These statistical test steps were performed by using PRIMER software package version 5.0 (Clarke, 1993; Clarke and Warwick, 2001). These statistical analyses are summarized base on research question and hypothesis of this study (Table 2.6).

Table 2.6 Research questions and statistical analyses of this experiment

Research questions	Hypothesis	Statistical analysis
1. Do sex, size, habitat and season affect on total number of food count and total number of food item of *P. viridis?*	These factors affect total number of food count and total number of food item of *P. viridis*	T-test and ANOVA (Post hoc Tukey HSD)
2. Do plankton abundance and environmental variables differ among habitats an seasons?	Plankton abundance and environmental variables vary among habitats and seasons	ANOVA (Post hoc Tukey HSD)
3. Do size classes affect on diet compositions of mussels, and how?	There is a difference foods composition among size classes of *P.viriris*	Cluster analysis ANOSIM SIMPER

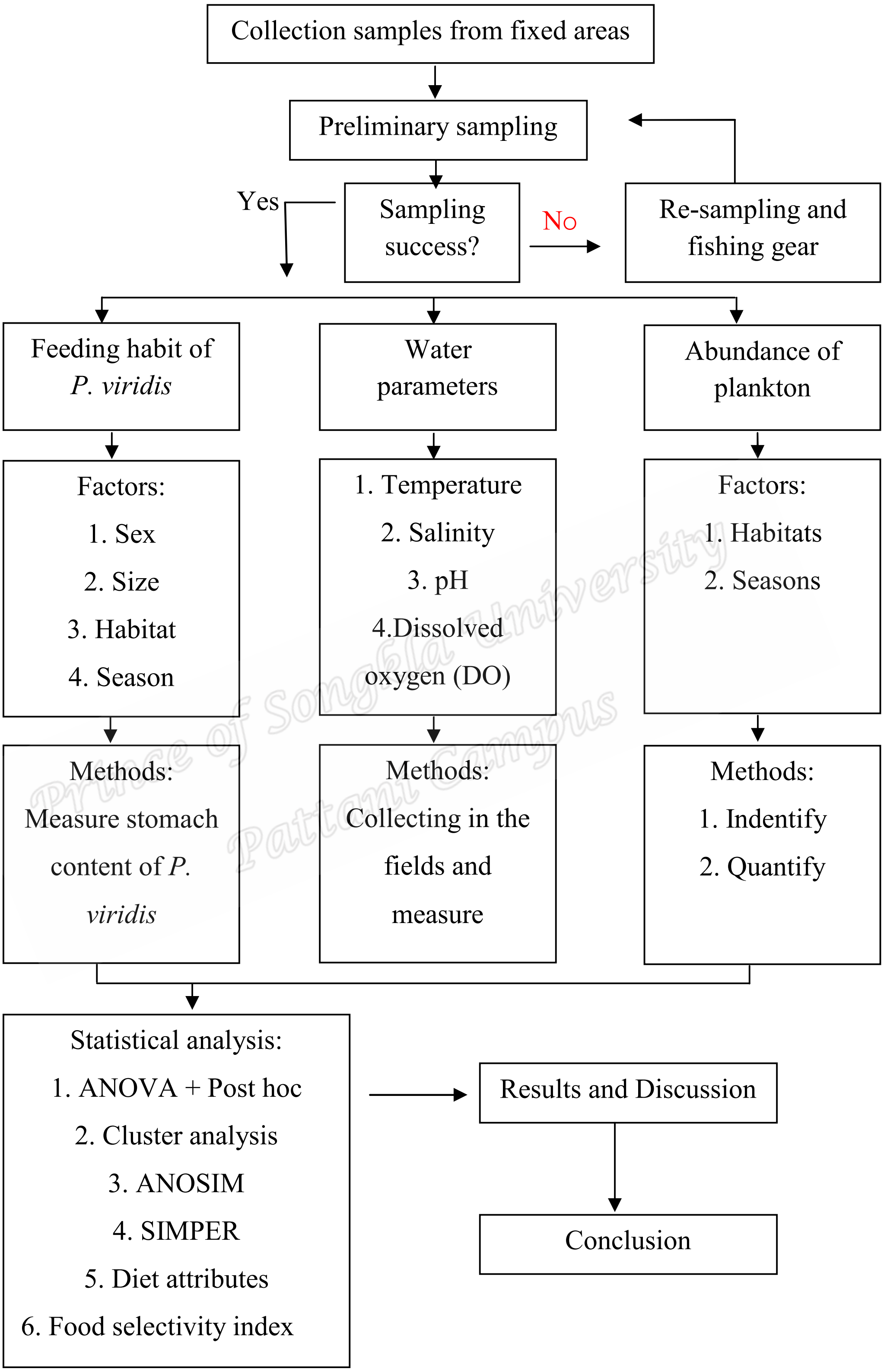


Figure 2.5 Diagram of the overall experimental of this study

CHAPTER III
RESULT

3.1 Environmental Variables of all Sampling Sites

Several environmental parameter measurements were conducted in all habitats prior to sampling of mussels. Summary of water parameters measured for all habitats are in Table 3.1. Results of monthly water parameters for an intensive study in Pattani bay habitat are in Table 3.2. For Pattani bay habitat, it was found that the highest temperature and pH (± Standard Deviation) were at Bana station in June 34.43±0.12°C and 7.87±0.06, respectively. The lowest temperature and pH occurred at Datok station in January (25.97±0.31°C.) and the lowest pH was in November (5.67±0.12). For salinity, the highest was at Rusamilae station in March 30.00±0.00 ppt and the lowest was at Bana station in January (4.33±0.58 ppt). Datok station had the highest DO (8.19±0.20 mg/L) in July and the lowest DO was at Datok station in December (3.84±0.16 mg/L).

Table 3.1 Summary of water parameters of all sampling sites

Habitat		Temperature (°C)	pH	Salinity (ppt)	DO (mg/L)
Aceh	Mean (±SD)	30.30±0.17	4.47±0.23	35.33±0.58	7.08±0.12
	Min.	30.20	4.2	35	6.95
	Max.	30.50	4.6	36	7.19
Trang	Mean (±SD)	29.40±0.10	5.67±0.15	4.00±1.00	5.22±0.04
	Min.	29.30	5.5	3	5.18
	Max.	29.50	5.8	5	5.26
Suratthani	Mean (±SD)	30.70±0.00	7.47±0.06	19.33±0.58	6.84±0.04
	Min.	30.70	7.4	19	6.79
	Max.	30.70	7.5	20	6.87
Pattani	Mean (±SD)	30.60±2.02	6.91±0.58	20.73±5.72	6.04±1.11
	Min.	25.70	5.6	4	3.72
	Max.	34.50	7.9	30	8.33

Table 3.2 Summary of water parameters in Pattani Bay

Month	Temperature			pH			Salinity			DO		
	Datok (±SD)	Bana (±SD)	Rusamilae (±SD)	Datok (±SD)	Bana (±SD)	Rusamilae (±SD)	Datok (±SD)	Bana (±SD)	Rusamilae (±SD)	Datok (±SD)	Bana (±SD)	Rusamilae (±SD)
June	33.17±0.21	34.43±0.12	n.s	7.57±0.25	7.87±0.06	n.s	20.33±0.58	21.33±1.53	n.s	6.84±0.33	7.15±0.10	n.s
July	32.30±0.26	33.20±0.26	n.s	7.50±0.26	7.73±0.21	n.s	20.67±0.58	22.33±1.15	n.s	8.19±0.20	7.40±0.44	n.s
August	32.07±0.31	33.33±0.21	n.s	7.20±0.26	6.43±0.29	n.s	21.67±0.58	19.67±1.15	n.s	7.23±0.26	7.99±0.25	n.s
September	31.77±0.35	31.63±0.15	29.23±0.35	5.90±0.30	6.17±0.35	7.10±0.30	22.33±0.58	25.00±0.00	24.33±0.58	5.51±0.18	6.10±0.04	6.96±0.15
October	29.50±0.44	30.03±0.21	30.00±0.17	6.87±0.06	6.83±0.15	7.13±0.15	24.67±0.58	20.33±0.58	24.67±0.58	6.00±0.17	5.96±0.09	5.74±0.15
November	29.37±0.80	31.87±0.06	29.13±0.21	5.67±0.12	5.83±0.21	6.00±0.10	15.33±0.58	18.33±0.58	24.67±0.58	3.93±0.04	5.12±0.06	5.63±0.08
December	28.17±0.06	29.47±0.21	27.83±0.06	6.57±0.15	6.50±0.10	6.93±0.23	7.33±0.15	16.67±0.58	21.33±0.58	3.84±0.16	5.35±0.06	5.21±0.03
January	25.97±0.31	27.30±0.00	28.00±0.10	7.57±0.12	6.90±0.10	6.83±0.25	5.33±0.58	4.33±0.58	19.67±0.58	5.21±0.25	7.31±0.10	5.34±0.10
February	28.93±0.06	29.27±0.06	29.80±0.10	6.73±.012	6.73±0.06	6.87±0.15	23.33±0.58	25.00±0.00	25.67±0.58	3.98±0.03	4.12±0.04	5.42±0.02
March	29.80±0.17	32.00±0.10	30.17±0.06	6.63±0.06	6.83±0.06	7.17±0.21	27.67±0.58	26.33±0.58	30.00±0.00	6.76±0.16	5.99±0.20	6.19±0.04
April	33.03±0.06	32.43±0.25	33.07±0.15	7.37±0.06	7.70±0.10	7.03±0.12	20.67±0.58	22.00±0.00	24.67±0.58	6.57±0.02	6.65±0.02	7.04±0.14
May	31.40±0.10	32.13±0.12	30.07±0.06	7.13±0.06	7.63±0.15	7.17±0.32	19.33±0.58	20.00±0.00	19.33±0.58	6.59±0.15	6.34±0.08	5.99±0.03
Mean(±SD)	30.46±2.19	31.43±2.03	29.70±1.52	6.89±0.62	6.93±0.66	6.91±0.36	19.06±6.66	20.11±5.72	23.81±3.30	5.89±1.41	6.29±1.09	5.95±0.67
-Min.	25.96	27.30	27.83	5.67	5.83	6.00	5.33	4.33	19.33	3.84	4.12	5.21
-Max.	33.16	34.43	33.07	7.57	7.87	7.17	27.67	26.33	30.00	8.19	7.99	7.04

n.s = non sampling

3.2 General Food for *P. viridis* from all Habitats

A total of 2,627 Asian green mussels (*Perna viridis*) were used for this study. It was found that, in general, *Coscinodiscus* (38.59%), green mussel larvae (22.19%), *Pleurosigma* (12.65%) and *Nitzschia* (4.29%) were the most dominant food items found in the stomachs of *P. viridis* (Figure 3.1 and 3.2). Dominant food items in different study sites were analyzed (Table 3.3). In Aceh, Indonesia, *Coscinodiscus* was by far the greater food in the stomach (62.1%), followed by green mussel larvae (9.06%) and *Nitzschia* (8.78%), respectively. For Trang province, *Coscinodiscus* was also the greatest food fed by *P. viridis* (29.02%), followed by green mussel larvae with almost equal ratio (26.96%), *Thalassionema* (8.15%) and *Nitzschia* (8.04%). In Suratthani, green mussel larvae were the greatest contributors as food for *P. viridis* (49.61%), followed by *Odontella* (11.59%), *Rhizosolenia* (7.73%) and *Skeletonema* (7.10%). In Pattani, *Coscinodiscus* was still the most dominant food items for *P. viridis* (37.91%), followed by a great domination of green mussel larvae (22.24%), *Pleurosigma* (13.7%) and *Chaetoceros* (4.31%).

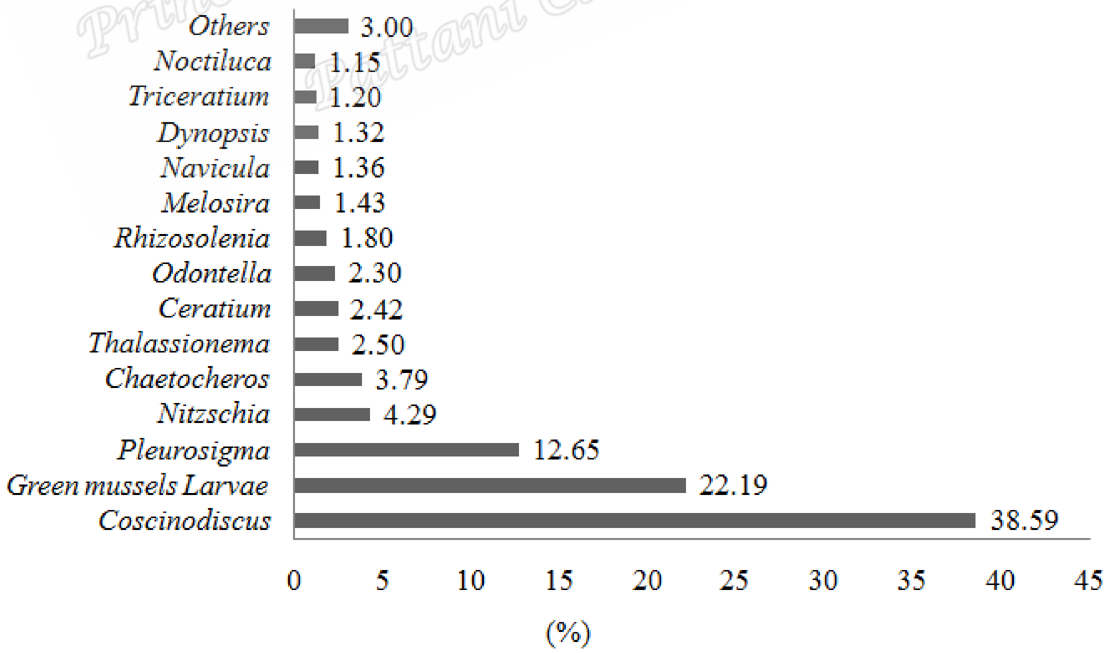


Figure 3.1 Most dominant food items found in the stomachs of *P. viridis* in all habitats

Table 3.3 Relative composition (%) of food found in the stomach of *P. viridis* of different habitats (N = number of mussels examined)

FOOD	Aceh N= 100	Trang N= 100	Suratthani N= 100	Pattani N= 2327	Overall N= 2627
PHYTOPLANKTON					
Ceratium	3.41	4.02	6.15	2.15	2.42
Chaetoceros	0.00	2.61	0.00	4.31	3.79
Coclhodinium	0.00	0.33	0.00	0.58	0.50
Coscinodiscus	**62.10**	**29.02**	**5.84**	**37.91**	**38.59**
Dynopsis	0.00	0.22	0.00	1.52	1.32
Eucampia	0.00	0.00	0.00	0.39	0.34
Gomyaulax	0.00	0.11	0.00	0.32	0.28
Guinardia	0.00	2.93	0.00	0.00	0.07
Gymnonidium	0.00	0.00	0.00	0.39	0.34
Melosira	3.18	0.11	0.00	1.36	1.43
Navicula	0.00	0.22	0.00	1.56	1.36
Nitzschia	8.78	8.04	0.00	3.94	4.29
Noctiluca	0.00	0.22	0.00	1.33	1.15
Odontella	0.00	2.61	11.59	2.16	2.30
Pleurosigma	**7.17**	**0.00**	**7.10**	**13.71**	**12.65**
Pseudo-nitzschia	0.00	3.59	0.00	0.00	0.08
Rhizosolenia	0.00	4.24	7.73	1.68	1.80
Skeletonema	0.00	0.00	7.10	0.00	0.23
Thalassionema	4.82	8.15	0.00	2.23	2.50
Thalassiosira	0.00	4.35	0.00	0.28	0.35
Triceratium	0.48	1.09	2.68	1.22	1.20
ZOOPLANKTON					
Ampipods	0.00	0.00	0.00	0.02	0.02
Barnacle larvae	0.00	0.33	0.71	0.13	0.15
Copepods	0.48	0.65	1.50	0.35	0.40
Green mussel larvae	**9.06**	**26.96**	**49.61**	**22.24**	**22.19**
Tintinnids	0.51	0.22	0.00	0.22	0.24

3.3 Diet Attributes

Based on study sites, the highest mean TA (total number of food count) value was in Aceh, the highest TI (total number of food item) value was in Suratthani and the greatest diet breadth index (*Bi*) was in Suratthani (0.28). Diet attributes for samples from Pattani was separately analyzed. Based on sizes, the highest TA (16.64±6.79) and TI (3.76±1.48) were both in the large mussel, but the largest *Bi* was in small size mussel (0.23). For sex, female mussel had the greater TA (16.76±7.34) and TI (3.94±1.53) compared to male but almost equal *Bi* was found between both sexes. Analysis based on study sites, mussels collected from Datok station had slightly greater TA (14.95±7.36) and TI (3.80±1.52) compared to other sites. Mussel from Rusamilae had the highest *Bi* (0.22) compared to other stations. For season, dry had the greatest TA (16.28±6.56) and TI (4.19±1.29) than other seasons, but the highest *Bi* was found in rainy season (0.19) (Table 3.4).

Table 3.4 Diet attributes of *P. viridis* (TA = total number of food count, TI = total number of food item, SD = standar deviation and *Bi* = diet breadth)

Source	Level	Sample Size	Total Amount	Mean TA (±SD)	Total Item	Mean TI (±SD)	*Bi*
All Sites	Aceh	100	3111	31.11±0.70	300	3.00±0.14	0.16
	Trang	100	920	9.20±0.70	379	3.79±0.14	0.23
	Suratthani	100	1268	12.68±0.70	395	3.95±0.14	0.28
	Pattani	2327	33717	14.48±0.14	8560	3.67±0.03	0.16
Pattani							
Sex	Male	1551	20708	13.35±6.82	5498	3.54±1.39	0.16
	Female	776	13009	16.76±7.34	3062	3.94±1.53	0.15
Size	Small	130	1081	8.31±3.31	414	3.18±1.28	0.23
	Medium	1857	26978	14.52±7.17	6866	3.69±1.45	0.15
	Large	340	5658	16.64±6.79	1280	3.76±1.48	0.17
Habitat	Datok	868	12980	14.95±7.36	3302	3.80±1.52	0.14
	Bana	869	12627	14.53±6.99	3139	3.61±1.45	0.15
	Rusamilae	590	8110	13.74±7.11	2119	3.59±1.32	0.22
Season	Moderate	706	11222	15.89±7.73	2521	3.57±1.61	0.15
	Rainy	782	8832	11.29±6.15	2519	3.22±1.28	0.19
	Dry	839	13663	16.28±6.56	3520	4.19±1.29	0.17

3.3.1 Food for *P. viridis* of Different Sexes from all Habitats

Dominant food items in different sexes were analyzed (Table 3.5). *Coscinodiscus* was the greatest food in the stomach of male mussel compared to other food (39.00%), followed by green mussel larvae (20.11%) and *Pleurosigma* (13.16%). For female, *Coscinodiscus* was also the greatest contributor as food for *P. viridis* (37.92%), followed by green mussel larvae (25.62%) and *Pleurosigma* (11.82%).

Table 3.5 Relative composition (%) of food found in the stomachs of *P. viridis* of different sex from all habitats (N = number of mussels examined)

FOOD	Male N= 1753	Female N= 874	Overall N= 2627
PHYTOPLANKTON			
Ceratium	2.52	2.26	2.42
Chaetoceros	4.10	3.27	3.79
Coclhodinium	0.56	0.42	0.50
Coscinodiscus	**39.00**	**37.92**	**38.59**
Dynopsis	1.33	1.31	1.32
Eucampia	0.35	0.33	0.34
Gomyaulax	0.32	0.21	0.28
Guinardia	0.09	0.03	0.07
Gymnonidium	0.30	0.39	0.34
Melosira	1.54	1.25	1.43
Navicula	1.47	1.17	1.36
Nitzschia	4.63	3.74	4.29
Noctiluca	1.11	1.22	1.15
Odontella	2.35	2.24	2.30
Pleurosigma	**13.16**	**11.82**	**12.65**
Pseudo-nitzschia	0.08	0.09	0.08
Rhizosolenia	1.83	1.76	1.80
Skeletonema	0.24	0.22	0.23
Thalassionema	2.65	2.27	2.50
Thalassiosira	0.39	0.27	0.35
Triceratium	1.28	1.08	1.20
ZOOPLANKTON			
Ampipods	0.02	0.02	0.02
Barnacle larvae	0.08	0.25	0.15
Copepods	0.29	0.60	0.40
Green mussel larvae	**20.11**	**25.62**	**22.19**
Tintinnids	0.23	0.24	0.24

3.3.2 Food for *P. viridis* of Different Size Classes from all Habitats

Dominant food items of different size classes of mussels from all sampling sites were analyzed (Table 3.6). For small size class, *Coscinodiscus* was the greatest food in the stomach than other food (39.41%), followed by green mussel larvae (14.15%) and *Pleurosigma* (12.58%), respectively. For the medium size, *Coscinodiscus* was the greatest food fed by *P. viridis* (37.61%), followed by green mussel larvae (22.79%) and *Pleurosigma* (12.49%). For large size, *Coscinodiscus* had a close ratio with small and medium size (39.49%), followed by green mussel larvae (22.5%) and *Pleurosigma* (13.60%).

Table 3.6 Relative composition (%) of food found in the stomachs of *P. viridis* of different size classes from all habitats (N = number of mussels examined)

FOOD	Small (<4 cm)	Medium (4-7.9 cm)	Large (8-11.9 cm)	Extra Large (>12 cm)	Overall
	N= 130	N= 2065	N= 409	N= 23	N= 2627
PHYTOPLANKTON					
Ceratium	1.67	2.56	2.08	1.56	2.42
Chaetoceros	3.98	4.29	2.26	0.00	3.79
Coclhodinium	2.50	0.55	0.09	0.00	0.50
Coscinodiscus	**39.41**	**37.61**	**39.49**	**65.63**	**38.59**
Dynopsis	3.52	1.26	1.37	0.00	1.32
Eucampia	0.46	0.27	0.64	0.00	0.34
Gomyaulax	0.65	0.32	0.09	0.00	0.28
Guinardia	0.00	0.09	0.00	0.00	0.07
Gymnonidium	1.20	0.32	0.32	0.00	0.34
Melosira	1.67	1.21	1.94	4.17	1.43
Navicula	3.24	1.61	0.28	0.00	1.36
Nitzschia	7.03	4.01	4.84	5.86	4.29
Noctiluca	2.59	1.32	0.42	0.00	1.15
Odontella	1.30	2.59	1.59	0.00	2.30
Pleurosigma	**12.58**	**12.49**	**13.60**	**9.11**	**12.65**
Pseudo-nitzschia	0.00	0.11	0.00	0.00	0.08
Rhizosolenia	0.00	1.53	3.26	0.00	1.80
Skeletonema	0.00	0.31	0.00	0.00	0.23
Thalassionema	2.87	2.44	2.68	2.73	2.50
Thalassiosira	0.00	0.28	0.68	0.00	0.35
Triceratium	1.02	1.32	0.87	0.26	1.20
ZOOPLANKTON					
Ampipods	0.00	0.01	0.05	0.00	0.02
Barnacle larvae	0.00	0.15	0.17	0.00	0.15
Copepods	0.19	0.34	0.64	0.65	0.40
Green mussel larvae	**14.15**	**22.79**	**22.35**	**9.11**	**22.19**
Tintinnids	0.00	0.22	0.26	0.91	0.24

Only 23 mussels collected were considered extra-large size (>12 cm). It showed that large domination of *Coscinodiscus* found in the stomach of *P. viridis* of this size class (65.63%), followed by green mussel larvae and *Pleurosigma* (both were 9.11%) and *Nitzschia* (5.86%).

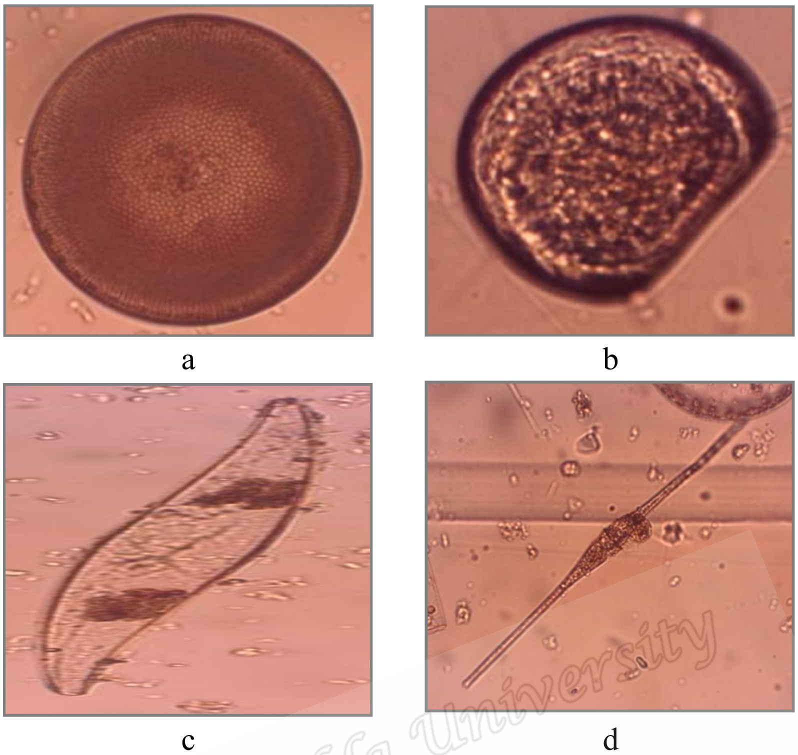


Figure 3.2 Most of food found in stomach of *P. viridis*.
Coscinodiscus (a) mussel larvae (b) *Pleurosigma* (c) *Nitzschia (d)*

3.3.3 Impacts of Sexes on Feeding of *P. viridis* from Pattani Bay

Dominant food items in different sexes were analyzed (Table 3.7). For the male, *Coscinodiscus* was the greatest contributor compared to other food (37.71%), followed by green mussel larvae (20.30%) and *Pleurosigma* (14.36%), respectively. For the female, *Coscinodiscus* was still the greatest food (38.23%), followed by green mussel larvae (25.34%) and *Pleurosigma* (12.68%).

T-test was performed to test significant difference in total number of food count and total number of food item found in the stomach of *P.viridis* based on the impact of sexes (Figure 3.3). It was found that the sex of mussel had highly significant impacts on both total number of food count and total number of food item in the stomachs of *P.viridis* examined ($p<0.01$).

The mean values with standard deviation (±SD) of total number of food count and total number of food item for male and female of *P.viridis* were 3.53±0.93, 3.98±0.94 and 1.84±0.38, 1.94±0.39, respectively.

Table 3.7 Relative composition (%) of food found in the stomachs of *P. viridis* of different sex from Pattani Bay habitat (N = number of mussels examined)

FOOD	Male N= 1551	Female N= 776	Overall N= 2327
PHYTOPLANKTON			
Ceratium	2.19	2.08	2.15
Chaetoceros	4.70	3.70	4.31
Coclhodinium	0.64	0.47	0.58
Coscinodiscus	**37.71**	**38.23**	**37.91**
Dynopsis	1.55	1.48	1.52
Eucampia	0.41	0.37	0.39
Gomyaulax	0.37	0.24	0.32
Gymnonidium	0.36	0.44	0.39
Melosira	1.41	1.26	1.36
Navicula	1.71	1.32	1.56
Nitzschia	4.39	3.22	3.94
Noctiluca	1.30	1.37	1.33
Odontella	2.26	1.99	2.16
Pleurosigma	**14.36**	**12.68**	**13.71**
Rhizosolenia	1.81	1.48	1.68
Thalassionema	2.33	2.07	2.23
Thalassiosira	0.32	0.22	0.28
Triceratium	1.30	1.09	1.22
ZOOPLANKTON			
Ampipods	0.02	0.02	0.02
Barnacle larvae	0.09	0.21	0.13
Copepods	0.24	0.53	0.35
Green mussel larvae	**20.30**	**25.34**	**22.24**
Tintinnids	0.22	0.22	0.22

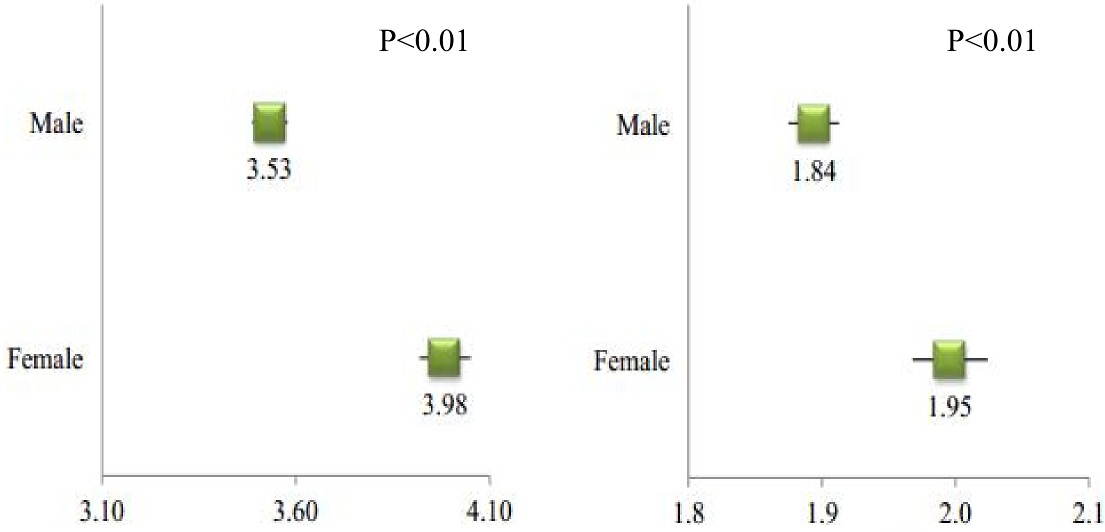


Figure 3.3 Total number of food count (left) and total number of food item (right) on impact of sex. Y axis is *P. viridis* sexes, X is total number of food.

3.3.4 Impacts of Size on Feeding of *P. viridis* from Pattani Bay

In general, it was found that *Coscinodiscus* (37.91%), green mussel larvae (22.24%), *Pleurosigma* (13.71%) and *Chaetoceros* (4.31%) were the most dominant food items found in the stomachs of *P. viridis* (Table 3.8). However, there was no extra-large *P.viridis* found in Pattani bay habitat. Dominant food items in different sizes in Pattani site were analyzed. For small size classes, *Coscinodiscus* was the greater food in the stomach than other food (39.41%), followed by green mussel larvae (14.15%) and *Pleurosigma* (12.58%), respectively. For the medium size, *Coscinodiscus* was the greatest food fed by *P. viridis* (39.27%), followed by green mussel larvae (21.45%) and *Pleurosigma* (13.24%). For large size, still *Coscinodiscus* was the greatest food (31.18%), followed by green mussel larvae as second most contributors (27.57%) and *Pleurosigma* (16.15%).

A One-way ANOVA was performed to test a significant difference of total number of food count and total number of food item found in the stomachs of *P. viridis* (Figure 3.4). It was found that sizes of *P. viridis* had highly significant impacts on both total number of food count of food and total number of food item in the stomachs of *P. viridis* examined (P<0.01). The mean values with standard deviation (±SD) of total number of food count and total number of food items for small, medium and large sizes of mussel were 2.82±0.57, 3.68±0.96, 3.98±0.88, and 1.74±0.36, 1.88±0.38, 1.90±0.39, respectively.

Analysis on diet overlap between different size classes of *P. viridis* based on Morisita-Horn index of overlap found that all three pairs of analyses indicated significant overlaps among them with the values of >6.0 (Table 3.9).

Table 3.8 Relative composition (%) of food found in the stomachs of *P. viridis* of different size from Pattani Bay habitat (N = number of mussels examined)

FOOD	S (<4 cm) N= 130	M (4-7.9 cm) N= 1857	L (8-11.9 cm) N= 340	Overall N= 2327
PHYTOPLANKTON				
Ceratium	1.67	2.32	1.40	2.15
Chaetoceros	3.98	4.58	3.11	4.31
Coclhodinium	2.50	0.59	0.12	0.58
Coscinodiscus	**39.41**	**39.27**	**31.18**	**37.91**
Dynopsis	3.52	1.36	1.89	1.52
Eucampia	0.46	0.29	0.88	0.39
Gomyaulax	0.65	0.34	0.12	0.32
Gymnonidium	1.20	0.34	0.44	0.39
Melosira	1.67	1.30	1.54	1.36
Navicula	3.24	1.74	0.39	1.56
Nitzschia	7.03	3.99	3.09	3.94
Noctiluca	2.59	1.43	0.58	1.33
Odontella	1.30	2.19	2.19	2.16
Pleurosigma	**12.58**	**13.24**	**16.15**	**13.71**
Pseudo-nitzschia	0.00	0.00	0.00	0.00
Rhizosolenia	0.00	1.16	4.49	1.68
Thalassionema	2.87	2.33	1.64	2.23
Thalassiosira	0.00	0.16	0.94	0.28
Triceratium	1.02	1.28	0.99	1.22
ZOOPLANKTON				
Ampipods	0.00	0.01	0.07	0.02
Barnacle larvae	0.00	0.12	0.23	0.13
Copepods	0.19	0.28	0.71	0.35
Green mussel larvae	**14.15**	**21.45**	**27.57**	**22.24**
Tintinnids	0.00	0.22	0.27	0.22

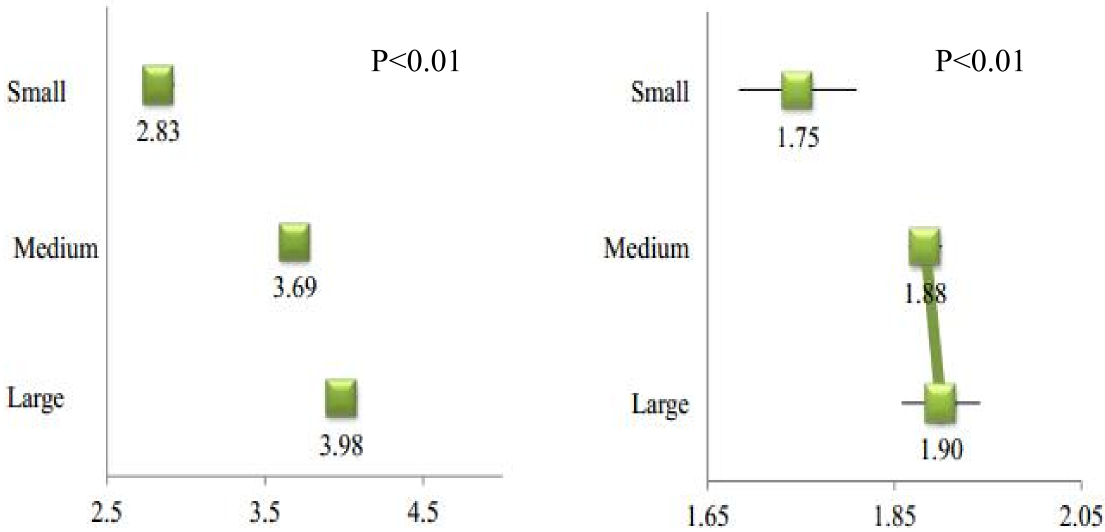


Figure 3.4 Total number of food count (left) and total number of food item (right) on impact of size. Y axis = *P. viridis* sizes, X = total number of food. Connected line = no significant different between pairwise

Table 3.9 Results of Morisita-Horn index on size classes overlap in Pattani Bay

Size	Small	Medium	Large
Small	-	0.98	0.92
Medium	0.98	-	0.97
Large	0.92	0.97	-

3.3.5 Impacts of Habitat on Feeding of *P. viridis* from Pattani Bay

2,327 Asian green mussels (*Perna viridis*) were found in Pattani Bay. It was found that, in overall, *Coscinodiscus* (37.91%), green mussel larvae (22.24%), *Pleurosigma* (13.71%) and *Chaetoceros* (4.31%) were the most dominant food items found in the stomachs of *P. viridis* (Figure 3.5). Dominant food items in different study sites were summarized (Table 3.10). In Datok station, *Coscinodiscus* was the greater food in the stomach than other food (42.19%), followed by green mussel larvae (21.03%) and *Pleurosigma* (11.02%), respectively. A closely similar percentage of *Coscinodiscus* was also found in Bana station (42.40%), followed by green mussel larvae (22.12%) and *Pleurosigma* (10.92%). For Rusamilae station, green mussel larvae were the greatest contributors as food for *P. viridis* (24.36%), followed by *Coscinodiscus* with an almost equal ratio (24.08%) and *Pleurosigma* (22.37%).

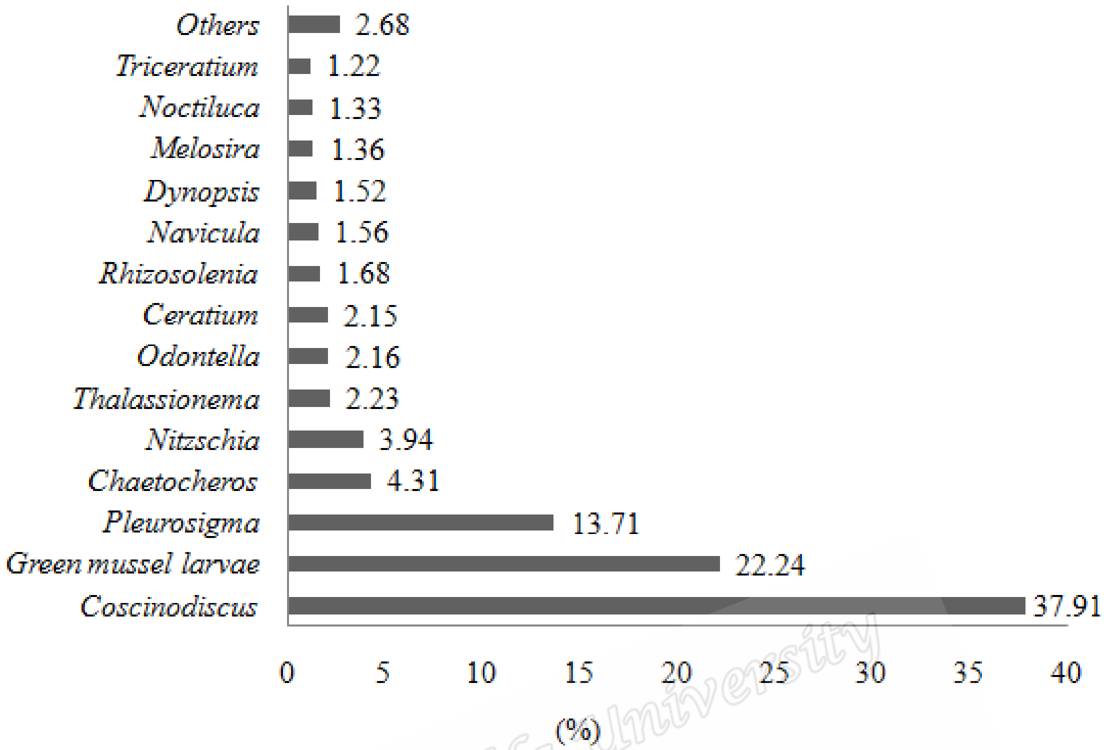


Figure 3.5 Most dominant food items found in the stomachs of *P. viridis* in Pattani Bay

One-way ANOVA was applied to test significant difference of total number of food count and total number of food item found in the stomach of *P. viridis* (Figure 3.6).

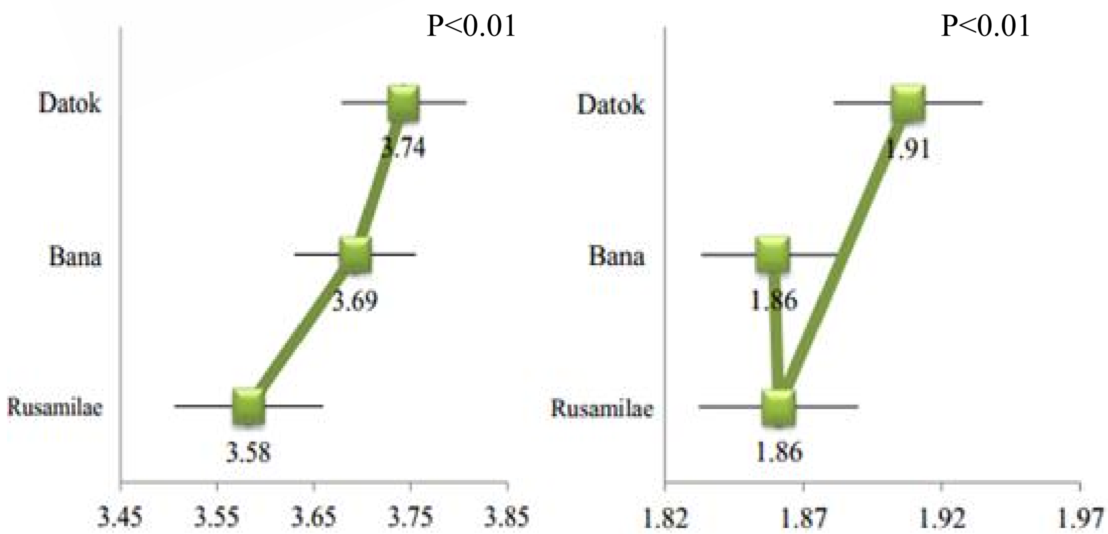


Figure 3.6 Total number of food count (left) and total number of food item (right) on impact of habitats. Y axis = habitat of *P. viridis*, X = total number of food. Connected line = no significant different between pairwise

It was found that the habitat of *P. viridis* collected had a significant impact on total number of food count (P<0.01) and highly significant impact on the total number of food item in the stomachs of mussel examined (P<0.01). The mean values with standard deviation (±SD) of total number of food count and total number of food item for Datok, Bana, and Rusamilae were 3.74±0.97, 3.69±0.94, 3.58±0.95 and 1.90±0.40, 1.85±0.39, 1.86±0.35, respectively.

Table 3.10 Relative composition (%) of food found in the stomachs of *P. viridis* of different stations in Pattani Bay habitat (N = number of mussels examined)

FOOD	Datok N= 868	Bana N= 869	Rusamilae N= 590	Overall N= 2327
PHYTOPLANKTON				
Ceratium	1.56	1.86	3.54	2.15
Chaetoceros	4.06	4.87	3.85	4.31
Coclhodinium	0.93	0.58	0.00	0.58
Coscinodiscus	**42.19**	**42.40**	**24.08**	**37.91**
Dynopsis	1.92	1.48	0.95	1.52
Eucampia	0.06	0.22	1.20	0.39
Gomyaulax	0.29	0.50	0.07	0.32
Gymnonidium	0.61	0.37	0.06	0.39
Melosira	1.72	1.62	0.37	1.36
Navicula	0.66	3.27	0.35	1.56
Nitzschia	5.05	3.03	3.58	3.94
Noctiluca	1.50	1.52	0.74	1.33
Odontella	2.94	1.65	1.71	2.16
Pleurosigma	**11.02**	**10.92**	**22.37**	**13.71**
Pseudo-nitzschia	0.00	0.00	0.00	0.00
Rhizosolenia	1.34	0.00	4.83	1.68
Thalassionema	1.52	1.85	3.97	2.23
Thalassiosira	0.00	0.00	1.17	0.28
Triceratium	1.09	1.04	1.71	1.22
ZOOPLANKTON				
Ampipods	0.01	0.02	0.05	0.02
Barnacle larvae	0.06	0.17	0.20	0.13
Copepods	0.28	0.32	0.51	0.35
Green mussel larvae	**21.03**	**22.12**	**24.36**	**22.24**
Tintinnids	0.18	0.19	0.33	0.22

3.3.6 Impacts of Seasons on Feeding of *P. viridis* from Pattani Bay

Dominant food items in different seasons were analyzed (Table 3.11). In moderate season, *Coscinodiscus* was the greatest food in the stomach of *P. viridis* (42.84%), followed by green mussel larvae (18%) and *Pleurosigma* (15.27%). During rainy season, *Coscinodiscus* was also the greatest food fed by *P. viridis* (31.05%), followed by green mussel larvae (22.16%) and *Pleurosigma* (21.03%). In dry season, food was still dominated by *Coscinodiscus* (38.30%), followed by green mussel larvae (25.78%) and *Pleurosigma* (7.70%). However, it was observed that the trend of domination of these three food items were different between seasons.

A One-way ANOVA was also applied to test the significant difference of total number of food count and total number of food item found in the stomach of *P. viridis* based on season impact (Figure 3.7). It was found that the season of mussel collected had highly significant impacts on both total number of food count and total number of food item in the stomachs of *P. viridis* examined ($P<0.01$). The mean values with standard deviation (±SD) of total number of food count and total number of food item for moderate, rainy, and dry seasons of *P. viridis* collected were 3.86±0.99, 3.23±0.90, 3.95±0.82, and 1.83±0.43, 1.75±0.36, 2.02±0.32, respectively.

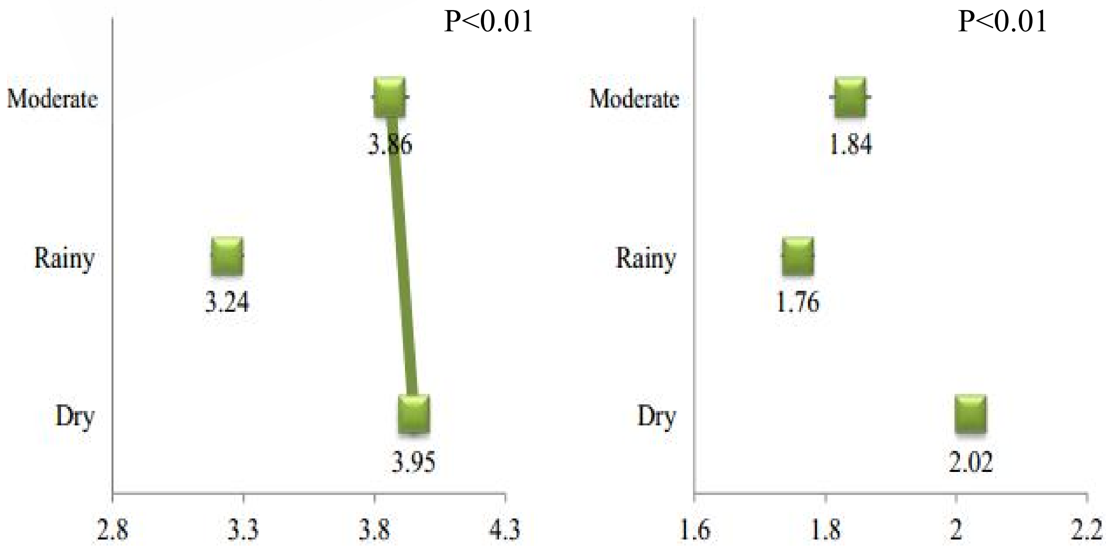


Figure 3.7 Total number of food count (left) and total number of food item (right) on impact of seasons. Y axis = season in Pattani , X = total number of food. Connected line = no significant different between pairwise

Table 3.11 Relative composition (%) of food found in the stomachs of *P. viridis* collected during different season in Pattani bay habitat (N = number of mussels examined)

FOOD	Moderate N= 706	Rainy N= 782	Dry N= 839	Overall N= 2327
PHYTOPLANKTON				
Ceratium	1.09	2.65	2.69	2.15
Chaetoceros	5.03	4.21	3.79	4.31
Coclhodinium	1.65	0.10	0.00	0.58
Coscinodiscus	**42.84**	**31.05**	**38.30**	**37.91**
Dynopsis	2.24	2.20	0.50	1.52
Eucampia	0.25	0.02	0.75	0.39
Gomyaulax	0.53	0.07	0.31	0.32
Gymnonidium	0.87	0.37	0.00	0.39
Melosira	1.10	1.82	1.26	1.36
Navicula	2.60	0.36	1.49	1.56
Nitzschia	4.22	3.02	4.30	3.94
Noctiluca	2.10	0.46	1.24	1.33
Odontella	0.43	3.62	2.63	2.16
Pleurosigma	**15.27**	**21.03**	**7.70**	**13.71**
Rhizosolenia	0.00	0.80	3.62	1.68
Thalassionema	0.61	3.79	2.55	2.23
Thalassiosira	0.00	0.00	0.70	0.28
Triceratium	0.53	1.37	1.69	1.22
ZOOPLANKTON				
Ampipods	0.01	0.03	0.03	0.02
Barnacle larvae	0.10	0.15	0.15	0.13
Copepods	0.25	0.41	0.40	0.35
Green mussel larvae	**18.00**	**22.16**	**25.78**	**22.24**
Tintinnids	0.28	0.29	0.12	0.22

3.4 Relative Abundance (%) of Plankton for all Habitats

Relative abundance of phytoplankton and zooplankton collected from all habitats together with *P. viridis* collection are shown in Table 3.12. It was found that different study sites had different composition and abundance of plankton. In Aceh, *Coscinodiscus* (23.3%) dominated the composition of plankton, followed by *Ceratium* (13.3%), Copepods, green mussel larvae and Tintinnids (10% each). In Trang, the contribution of plankton was equal at 11.8% for *Ceratium, Coscinodiscus, Psuedo-*

Nizshia, Rhizosolina, Thalassiosira and Copepods. Copepods, green mussel larvae and *Odotella* were the greatest contributors from Suratthani with 30, 20 and 10%, respectively.

Table 3.12 Relative abundance (%) of plankton found in water column from all habitats

FOOD	Habitats				
	Aceh	Trang	Suratthani	Pattani	Overall
PHYTOPLANKTON					
Asterionella	0.00	0.00	0.00	0.20	0.18
Bacteriastrum	0.00	5.88	0.00	0.00	0.18
Bidullphia	0.00	0.00	0.00	0.10	0.09
Campylodiscus	0.00	0.00	0.00	0.20	0.18
Ceratium	13.33	11.76	5.00	3.05	3.89
Chaetoceros	0.00	5.88	0.00	5.51	5.13
Coscinodiscus	**23.33**	**11.76**	**5.00**	**16.34**	**16.37**
Dynopsis	0.00	0.00	0.00	2.26	2.04
Eucampia	0.00	0.00	0.00	0.59	0.53
Gomyaulax	0.00	0.00	0.00	0.10	0.09
Lauderia	0.00	0.00	0.00	0.10	0.09
Lyngbya	0.00	0.00	0.00	0.20	0.18
Melosira	6.67	0.00	0.00	4.72	4.60
Navicula	0.00	0.00	0.00	3.74	3.36
Nitzschia	6.67	0.00	0.00	4.92	4.78
Noctiluca	0.00	0.00	0.00	2.66	2.39
Obelia	0.00	0.00	0.00	0.30	0.27
Odontella	0.00	5.88	10.00	2.56	2.65
Pleurosigma	**10.00**	**0.00**	**5.00**	**10.43**	**10.00**
Pseudo-nitzschia	0.00	11.76	0.00	0.00	0.35
Rhizosolenia	0.00	11.76	5.00	1.28	1.59
Skeletonema	0.00	0.00	5.00	0.00	0.09
Thalassionema	10.00	5.88	0.00	4.13	4.42
Thalassiosira	0.00	11.76	0.00	1.57	1.77
Triceratium	0.00	0.00	0.00	1.97	1.77
ZOOPLANKTON					
Amphipods	0.00	0.00	0.00	1.97	1.77
Barnacle larvae	0.00	0.00	10.00	4.13	3.89
Copepods	**10.00**	**11.76**	**30.00**	**13.88**	**13.89**
Green mussel larvae	10.00	0.00	20.00	8.07	8.14
Tintinnids	10.00	5.88	5.00	5.02	5.31

3.5 Density of Plankton Collected from all Habitats

Density of plankton in all habitats was measured together with *P. viridis* collection, which was 1,071,429 cell/L^{-1} from Aceh habitat, 309,524 cell/L^{-1} from Suratthani habitat and 190,476 cell/L^{-1} from Trang habitat.

For Pattani Bay, plankton samples were collected monthly from three different stations including Datok, Bana and Rusamilae (Table 3.13). In Datok, the highest plankton density was in September (482,143 cell/L^{-1}) and the lowest was in December (125,000 cell/L^{-1}). In Bana, both November and December demonstrated the highest plankton density (619,048 cell/L^{-1}), the lowest was in January (142,857 cell/L^{-1}). For Rusamilae station, the highest density was in March (428,571 cell/L^{-1}), while the lowest was found in October (220,238 cell/L^{-1}).

Table 3.13 Density of plankton collected from three stations in Pattani Bay

Months	Density (cell/L^{-1})		
	Datok	Bana	Rusamilae
June 2016	339,286	255,952	n.s
July 2016	166,667	226,190	n.s
August 2016	184,524	250,000	n.s
September 2016	482,143	214,286	339,286
October2016	309,524	380,952	220,238
November 2016	428,571	619,048	309,524
December 2016	125,000	619,048	309,524
January 2017	130,952	142,857	303,571
February 2017	398,810	339,286	303,571
March 2017	410,714	446,429	428,571
April 2017	369,048	315,476	321,429
May 2017	428,571	303,571	267,857

n.s =no sampling

3.6 Relative Abundance (%) of Plankton in Pattani Bay

Overall, it was found that *Coscinodiscus* (16.34%), Copepods (13.88%), *Pleurosigma* (10.43%) and green mussel larvae (8.07%) were the most abundant planktons found in the Pattani Bay (Table 3.14). However, different composition and abundance are observed in different study sites.

In Datok station, *Coscinodiscus* was the greatest contributor (18.05%), followed by Copepods (13.47%) and *Pleurosigma* (8.31%).

For Bana station, *Coscinodiscus* was also the highest contributor (18.75%), followed by Copepods (13.22%) and *Pleurosigma* (10.10%). In Rusamilae station, Copepods became the most dominant plankton (15.54%), followed by *Pleurosigma* (13.94%) and *Coscinodiscus* (9.96%).

Table 3.14 Relative abundance of plankton (%) found in three different stations from Pattani Bay

FOOD	Stations			
	Datok	Bana	Rusamilae	Overall
PHYTOPLANKTON				
Asterionella	0.00	0.00	0.80	0.20
Bidullphia	0.00	0.00	0.40	0.10
Campylodiscus	0.29	0.24	0.00	0.20
Ceratium	3.44	2.88	2.79	3.05
Chaetoceros	5.44	4.81	6.77	5.51
Coscinodiscus	**18.05**	**18.75**	**9.96**	**16.34**
Dynopsis	1.43	4.33	0.00	2.26
Eucampia	0.00	0.00	2.39	0.59
Gomyaulax	0.00	0.24	0.00	0.10
Lauderia	0.00	0.24	0.00	0.10
Lyngbya	0.29	0.00	0.40	0.20
Melosira	7.16	3.85	2.79	4.72
Navicula	3.72	6.01	0.00	3.74
Nitzschia	7.16	2.88	5.18	4.92
Noctiluca	2.87	3.13	1.59	2.66
Obelia	0.86	0.00	0.00	0.30
Odontella	2.29	1.68	4.38	2.56
Pleurosigma	**8.31**	**10.10**	**13.94**	**10.43**
Rhizosolenia	0.29	0.48	3.98	1.28
Thalassionema	4.01	2.64	6.77	4.13
Thalassiosira	0.00	0.00	6.37	1.57
Triceratium	0.57	1.68	4.38	1.97
ZOOLANKTON				
Amphipods	3.44	1.44	0.80	1.97
Barnacle larvae	4.01	5.53	1.99	4.13
Copepods	**13.47**	**13.22**	**15.54**	**13.88**
Green mussel larvae	7.74	9.86	5.58	8.07
Tintinnids	5.16	6.01	3.19	5.02

3.7 Food Selectivity of *P. viridis* from all Habitats

The valuation of selectivity index made by *P. viridis* from different habitats were analyzed and reported in Table 3.15. In Aceh, the top most prey selected by *P. viridis* were *Triceratium* (+1), followed by *Coscinodiscus* (+0.4) and *Nitzschia* (+0.1). Green mussel larvae were considered randomly selected (0), while others were actively rejected by *P. viridis* (<0). In Trang habitat, several prey items were highly selected by *P. viridis* with the value of +1, such as *Dynopsis*, *Eucampia*, *Gomyaulax* and *Guinardia.* Copepods and Tintinnids had the lowest values (-0.9) indicating less favorable for *P. viridis*. In Suratthani habitat, *Triceratium* had the value of +1, followed by green mussel larvae (+0.4), and *Pleurosigma, Rhizosolenia* and *Skeletonema* (+0.2). Planktons with the lowest selectivity index value were Barnacle larvae (-0.9), Copepods (-0.9), and Tintinnids (-1.0). For Pattani habitat, *Gymnonidium* had the highest value, followed by *Gomyaulax* and green mussel larvae (+0.5) and *Coscinodiscus* (+0.4). *Asterionella, Bidullphia, Campylodiscus,* and Copepods had negative values of selectivity index.

3.8 Food Selectivity of *P. viridis* from Pattani Bay

Results of food selectivity index for *P. viridis* collected from different stations in Pattani Bay are in Table 3.16. In Datok station, food with highest value of selection (+1.0) included *Coclhodinium, Eucampia, Gomyaulax* and *Gymnonidium*. Food completely rejected by *P. viridis* included *Campylodiscus, Lyngbia, Obelia*, amphipods, Barnacle larvae and Copepods (-1). Most of the food indicated somewhat selected by *P. viridis* with different favorable of selection. In Bana, *Coclhodinium, Eucampia, Gymnonidium* had the highest value of prey selection. However, the lowest values, -1 indicating completely rejected, were found for *Campylodiscus, Lauderia* and *Rhizosolenia.* In Rusamilae station, several preys such as *Dynopsis, Gomyaulax* and *Gymnonidium* had the value of +1.0 indicating highly required by *P. viridis*. Several planktons such as *Asterionella*, *Bidullphia* and *Lyngbya* were completely rejected with the index value of -1.0.

Table 3.15 Values of Ivlev's food selectivity index of *P. viridis* collected from different habitats

FOOD	Habitats			
	Aceh	Trang	Suratthani	Pattani
PHYTOPLANKTON	-	-	-	-
Asterionella	-	-	-	-1
Bactriastrum	-	-1	-	-
Bidullphia	-	-	-	-1
Campylodiscus	-	-	-	-1
Ceratium	-0.6	-0.5	0.1	-0.2
Chaetoceros	-	-0.4	-	-0.1
Coclhodinium	-	1	-	1
Coscinodiscus	**0.5**	**0.4**	**0.1**	**0.4**
Dynopsis	-	1	-	-0.2
Eucampia	-	1	-	-0.2
Gomyaulax	-	1	-	0.5
Guinardia	-	1	-	-
Gymnonidium	-	-	-	1
Lauderia	-	-	-	-1
Lyngbya	-	-	-	-1
Melosira	-0.4	1	-	-0.6
Navicula	-	1	-	-0.4
Nitzschia	0.1	1	-	-0.1
Noctiluca	-	1	-	-0.3
Obelia	-	-	-	-1
Odontella	-	-0.4	0.1	-0.1
Pleurosigma	-0.2	-	0.2	0.1
Pseudo-nitzschia	-	-0.5	-	-
Rhizosolenia	-	-0.5	0.2	0.1
Skeletonema	-	-	0.2	-
Thalassionema	-0.3	0.2	-	-0.3
Thalassiosira	-	-0.5	-	-0.7
Triceratium	1	1	1	-0.2
ZOOPLANKTON				
Amphipods	-	-	-	-1.0
Barnacle larvae	-	1	-0.9	-0.9
Copepods	-0.9	-0.9	-0.9	-1.0
Green mussel larvae	**0.0**	**1**	**0.4**	**0.5**
Tintinnids	-0.9	-0.9	-1	-0.9

Table 3.16 Values of Ivlev's food selectivity index of *P. viridis* collected from three different stations in Pattani Bay

FOOD	Stations			
	Datok	Bana	Rusamilae	Overall
PHYTOPLANKTON				
Asterionella	-	-	-1	-1
Bidullphia	-	-	-1	-1
Campylodiscus	-1	-1	-	-1
Ceratium	-0.4	-0.2	0.1	-0.2
Chaetoceros	-0.1	0.0	-0.3	-0.1
Coclhodinium	1	1	-	1
Coscinodiscus	**0.4**	**0.4**	**0.4**	**0.4**
Dynopsis	0.1	-0.5	1	-0.2
Eucampia	1	1	-0.3	-0.2
Gomyaulax	1	0.3	1	0.5
Gymnonidium	1	1	1	1
Lauderia	-	-1	-	-1
Lyngbya	-1	-	-1	-1
Melosira	-0.6	-0.4	-0.8	-0.6
Navicula	-0.7	-0.3	1	-0.4
Nitzschia	-0.2	0.0	-0.2	-0.1
Noctiluca	-0.3	-0.3	-0.4	-0.3
Obelia	-1	-	-	-1
Odontella	0.1	0.0	-0.4	-0.1
Pleurosigma	**0.1**	**0.0**	**0.2**	**0.1**
Rhizosolenia	0.6	-1	0.1	0.1
Thalassionema	-0.5	-0.2	-0.3	-0.3
Thalassiosira	-	-	-0.7	-0.7
Triceratium	0.3	-0.2	-0.4	-0.2
ZOOPLANKTON				
Amphipods	-1.0	-1.0	-0.9	-1.0
Barnacle larvae	-1.0	-0.9	-0.8	-0.9
Copepods	-1.0	-1.0	-0.9	-1.0
Green mussel larvae	**0.5**	**0.4**	**0.6**	**0.5**
Tintinnids	-0.9	-0.9	-0.8	-0.9

3.9 Result of Multivariate Analysis

Multivariate analysis was conducted to test the impact of sizes on food composition in stomachs of *P. viridis* examined from Pattani Bay habitat. Dendogram of cluster analysis (Figure 3.8) clearly separated *P. viridis* based on food composition of two different groups.

Group 1 consisted of dietary samples of *P. viridis* from medium (s2) and large size (s3). Group 2 comprised of small size of *P. viridis* (s1). It was observed that the Group 1 was clearly formed two sub-clusters with different size classes formed different sub-clusters (s2 and s3). Results from analysis of similarity (ANOSIM) indicated significant difference between Group 1 and Group 2 (Global R = 0.884, P value = 0.001).

Results from similarity percentage (SIMPER) indicated that *Coscinodiscus* (19.06%), green mussel larvae (15.78%), *Pleurosigma* (12.13%) and *Chaetoceros* (5.86%) were the greatest contributors to the formation of group 1. For Group 2, almost similar contribution of plankton especially the three main items compared to Group 1 was observed. *Coscinodiscus*, (24.89%), green mussel larvae (13.24%), *Pleurosigma* (12.91%) and *Nitzschia* (9.82%) were the main food contributed to the formation of this group (Table 3.17).

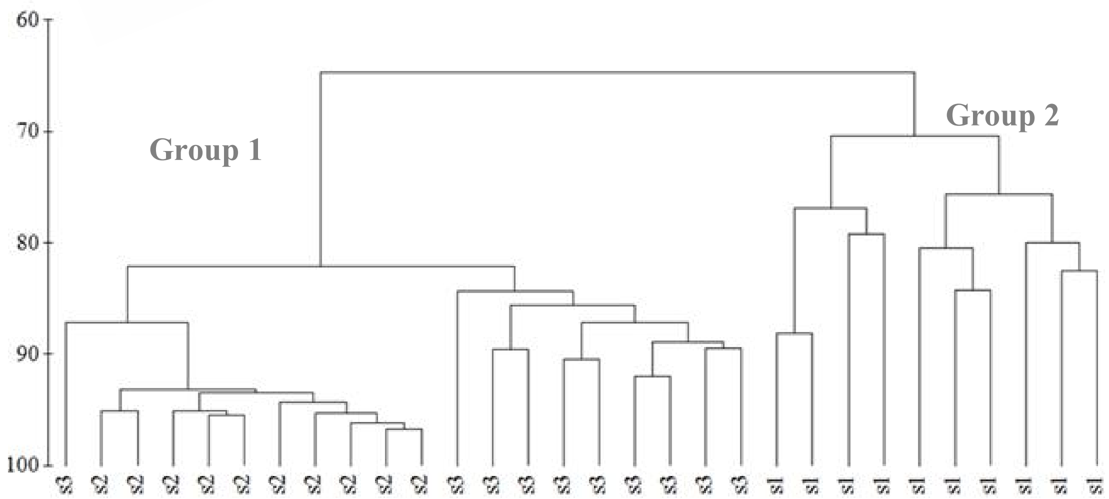


Figure 3.8 Dendogram of cluster analysis for food composition of *P. viridis* of different size classes collected from Pattani Bay. Y axis = Bray-Curtis similarity index, X = size classes (s1= small size, s2= medium size and s3= large size)

Table 3.17 Summary of SIMPER result of the impact on different size on food composition in *P. viridis*

Size	Food types	Percentage contribution
Group 1 (s2 and s3)	*Coscinodiscus*	19.06
	Green mussel larvae	15.78
	Pleurosigma	12.13
	Chaetoceros	5.86
	Nitzschia	5.73
	Odontella	4.46
	Rhizosolenia	4.28
	Thalassionema	3.99
	Ceratium	3.84
	Dynopsis	3.78
	Melosira	3.56
	Triceratium	3.13
	Noctiluca	2.74
	Navicula	2.03
Group 2 (s1)	*Coscinodiscus*	24.89
	Green mussel larvae	13.24
	Pleurosigma	12.91
	Nitzschia	9.82
	Dynopsis	6.52
	Chaetoceros	6.13
	Thalassionema	4.47
	Ceratium	3.84
	Coclhodinium	3.58
	Navicula	3.28
	Noctiluca	2.88

CHAPTER IV
DISCUSSION

4.1 General Discussion

Bivalves are known as a filter suspension feeder, which feed on high biotic particles from the strained material from water column and prefer to reject the inorganic particles (Jorgensen, 1996). This study confirms that Asian green mussel (*P. viridis*) is a planktivorous feeder fed on various types of food items including both phytoplankton and zooplankton. In general, the most dominant food items in term of number of food found in the stomachs were *Coscinodiscus*, green mussel larvae, *Pleurosigma* and *Nitzschia*. It is clear that phytoplankton is a major food source for *P. viridis* in this study. This domination of phytoplankton as main food for *P. viridis* was reported by various scientists (Villalejo-Fuerte *et al.*, 2005; Rouillon, *et al.,* 2005; Muñetón-Gómez *et al.,* 2010; Soon and Ransangan, 2016). However, an observation of having green mussel larvae as the second largest food contributor after *Coscinodiscus* for *P. viridis* from this study has never been reported anywhere before. Moreover, it was also found from this study that in Suratthani habitat green mussel larvae were the greatest food found in *P. viridis* sample, which is considered the first report ever that filter feeder animal like *P. viridis* feeding mainly on zooplankton. This fact is probably due to an availability of green mussel larvae in that particular study area serving as main food for *P. viridis* living in that area.

Perna viridis selects this food based on availability of its food supply (Wong and Cheung, 2001; Rouillon, *et al.,* 2005; Alvaro, 2006; Muñetón-Gómez *et al.,* 2010). Such feeding habit is considered a response of *P. viridis* to the 'optimum foraging theory' in which the cost/benefit ratio in catching prey is considered (Labropoulou and Papadopoulou-Smith, 1999). Mussels will choose food with the highest benefit to them such as green mussel larvae instead of injecting other food. As Suratthani habitat is known as the largest *P. viridis* and other mussels framing in Thailand, their large amount of larvae produced are later on served as major food source for *P. viridis* in this area. Apart from Suratthani habitat, *P. viridis* samples from Trang habitat also indicated a great contribution for *P. viridis* food. This is relevant with the significant numbers of *P. viridis* farms in this area. Somehow, Aceh habitat was not considered as *P. viridis* farms, it was a wild habitat for *P. viridis*.

For Pattani Bay habitat, relative contribution of green mussel larvae is smaller compared to the previous two habitats, but the number is still significant. This is again coincident with only very small *P. viridis* farm is in Pattani Bay now. In Aceh, contribution of *Coscinodiscus* was by far greater than others and the role of green mussel larvae was not significant. This is probably due to an absence of *P. viridis* farm in this habitat and only natural mussels are present which is in small density. Therefore, the density of green mussel larvae is very rare compared to others leading to small contribution of green mussel larvae in stomachs of *P. viridis* samples collected from Aceh habitat. This is supported by Wong and Cheung (2001) and Davenport *et al.* (2011), who mentioned that food richness in any habitat is caused by food type and food ingested number. Feeding mechanism that ensuring a number of foods found in the stomach of *P. viridis* could be related to sex and size of its *P. viridis* (Alvaro, 2006; Ashraful *et al.,* 2009; Davenport *et al.,* 2011). The size of cell shape of plankton affected on type of food and the number of food-ingested animals (Troost *et al.,* 2009; Frau *et al.,* 2016). This study also investigated the impacts of size, sex, habitat and season on feeding habits of green m *P. viridis* ussels in Pattani bay habitat.

4.2 Impact of Sexes

This study found that female mussels fed more food both in terms of total number of food count and total number of food item in the stomachs (Figure 3.3 and Appendix 1 and 2). This result is different from the work reported by Ashraful *et al.* (2009) who indicated that male of *P. viridis* fed more phytoplankton and zooplankton than female (total of 27.5% and 25%, respectively). It is also observed from this study that female mussel had bigger size than male (means ±SD of 6.75±1.77 cm and 6.03±139 cm, respectively). Thus, two assumptions can be drawn from this finding. Firstly, female mussel requires more food due to reproduction requirement where huge number food intake is required to have energy for releasing ovary into the water and recover the energy loss after spawning (Lopez-Lima *et al.,* 2014). Secondly, size of mussel plays a big role in food intake where the larger the size the more food intake as the female mussel can reach up to 10 cm within a month (Power *et al.,* 2004).

4.3 Impact of Sizes

Result from one-way ANOVA test reveals that total number of food count and total number of food item differed significantly among the sizes of *P. viridis* ($P<0.01$) (Figure 3.4 and Appendix 4). This study found that *P. viridis* feeds mostly on the same suit of prey, which is *Coscinodiscus*. They relative contribution of *Coscinodiscus* between three different size classes was slightly different which were 39.41% for small size class, 39.27% for medium size class and reducing to 31.18% for large size class. This means that the larger the size the lesser contribution of *Coscinodiscus* in the stomach of *P. viridis.*

Cluster analysis clearly separated size classes of *P. viridis* into two main clusters to confirm dietary shift in mussels of different sizes (Figure 3.8). However, the large and medium sizes are grouped together in this analysis although they showed a distinct separation with each other but with a very low similarity value. SIMPER analysis in this study identified foods responsible for such grouping of the mussels. *Coscinodiscus* (19.06%), green mussel larvae (15.78%)*, Pleurosigma* (12.13%) and *Chaetoceros* (5.86%) were the greatest contributors to the formation of the first group. For the second group, *Coscinodiscus* (24.89%), green mussel larvae (13.24%), *Pleurosigma* (12.91%) and *Nitzschia* (9.82%) were the main food (Table 3.17). It is observed that the three main food items for *P. viridis* of these two groups are similar but different only in term of percentage contribution. The difference is found in the fourth most important food item where they feed differently. Dolmer, (2000), Alvaro (2006) and Davenport *et al*. (2011) also documented the impact of size class on food of mussels.

There are several factors being able to justify this finding. Soon and Ransangan (2014) reported that larger mussels feed more due to the requirement of food for gonad development and reproduction. In this case, Rajagopal *et al.* (2006) stated that the reproduction or spawning time of *P. viridis* occurred since a medium size (4-7.9 cm). Alvaro (2006) described such phenomenon that the larger mussel had faster food clearance rate compared to the smaller mussel. Davenport *et al.* (2011)

stated that food capture or processing structure of larger mussels creating the easier catch on prey. Additionally, Galimany *et al.* (2011) pointed out that energy for ingesting food by mussels was dependent on size. The larger mussel had more energy intake than the smaller size.

4.4 Impact of Habitats

This study indicated that different study sites or habitats, in Pattani bay, significantly affected total number of food count and total number of food item. As the mean values of total count of food numbers for Datok, Bana, and Rusamilae are 3.74±0.97, 3.69±0.94 and 3.58±0.95, respectively (Figure 3.6 and Appendix 7). It seems that *P. viridis* residing in Datok which is the innermost site in the bay for this study, consumes more food than the outer part of the bay like Bana and Rusamilae. Total number of food item also is confirmed by this assumption, where Datok having the highest value compared to outer habitats. However, some researchers (Rouillon, *et al*., 2005; Alvaro, 2006; Galimany *et al*., 2011; Peharda *et al*., 2012) have reported impacts of habitats on food of mussels. According to this phenomenon, it is postulated that Datok site may have more abundant and diverse plankton for *P. viridis* to select compared to others as indicated by collection of plankton in this study. This is coincident with the statement made by Rajagopal *et al.* (2006) and Davenport *et al.* (2011) that mussels that are living in poor food source and unfavorable conditions may affect a number of food ingestion.

Moreover, the different of food particle among habitat may cause the difference in quality and quantity of food source (Alvaro, 2006). The more abundance of plankton in Datok station is due probably it settles inside a semi-enclosed bay compared to more open habitats in Bana and Datok as Rouillon *et al.* (2005) stated that the estuarine area, closer to the shore had more abundant of phytoplankton compare to open shore area.

Another reason to explain site difference is water depth. It was reported that mussels living a few meters difference of depth show different total of food number in the stomach (Davenport *et al.,* 2011). Datok and Bana stations were located inside the bay, where the average of depth was between 0.2-1.5 meters, while Rusamilae was in the outer bay or open shore with the depth of 5 meters (Hajisamae and Yeesin, 2014).

4.5 Impact of Seasons

This study found that food of *P. viridis* differed significantly between seasons ($P<0.01$). The mean values of total number of food count and total number of food item for moderate, rainy, and dry seasons of *P. viridis* collected were 3.86±0.99, 3.23±0.90, 3.95±0.82, and 1.83±0.43, 1.75±0.36, 2.02±0.32, respectively (Figure 3.7 and Appendix 10). Although total number of food count and total number of food item were different between seasons, dominant food items for each season was slightly similar with some difference in percentage contribution. *Coscinodiscus* was the greatest food in the stomach of *P. viridis* during moderate season (42.84%), followed by green mussel larvae (18%) and *Pleurosigma* (15.27%). The food composition is also slightly similar in rainy season when *Coscinodiscus* was also the greatest food fed by *P. viridis* (31.05%), followed by green mussel larvae (22.16%) and *Pleurosigma* (21.03%). Again in dry season, food was still dominated by *Coscinodiscus* (38.30%), followed by green mussel larvae (25.78%) and *Pleurosigma* (7.70%). However, it was observed that the trend of domination of these three food items were different between seasons. This result is corresponding together with others researchers (Peharda *et al.,* 2012; Lopez-Lima *et al.,* 2014). Several reasons to explain these circumstances could be related to seasonal changes (Lopez-Lima *et al.,* 2014). The difference of seasonal pattern may contribute to different food found in the stomach, where in dry season, *P. viridis* consumed more food compared to other seasons due dry season is confirmed as favorable conditions and healthy water environmental (Rajagopal *et al.,* 2006).

In general, data of water parameter in this study showed that environmental variables during dry season were slightly better than other seasons. This is coincident with the conclusion made by Adugna and Wondie (2016) that dry season raised the highest food source presented in water column. Moreover, a suitable environmental condition was stated as the feasibility of *P. viridis* farming (Lovatelli, 1998; Soon and Ransangan, 2016). Low salinity certainly has a significant impact on feeding rates of *P. viridis* (Wong and Cheung, 2001). Results from this study also showed that mussel fed less food in rainy season. It is suggested that the *P. viridis* preferred saline water and will be uncomfortable during rainy season leading to less food consumption. In

Pattani bay, salinity dropped from 20-25 ppt to 4 ppt due to the higher emersion of inflow water from Pattani and Yaring Rivers. This may cause the low density of phytoplankton in the area (Drake *et al.,* 2010; Sharma *et al.,* 2016). Results from this study also indicated that total abundance of plankton in water column were lower during the rainy season.

4.6 Feeding Selectivity of *P. viridis*

Perna viridis is well known as opportunistic mussel, which selected on specific food for attaining metabolic and reproductive system (Bayne *et al.,* 1993; Soon and Ransangan, 2016). Generally, *P. viridis* actively selected on *Coscinodiscus* and green mussel larvae and rejected on several plankton groups such as *Melosira* and *Noctiluca* (Table 3.15 and 3.16). Actively selected on *Coscinodiscus* and green mussel larvae are reflected the existence and the abundance of this plankton found in the water column (Rouillon *et al.,* 2005; Villalejo-Fuerte *et al.,* 2005; Muñetón-Gómez *et al.,* 2010). Especially in Suratthani, a large *P. viridis* farming area, the abundance of green mussel larvae was an evident of selected this food by *P. viridis*.

During spawning season, *P. viridis* could select on green mussel larvae as primary food in great quantities (Alvaro, 2006). Furthermore, *Coscinodiscus* contains more lipid, carbohydrate and protein compared to other foods that is highly required by *P. viridis* for gonad development (Bayne *et al.,* 1993; Al-Barwani *et al.,* 2012). Lopez-Lima *et al.* (2014) mentioned that ingestion on proper foods was pointed out to energy demand, where *P. viridis* needs them to establish the increased energy with gametogenesis process. Actively rejected on *Melosira*, *Noctiluca* and others zooplanktons e.g Amphipods and Copepods are reflected to different population. Where those two kinds of phytoplankton were abundance in deep water (Rouillon, *et al.,* 2005; Muñetón-Gómez *et al.,* 2010), meanwhile the prey's size zooplankton may affected on rejected prey (Lehane and Davenport, 2006; Troost *et al.,* 2009; Frau *et al.,* 2016). Another assumption is that rejected on prey could relate with chemical characters of plankton cells such as discharge metabolite (Cognie *et al.,* 2001). In another point, zooplankton had an escape ability to avoid from *P. viridis* ingested (Troost *et al.,* 2009; Molina *et al.,* 2010). Our suggestion is that *P. viridis* prefers to consume phytoplankton as the first producer of the aquatic animal food chain.

CHAPTER V
CONCLUSION AND SUGGESTION

5.1 Conclusion

Based on objectives and results of the present study, some conclusion are made as follows:

1. *Perna viridis* is omnivorous, feeding on a wide range of phytoplankton and zooplankton
2. *Coscinodiscus* was the major food item (38.59%), followed by green mussel larvae (22.19%) and *Pleurosigma* (12.65%)
3. Sex, size, habitat and season affected both on total count and total item of food fed by *P. viridis*
4. *P. viridis* demonstrated specific food selection based on availability of food resources in the habitats they reside
5. This finding helps in understanding how *P. viridis* feeds and selects food in nature

5.2 Suggestion

Based on this research, some suggestions for future management and study are provided. Firstly, Pattani Bay was a major *P. viridis* cultured area in the past and contributed largely to local economy, considering of having *P. viridis* farm back by a proper management will be another tool to optimize the utilization of the bay. This is due to this study found that the green mussel larvae are the main food source of *P. viridis* and also for other aqutic animals. It is woth to consider the role of *P. viridis* farming as a complex ecosystem for other animals as they their larvae is very important in food web. Secondly, reaserch in details for *P. viridis* feeding habits by utlizing the methods of lipid biomaker, stable isotope and histological sections analyses are very important to discover in depth scientific information about this aspect.

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APPENDIX

Appendix for summary T-test analysis on impact of sexes based on total number of food count (TA) and total number of food item (TI) in Pattani Bay

Appendix 1 Summary of T-test on impact of sexes based on total number of food count (TA) and total number of food item (TI) in Pattani Bay

Sexes	Sample	Mean	SE	St.Dev
Total number of food count				
-Male	1551	3.53	0.02	0.93
-Female	776	3.98	0.03	0.94
Total number of food item	Sample	Mean	SE	St.Dev
-Male	1551	1.84	0.01	0.38
-Female	776	1.95	0.01	0.39

Appendix 2 Result of T-test on impact of sexes based on total number of food count (TA) and total number of food item (TI) in Pattani Bay

Source	df	Tstat	T critical	*P value*
Sexes				
-Total number of food count	2325	-10.97	1.96	**<0.01**
-Total number of food item	2325	-5.99	1.96	**<0.01**

Appendix for summary of data Analysis of Variance (ANOVA) and Tukey Highly Significant Different (HSD) on impact of sizes in Pattani Bay based on total number of food count (TA) and total number of food item (TI)

Appendix 3 Summary of ANOVA test on impact of sizes based on total number of food count (TA) and total number of food item (TI) in Pattani Bay

Sizes	Sample	Mean	SE	St.Dev
Total number of food count				
-Small	130	2.82	0.08	0.57
-Medium	1857	3.68	0.02	0.96
-Large	340	3.98	0.05	0.88
Total number of food item	Sample	Mean	SE	St.Dev
-Small	130	1.74	0.03	0.36
-Medium	1857	1.88	0.00	0.38
-Large	340	1.90	0.02	0.39

Appendix 4 Result of One-Way ANOVA test on impact of sizes based on total number of food count (TA) and total number of food item (TI) in Pattani Bay

Source	df	MS	F	*P value*
Sizes				
-Total number of food count	2	134.051	203.17	**<0.01**
-Total number of food item	2	2.500	18.52	**<0.01**

Appendix 5 Results of Tukey HSD pairwise test among sizes based on total number of food count (TA) and total number of food item (TI) in Pattani Bay

Pair wise	*P value*		
Total number of food count	Small	Medium	Large
-Small	-	**<0.01**	**<0.01**
-Medium	**<0.01**	-	**<0.01**
-Large	**<0.01**	**<0.01**	-
Total number of food item	Small	Medium	Large
-Small	-	**<0.01**	**<0.01**
-Medium	**<0.01**	-	0.7
-Large	**<0.01**	>0.7	-

Appendix for summary of data Analysis of Variance (ANOVA) and Tukey Highly Significant Different (HSD) on impact of habitats in Pattani Bay based on total number of food count (TA) and total number of food item (TI)

Appendix 6. Summary of ANOVA test on impact of habitats based on total number of food count (TA) and total number of food item (TI) in Pattani Bay

Habitats	Sample	Mean	SE	St.Dev
Total number of food count				
-Datok	868	3.74	0.03	0.97
-Bana	869	3.69	0.03	0.94
-Rusamilae	590	3.58	0.03	0.95
Total number of food item	Sample	Mean	SE	St.Dev
-Datok	868	1.90	0.01	0.40
-Bana	869	1.85	0.01	0.39
-Rusamilae	590	1.86	0.01	0.35

Appendix 7. Result of One-Way ANOVA test on impact of habitats based on total number of food count (TA) and total number of food item (TI) in Pattani Bay

Source	df	MS	F	*P value*
Habitats				
-Total number of food count	2	2.914	4.42	**<0.01**
-Total number of food item	2	0.726	5.38	**<0.01**

Appendix 8 Results of Tukey HSD pairwise test among habitats based on total number of food count (TA) and total number of food item (TI) in Pattani Bay

Pair wise	*P value*		
Total number of food count	Datok	Bana	Rusamilae
-Datok	**-**	0.4	**<0.01**
-Bana	0.4	**-**	**<0.05**
-Rusamilae	**<0.01**	**<0.05**	**-**
Total number of food item	Datok	Bana	Rusamilae
-Datok	**-**	**<0.05**	**<0.05**
-Bana	**<0.05**	**-**	0.9
-Rusamilae	**<0.05**	0.9	**-**

Appendix for summary of data Analysis of Variance (ANOVA) and Tukey Highly Significant Different (HSD) on impact of seasons in Pattani Bay based on total number of food count (TA) and total number of food item (TI)

Appendix 9. Summary of ANOVA test on impact of seasons based on total number of food count (TA) and total number of food item (TI) in Pattani Bay

Seasons	Sample	Mean	SE	St.Dev
Total number of food count				
Moderate	706	3.86	0.03	0.99
Rainy	782	3.23	0.03	0.90
Dry	839	3.95	0.03	0.82
Total number of food item	Sample	Mean	SE	St.Dev
Moderate	706	1.83	0.01	0.43
Rainy	782	1.75	0.01	0.36
Dry	839	2.02	0.01	0.32

Appendix 10. Result of One-Way ANOVA test on impact of seasons based on total number of food count (TA) and total number of food item (TI) in Pattani Bay

Source	df	MS	F	*P value*
Seasons				
-Total number of food count	2	191.066	289.58	**<0.01**
-Total number of food item	2	16.222	120.18	**<0.01**

Appendix 11 Results of Tukey HSD pairwise test among seasons based on total number of food count (TA) and total number of food item (TI) in Pattani Bay

Pair wise	*P value*		
Total number of food count	Moderate	Rainy	Dry
Moderate	-	**<0.01**	0.07
Rainy	**<0.01**	-	**<0.01**
Dry	0.07	**<0.01**	-
Total number of food item	Moderate	Rainy	Dry
Moderate	-	**<0.01**	**<0.01**
Rainy	**<0.01**	-	**<0.01**
Dry	**<0.01**	**<0.01**	-

Appendix of raw data of food/prey found in stomach of *P. viridis* and water column from additional sampling sites for Ivlev's selectivity index analysis

Appendix 12 Percentage (%) of raw data of food/prey found in stomach of *P. viridis* and water column from Aceh habitat for Ivlev's selectivity index analysis

Food/Prey	Stomach (%)	Water column (%)
Ceratium	3.41	13.33
Copepods	0.48	10.00
Coscinodiscus	62.10	23.33
Melosira	3.18	6.67
Green mussel larvae	9.06	10.00
Nitzschia	8.78	6.67
Pleurosigma	7.17	10.00
Thalassionema	4.82	10.00
Tintinnids	0.51	10.00
Triceratium	0.48	0.00

Appendix 13 Percentage (%) of raw data of food/prey found in stomach of *P. viridis* and water column from Trang habitat for Ivlev's selectivity index analysis

Food/Prey	Stomach (%)	Water Column (%)
Bactriastrum	0.00	5.88
Barnacle larvae	0.33	0.00
Ceratium	4.02	11.76
Chaetoceros	2.61	5.88
Coclhodinium	0.33	0.00
Copepods	0.65	11.76
Coscinodiscus	29.02	11.76
Dynopsis	0.22	0.00
Gomyaulax	0.11	0.00
Guinardia	2.93	0.00
Melosira	0.11	0.00
Green mussel larvae	26.96	0.00
Navicula	0.22	0.00
Nitzschia	8.04	0.00
Noctiluca	0.22	0.00
Odontella	2.61	5.88
Pseudo-nitzschia	3.59	11.76
Rhizosolenia	4.24	11.76
Thalassionema	8.15	5.88
Thalassiosira	4.35	11.76
Tintinnids	0.22	5.88
Triceratium	1.09	0.00

Appendix 14 Percentage (%) of raw data of food/prey found in stomach of *P. viridis* and water column from Suratthani habitat for Ivlev's selectivity index analysis

Food/Prey	Stomach (%)	Water Column (%)
Barnacle larvae	0.71	10
Ceratium	6.15	5
Copepods	1.50	30
Coscinodiscus	5.84	5
Green mussel larvae	49.61	20
Odontella	11.59	10
Pleurosigma	7.10	5
Rhizosolenia	7.73	5
Skeletonema	7.10	5
Tintinnids	0.00	5
Triceratium	2.68	0

Appendix of raw data of food/prey found in stomach of *P. viridis* and water column from Pattani Bay for Ivlev's selectivity index analysis

Appendix 15 Percentage (%) of raw data of food/prey found in stomach of *P. viridis* and water column from Datok habitat for Ivlev's selectivity index analysis

Food/Prey	Stomach (%)	Water Column (%)
Ampipods	0.01	3.44
Barnacle larvae	0.06	4.01
Campylodiscus	0.00	0.29
Ceratium	1.56	3.44
Chaetoceros	4.06	5.44
Coclhodinium	0.93	0.00
Copepods	0.28	13.47
Coscinodiscus	42.19	18.05
Dynopsis	1.92	1.43
Eucampia	0.06	0.00
Gomyaulax	0.29	0.00
Lyngbya	0.00	0.29
Gymnonidium	0.61	0.00
Melosira	1.72	7.16
Green mussel larvae	21.03	7.74
Navicula	0.66	3.72
Nitzschia	5.05	7.16
Noctiluca	1.50	2.87
Obelia	0.00	0.86
Odontella	2.94	2.29
Pleurosigma	11.02	8.31
Rhizosolenia	1.34	0.29
Thalassionema	1.52	4.01
Tintinnids	0.18	5.16
Triceratium	1.09	0.57

Appendix 16 Percentage (%) of raw data of food/prey found in stomach of *P. viridis* and water column from Bana habitat for Ivlev's selectivity index analysis

Food/Prey	Stomach (%)	Water Column (%)
Ampipods	0.02	1.44
Barnacle larvae	0.17	5.53
Campylodiscus	0.00	0.24
Ceratium	1.86	2.88
Chaetoceros	4.87	4.81
Coclhodinium	0.58	0.00
Copepods	0.32	13.22
Coscinodiscus	42.40	18.75
Dynopsis	1.48	4.33
Eucampia	0.22	0.00
Gomyaulax	0.50	0.24
Gymnonidium	0.37	0.00
Lauderia	0.00	0.24
Melosira	1.62	3.85
Green mussel larvae	22.12	9.86
Navicula	3.27	6.01
Nitzschia	3.03	2.88
Noctiluca	1.52	3.13
Odontella	1.65	1.68
Pleurosigma	10.92	10.10
Rhizosolenia	0.00	0.48
Thalassionema	1.85	2.64
Tintinnids	0.19	6.01
Triceratium	1.04	1.68

Appendix 17 Percentage (%) of raw data of food/prey found in stomach of *P. viridis* and water column from Rusamilae habitat for Ivlev's selectivity index analysis

Food/Prey	Stomach (%)	Water Column (%)
Ampipods	0.05	0.80
Asterionella	0.00	0.80
Barnacle larvae	0.20	1.99
Bidullphia	0.00	0.40
Ceratium	3.54	2.79
Chaetoceros	3.85	6.77
Copepods	0.51	15.54
Coscinodiscus	24.08	9.96
Dynopsis	0.95	0.00
Eucampia	1.20	2.39
Gomyaulax	0.07	0.00
Gymnonidium	0.06	0.00
Lyngbya	0.00	0.40
Melosira	0.37	2.79
Green mussel larvae	24.36	5.58
Navicula	0.35	0.00
Nitzschia	3.58	5.18
Noctiluca	0.74	1.59
Odontella	1.71	4.38
Pleurosigma	22.37	13.94
Rhizosolenia	4.83	3.98
Thalassionema	3.97	6.77
Thalassiosira	1.17	6.37
Tintinnids	0.33	3.19
Triceratium	1.71	4.38

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List of Publication and Proceeding

- Iqbal, T.H., Hajisamae, S. and Khongpuang, S. 2017. Feeding Habits of Asian Green Mussel (*Perna viridis*): A Case Study from Andaman Sea and Gulf of Thailand. The 5th Asian Academic Society International Conference. Hotel V-Wish, Khon Kaen. July 26th- 27th 2017. 480-485.