



การเปลี่ยนแปลงของประชาคมแพลงก์ตอนและสภาวะแวดล้อมทางน้ำ บริเวณแพเลี้ยงหอยแมลงภู่มะนาวในอ่าวไทย Temporal Variations in Plankton Community and Hydrographic Conditions in a Green Mussel Raft-Cultured Area, Si Racha Bay, the Gulf of Thailand

Pailin Jitchum^{1*} Alonggot Intarachart² and Ladda Wongrat¹

บทคัดย่อ

การศึกษาประชาคมแพลงก์ตอนดำเนินการโดยการเก็บตัวอย่างทุกสองสัปดาห์ตั้งแต่เดือนกันยายน พ.ศ. 2549 – เดือนสิงหาคม พ.ศ. 2550 บริเวณแพเลี้ยงหอยแมลงภู่มะนาวในอ่าวศรีราชาฝั่งอ่าวไทย วิธีการเก็บตัวอย่างแพลงก์ตอนพืชโดยการกรองน้ำทะเลผ่านถุงกรองที่มีขนาดของช่องตา 20 ไมโครเมตร และการเก็บตัวอย่างแพลงก์ตอนสัตว์โดยวิธีการลากถุงเก็บแพลงก์ตอนขนาดช่องตา 330 ไมโครเมตรในแนวตั้ง ทำการตรวจวัดค่าทางสิ่งแวดล้อม จุดเก็บตัวอย่าง และการวิเคราะห์สารอาหารทำในห้องปฏิบัติการ พบแพลงก์ตอนพืชทั้งสิ้น 57 สกุล และแพลงก์ตอนสัตว์ 34 กลุ่ม ค่าเฉลี่ยของแพลงก์ตอนพืชอยู่ที่ $38,777 \pm 27,453$ ยูนิต์ต่อลิตร และค่าเฉลี่ยของแพลงก์ตอนสัตว์ที่ $3,368 \pm 1,183$ ตัวต่อเมตร³ กลุ่มเด่นของแพลงก์ตอนพืชคือไดอะตอม และแพลงก์ตอนสัตว์ ได้แก่ copepods, cirripede nauplii, *Lucifer* sp., and *Sagitta* spp. พบการเปลี่ยนแปลงขององค์ประกอบของแพลงก์ตอนพืชอย่างเด่นชัดในเดือนกรกฎาคม พ.ศ. 2550 โดยพบการเพิ่มจำนวนของไดโนแฟลกเจลเลตชนิด *Ceratium furca* (Ehrenberg) Claparède & Lachmann แทนที่ประชาคมแพลงก์ตอนพืชเดิม การเปลี่ยนแปลงของประชาคมแพลงก์ตอนที่เด่นชัด คือการเปลี่ยนแปลงของปริมาณแพลงก์ตอนตามระยะเวลาระหว่างเดือนต่อเดือนในรอบปี ซึ่งพบว่ามีปริมาณสูงในช่วงฤดูมรสุมตะวันตกเฉียงใต้ นอกจากนี้ค่าผลผลิตเบื้องต้นเฉลี่ย (3.85 ± 2.79 mg m⁻³) ในช่วงฤดูมรสุมตะวันตกเฉียงใต้สูงกว่าค่าเฉลี่ย (1.11 ± 0.36 mg m⁻³) ในช่วงฤดูมรสุมตะวันออกเฉียงเหนือ ทั้งนี้องค์ประกอบของประชาคมแพลงก์ตอนได้รับอิทธิพลจากอุณหภูมิของน้ำทะเล ความเค็ม ปริมาณแอมโมเนีย และปริมาณออกซิเจนที่ละลายในน้ำทะเล สภาวะของตัวแปรทางสิ่งแวดล้อมและสารอาหารมีการเปลี่ยนแปลงตามระยะเวลา แต่ทั้งนี้ค่าสูงสุดของปริมาณสารอาหาร และค่าปริมาณออกซิเจนที่ละลายในน้ำยังคงอยู่ในเกณฑ์ที่เหมาะสมสำหรับมาตรฐานน้ำทะเลเพื่อการเพาะเลี้ยงสัตว์น้ำ

¹ Department of Fishery Biology, Faculty of Fisheries, Kasetsart University, Chatuchak, Bangkok, 10900

² Si Racha Fisheries Research Station, Faculty of Fisheries, Kasetsart University, Si Racha, Chon Buri, 20120

* Corresponding Author, E-Mail: ffsplj@ku.ac.th

ABSTRACT

The plankton community was studied twice a week from September 2006 to August 2007, in a green mussel raft-cultured area, Si Racha Bay, in the Gulf of Thailand. Phytoplankton was collected by filtering with a 20 μm plankton net and zooplankton was collected by vertical hauling with a plankton net of 330 μm mesh size. Several hydrographical conditions were measured *in situ* but nutrient analyses of water samples were carried out in the laboratory. Fifty seven genera of phytoplankton and 34 groups of zooplankton were recorded. The mean abundance of phytoplankton was $38,777 \pm 27,453$ units l^{-1} while that of zooplankton was $3,368 \pm 1,183$ ind. m^{-3} . The dominant group of phytoplankton was diatoms; while copepods, cirripede nauplii, *Lucifer* sp., and *Sagitta* spp. were the major contributors to zooplankton abundance. Noticeable variation in composition of phytoplankton was demonstrated by an algal bloom of dinoflagellates (*Ceratium furca* (Ehrenberg) Claparède & Lachmann) in July 2007. The plankton community showed no significant differences in abundance between months in the annual cycle but the high value was during the Southwest monsoon. Moreover, the average value of primary production (3.85 ± 2.79 mg m^{-3}) during the Southwest monsoon was higher than that of the Northeast monsoon season (1.11 ± 0.36 mg m^{-3}). Composition variation was also influenced by water temperature, salinity, ammonia and dissolved oxygen. Hydrographical conditions and nutrients showed temporal fluctuations. In this regard, the maximum values of nutrients and dissolved oxygen agreed with Thai standard levels of seawater suitable for an aquaculture area.

คำสำคัญ: ประชาคมแพลงก์ตอน ความหนาแน่น ปริมาณธาตุอาหาร แพลงก์ตอนแมลงงู อ่าวไทย

Keywords: Plankton Community, Abundance, Nutrients, Green Mussel Raft-Cultured Area, The Gulf of Thailand

INTRODUCTION

Phytoplankton is generally a main food source for bivalves in terms of suspension feeders in coastal ecosystems. Many empirical studies show the relation between bivalve growth and phytoplankton biomass or primary production in coastal waters such as Wright et al. (1982), Fréchetté et al. (1989), Smaal and Van Stralen (1990), Norén et al. (1999), Thorp and Casper (2002) and Edwards et al. (2005). Also grazing by bivalves may control phytoplankton biomass and hence low phytoplankton densities have been attributed to high grazing rate by the bivalves. Moreover, phytoplankton biomass may have an affect on the abundance of zooplankton through filtration of micro-zooplankton or grazing

by herbivorous and omnivorous zooplankton (Uye and Shimazu, 1997; Calbet and Landry, 1999).

A potential feedback mechanism of bivalve activity increases inorganic nutrients in the water column by excretion that directly affects phytoplankton biomass. The complex relation between bivalve population and its environments depends on the spatial and temporal hydrographic condition and also phytoplankton abundance and composition (Hawkins et al., 1998; Prins et al., 1998). For example, in a natural ecosystem, if the species composition of phytoplankton changes, it would impact primary production and also the carrying capacity of the ecosystem. Accordingly, the environmen-

tal variables and phytoplankton community could describe the effect on the bivalve growth and production (Fréchetté and Bourget, 1985; Fréchetté et al., 1989; Prins et al., 1998; Smaal and Van Stralen, 1990; Dame and Prins, 1998).

Si Racha Bay is a large raft-culture area of green mussel [*Perna viridis* (Linnaeus, 1758)] in the eastern coast of the Gulf of Thailand. Many studies have focused on phytoplankton diversity and environmental variables (Yoosamran et al., 2004; 2006). However, few studies looked at zooplankton community (Chuchit et al., 2003) or the two components in the same area (Pienpichit, 1999). Relationships between dinoflagellate bloom and environmental factors were established by Chuchit (2004), Chuchit and Yoosamran (2005; 2006) and Mardnui and Lirdwitayaprasit (2007). Si Racha Bay is a good representative area to study the impact of plankton communities on mussel culture. Therefore, the aim of this study was to investigate the major environmental factors influencing the seasonal variability of the plankton community in this mussel raft-cultured area.

MATERIALS AND METHODS

Our study was conducted in a raft-culture area of green mussel located in Si Racha Bay ($13^{\circ}11' N$, $100^{\circ}55' E$), a shallow bay with an area of 12 km^2 in the eastern coast of the Gulf of Thailand (Figure. 1). The raft-cultured mussel

area was about 0.65 km^2 in 2005 (Seekao et al., 2006). The mean depth is 5 meters and the tide is a mixed type. The mean tidal range within the bay is slightly less than 2.5 m and tidal current averages 1.1 m s^{-1} in flood tide and 1 m s^{-1} in ebb tide (Anongponyoskun and Bundismith, 1998). Six sampling stations along two transect lines were set in three areas: low intertidal station (average depth of 3 m), mid-intertidal station (average depth of 7 m) and outside area station (average depth of 10 m) (Figure 1).

Plankton sampling and hydrographic conditions recording were carried out during daytime twice a week from September 2006 to August 2007 (Figure 1). At each station, hydrographic conditions were measured *in situ* for water temperature and dissolved oxygen using DO meter (YSI 550), salinity (refractometer, Asahi) and pH (pH meter, YSI 60). Monthly mean precipitable water data were obtained from Thai Meteorological Department (http://www.tmd.go.th/province_stat). Water samples were collected from 50 centimeters depth from surface. Water samples were analyzed in the laboratory for their nutrient contents (nitrite, nitrate, ammonia, orthophosphate, silicate) (APHA, AWWA and WEF, 1998). Chlorophyll a concentration was used as an index of phytoplankton biomass that was determined by spectrophotometric method (Strickland and Parsons, 1972).



Figure 1. Geographic location of Si Racha Bay ($13^{\circ}11' N$, $100^{\circ}55' E$), showing position of sampling stations in the inner, middle and outer area of bay.

Phytoplankton composition was studied by filtering technique. Twenty liters of sub-surface seawater was filtered through a plankton net of 20 μm mesh size. Genera identification and enumeration of phytoplankton samples were done as an average of 3 randomized orders using a Sedgewick-Rafter counter slide under a microscope in the laboratory. Phytoplankton were counted in terms of cells, filaments or colonies. The abundance of phytoplankton was expressed as number of units per liter (Wongrat and Boonyapiwat, 2003).

Zooplankton was collected using a conical 0.6 m diameter plankton net of 330 μm mesh size. The net was towed vertically from bottom to the surface at about 1 knot, with 2 replications per station. The net was fitted with a flow meter to determine the amount of water filtered during each tow. Net samples were immediately preserved in 5% buffered formaldehyde solution. Zooplankton samples were identified to higher groupings and abundance was expressed as number of individuals per m^3 (Postel et al., 2000).

Pearson correlation analysis was used to determine the relationship between the hydrographical variables and phytoplankton biomass (chlorophyll a concentration) and also phytoplankton and zooplankton abundances (Legendre and Legendre, 1983). Analysis of variance (ANOVA) was used to test the differences in phytoplankton and zooplankton abundances between stations and months. Data were transformed prior to analysis of variance (ANOVA) in all cases (Zar, 1984).

RESULTS

1. Hydrographical variables and nutrients

Pooled data of hydrographical variables and nutrients showed no significant differences between stations. Figure 2 shows the annual cycle of the hydrographical data and nutrient values in Si Racha Bay. The water temperature ranged between 26.1 $^{\circ}\text{C}$ in January 2007 and 31.7 $^{\circ}\text{C}$ in April 2007 and showed no distinct seasonal variations apart from a slightly low value in January to February 2007. Salinity values were relatively high and varied from 13.5 psu in October 2006 to 32.5 psu in January – February 2007. Monthly values were less variable during the Northeast monsoon than during the Southwest monsoon. pH fluctuated between 7.91 in November 2006 to 8.60 in July 2007. Dissolved oxygen varied between a minimum of 5.96 mg l^{-1} in April 2007 and a maximum of 9.16 mg l^{-1} in January 2007. Average monthly precipitation for 30 years showed a clear trend with a maximum of 286.9 mm in September and a minimum of 8.9 mm in December. This trend relates to two monsoon seasons; hence, the increase during the Southwest monsoon is the wet season (May - October) and the decrease during the Northeast monsoon is the dry season (November - February).

Nitrite values fluctuated with a minimum of 0.0017 mg l^{-1} in January 2007 and a maximum of 0.0101 mg l^{-1} in April 2007. Nitrate values ranged between 0.0039 mg l^{-1} in December 2006 and 0.024 mg l^{-1} in January 2007. Ammonia varied from 0.0185 mg l^{-1} in May 2007 to 0.1170 mg l^{-1} in April 2006. Silicate values varied from 0.0053 mg l^{-1} in March to 2.478 mg l^{-1} in July 2006. Orthophosphate fluctuated between 0.003

mg l⁻¹ in August 2007 and 0.515 mg l⁻¹ in December 2006 (Figure 2). During the sampling period, nutrient values showed no distinct seasonal patterns but fluctuated in temporal variations.

Average chlorophyll a concentration ranged between 0.80 mg m⁻³ in January 2007 and 7.51 mg m⁻³ in October 2006 and the mean value was 2.59 ± 2.33 mg m⁻³ over the sampling period (Figure 2). Chlorophyll a values regularly changed with two peaks in concentration: a low peak (4.27 mg m⁻³) in May 2007 and a high peak (6.80 – 7.54 mg m⁻³) in September to October 2006 during the Southwest monsoon (May to October). The lowest total chlorophyll a concentration was recorded in December 2006 to January 2007 during the Northeast monsoon season. The graph also shows two fairly constant periods from November 2006 to March 2007 and June to August 2007. These periods showed a clear average value of 3.85 ± 2.79 mg m⁻³ during the Southwest monsoon that was higher than during the Northeast monsoon season (1.11 ± 0.36 mg m⁻³) and summer (1.77 ± 0.80 mg m⁻³).

Pearson correlation analyses between hydrographic conditions, nutrients and phytoplankton biomass (Chlorophyll a concentration) are shown in Table 1. The results indicate that chlorophyll a concentration was positively correlated to temperature ($r = 0.340$, $P < 0.05$), but showed a negative correlation to salinity ($r = -0.661$, $P < 0.05$), ammonia ($r = -0.546$, $P < 0.05$) and dissolved oxygen ($r = -0.328$, $P < 0.05$). Other hydrographical conditions (rainfall, pH) and nutrients (nitrite, nitrate, orthophosphate, silicate) were not correlated to chlorophyll a concentration. Chlorophyll a concentration

showed no significant differences between months (Figure 2) although the average values of concentration tended to be high in September to October 2006 and May 2007.

2. Plankton community

2.1 Phytoplankton

A total of 57 genera of phytoplankton were recorded. They consisted of four classes: Cyanophyceae (blue-green algae), Bacillariophyceae (diatoms), Dinophyceae (dinoflagellates) and Dictyochophyceae (silicoflagellates). Diatoms was the most diverse group, comprising 50 genera, followed by dinoflagellates (7 genera), blue-green algae (2 genera) and silicoflagellate (1 genus) (Table 2). The number of genera ranged from 23 genera in September 2006 to 46 genera in February and May 2007. Phytoplankton showed no significant differences in abundance between stations and so values were pooled within the 6 stations of 3 sampling areas. The total abundance of phytoplankton varied during the period of study from a minimum of 5,551 units l⁻¹ in April 2007 to a maximum of 95,531 units l⁻¹ in August 2007 (Figure 3). The mean abundance was 38,777 ± 27,453 units l⁻¹. The variation in abundance of phytoplankton regularly changed with three peaks: the highest peak (95,531 units l⁻¹) in August 2007 and two smaller ones (67,926 and 73,083 units l⁻¹) in October and November 2006, respectively. The maximum peak of abundance coincided with the abundance of diatom genera: *Chaetoceros*, *Bacteriastrium* and *Thalassionema* (Figure 3). The figure shows two relatively constant abundance periods between December 2006 to January 2007 and May to July 2007.

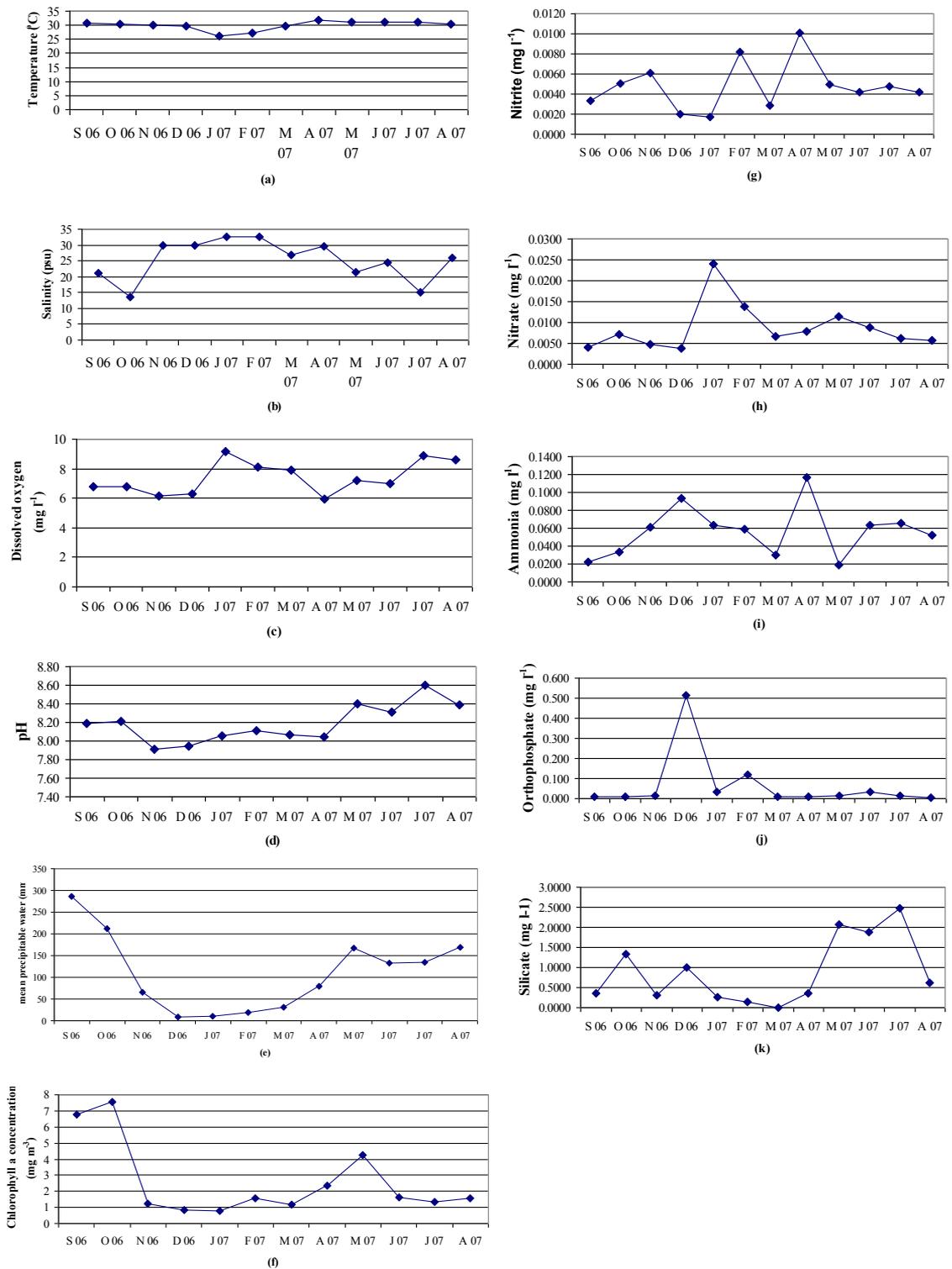


Figure 2. The annual average hydrographic condition in Si Racha Bay; water temperature (a), salinity (b), dissolved oxygen (c), pH (d), precipitation (e) and nutrients; chlorophyll a concentration (f), nitrite (g), nitrate (h), ammonia (i), orthophosphate (j), silicate (k).

Table 1. Correlation coefficients (r) in relationships between hydrographic conditions, nutrients and plankton abundance; * P < 0.05

Parameter	Chlorophyll a	Phytoplankton	Zooplankton
Water temperature (°C)	0.340*	0.106	0.705*
Salinity (psu)	-0.661*	-0.275	-0.398*
Dissolved oxygen (mg l ⁻¹)	-0.328*	0.115	-0.086
pH	0.183	0.249	0.601*
Rainfall (mm)	0.242	0.440*	0.580*
NO ₂ ⁻ (mg l ⁻¹)	0.046	0.069	-0.115
NO ₃ ⁻ (mg l ⁻¹)	-0.222	-0.298	-0.394*
NH ₃ (mg l ⁻¹)	-0.546*	-0.389*	-0.119
PO ₄ ³⁻ (mg l ⁻¹)	-0.285	-0.354*	-0.197
SiO ₄ ³⁻ (mg l ⁻¹)	0.143	-0.009	0.550*
Chlorophyll a (mg m ⁻³)	-	0.242	0.122

Noticeable variation in seasonal abundance of phytoplankton during the two monsoons was demonstrated in this study area. During the Southwest monsoon (May – October), the average abundance of phytoplankton had a highest value of $50,001 \pm 26,305$ units l⁻¹ while an average value of $34,975 \pm 29,186$ units l⁻¹ was recorded during the Northeast monsoon (November – February). The lowest average abundance was $12,710 \pm 10,125$ units l⁻¹ in summer (March – April).

The contribution of various phytoplankton groups was dominated by diatoms, comprising 86.64% of total abundance. Their mean value was $33,596 \pm 27,975$ units l⁻¹, followed by dinoflagellates (8.09%, $3,138 \pm 7,204$ units l⁻¹), blue-green algae (5.24%, $2,034 \pm 4,062$ units l⁻¹), and silicoflagellates (0.02%, 10 ± 14 units l⁻¹), respectively (Table 2). Six important genera that

frequently occurred in terms of relative abundance were *Chaetoceros* (52.22%), *Bacteriastrium* (9.41%), *Ceratium* (7.31%), *Thalassionema* (5.50%), *Oscillatoria* (5.23%) and *Pleurosigma* (2.54%).

Diatoms dominated with a high percentage composition in most of the sampling period during both monsoons (Figure 4). A shift in dominant group developed from diatoms to dinoflagellates (*Ceratium furca* (Ehrenberg) Claparède & Lachmann) in July 2007 with a maximum value of 25,610 units l⁻¹. Blue-green algae (*Oscillatoria*) had high abundance in September 2006 with a maximum value of 14,743 units l⁻¹ but silicoflagellates were low in percentage over the whole study period.

Pearson correlation analyses between hydrographic conditions, nutrients and phytoplankton abundance are shown in Table 1. The

results indicate that phytoplankton abundance was positively correlated to rainfall ($r = 0.440$, $P < 0.05$), but showed negatively correlation to ammonia ($r = -0.389$, $P < 0.05$), and orthophosphate ($r = -0.354$, $P < 0.05$). Other hydrographical conditions (water temperature, salinity, dissolved oxygen, pH) and nutrients (nitrite, nitrate,

silicate) were not correlated to phytoplankton abundance. Phytoplankton abundance showed no significant difference between months (Figure 2) although the average values of abundance tended to be high in November 2006 and August 2007.

Table 2. Phytoplankton diversity with mean, maximum and minimum values of abundance (unit l^{-1}), and mean value for contribution (%) to total abundance of each taxon

Taxa	Abundance (unit l^{-1})			Mean %
	Mean	Max	Min	
DIVISION CYANOPHYTA				
CLASS CYANOPHYCEAE				
<i>Lyngbya</i>	8	45	0	0.02
<i>Oscillatoria</i>	2026	14743	85	5.23
DIVISION CHROMOPHYTA				
CLASS BACILLARIOPHYCEAE				
ORDER BIDDULPHIALES				
<i>Cyclotella</i>				
<i>Lauderia</i>	491	2716	0	1.27
<i>Skeletonema</i>	62	221	0	0.16
<i>Thalassiosira</i>	341	3173	0	0.88
<i>Planktoniella</i>	1	5	0	0
<i>Paralia</i>	13	34	0	0.03
<i>Melosira</i>	667	7539	0	1.72
<i>Corethron</i>	31	345	0	0.08
<i>Palmeria</i>	1	6	0	0
<i>Coscinodiscus</i>	353	1722	14	0.91
<i>Pseudoguinaridia</i>	12	50	0	0.03
<i>Actinoptychus</i>	1	9	0	0
<i>Asteromphalus</i>	1	9	0	0
<i>Leptocylindrus</i>	365	3804	0	0.94
<i>Dactyliosolen</i>	50	435	0	0.13
<i>Guinaridia</i>	249	1645	0	0.64
<i>Proboscia</i>	724	3945	0	1.87
<i>Pseudosolenia</i>	300	1123	0	0.77
<i>Rhizosolenia</i>	664	2523	2	1.71

<i>Climacodium</i>	13	115	0	0.03
<i>Eucampia</i>	131	833	0	0.34
<i>Hemiaulus</i>	623	3300	0	1.61
<i>Biddulphia</i>	0	4	0	0
<i>Cymatosira</i>	0	2	0	0
<i>Bacteriastrum</i>	3650	24610	10	9.41
<i>Chaetoceros</i>	20249	62270	616	52.22
<i>Ditylum</i>	353	2463	0	0.91
<i>Odontella</i>	48	166	1	0.12
ORDER BACILLARIALES				
<i>Asterionella</i>	18	79	0	0.05
<i>Fragilaria</i>	2	5	0	0
<i>Synedra</i>	1	10	0	0
<i>Thalassionema</i>	2131	13426	2	5.50
<i>Amphora</i>	0	2	0	0
<i>Gyrosigma</i>	20	195	0	0.05
<i>Navicula</i>	20	105	0	0.05
<i>Pleurosigma</i>	281	3847	1	2.54
<i>Gammatophora</i>	0	1	0	0
<i>Climacosphenia</i>	4	13	0	0.01

Table 2. Phytoplankton diversity with mean, maximum and minimum values of abundance (unit l⁻¹), and mean value for contribution (%) to total abundance of each taxon (cont.)

Taxa	Abundance (unit l ⁻¹)			Mean %
	Mean	Max	Min	
<i>Nitzschia</i>	97	333	0	0.25
<i>Bacillaria</i>	53	128	0	0.14
<i>Pseudo-nitzschia</i>	520	1823	1	1.34
<i>Cocconeis</i>	3	31	0	0.01
<i>Lyrella</i>	1	4	0	0
<i>Diploneis</i>	0	3	0	0
<i>Denticula</i>	0	1	0	0
<i>Epithemia</i>	1	5	0	0
<i>Surirella</i>	23	157	0	0.06
<i>Entomoneis</i>	21	74	0	0.05
CLASS DINOPHYCEAE				
<i>Prorocentrum</i>	19	135	2	0.05
<i>Dinophysis</i>	61	142	2	0.16

<i>Ornithocercus</i>	0	2	0	0
<i>Noctiluca</i>	32	171	0	0.08
<i>Ceratium</i>	2836	25610	34	7.31
<i>Pyrophacus</i>	10	65	0	0.03
<i>Protoperdinium</i>	180	601	0	0.46
CLASS DICTYOCOPHYCEAE				
<i>Dictyocha</i>	10	38	0	0.02

2.2 Zooplankton

Zooplankton belonging to 11 phyla were recorded: Sarcomastigophora, Cnidaria, Ctenophora, Nemertea, Annelida, Mollusca, Arthropoda, Phoronida, Chaetognatha, Echinodermata and Chordata. They were identified into 34

groups (Table 3). Crustaceans, mainly copepods, was the majority group. Other common groups were cirripede nauplii, *Lucifer* sp., and *Sagitta* spp. The number of groups fluctuated from 19 groups in August 2007 to 31 groups in January 2007.

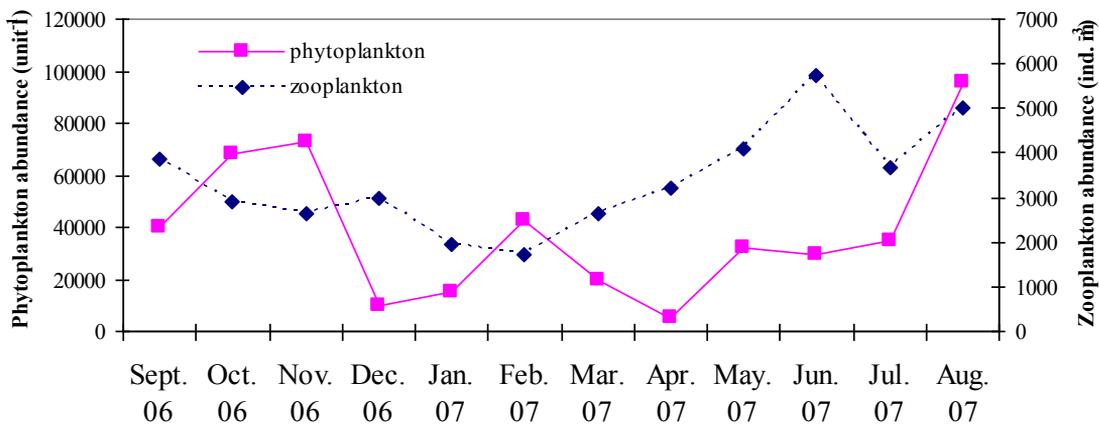


Figure 3. Total abundance of phytoplankton and zooplankton in Si Racha Bay

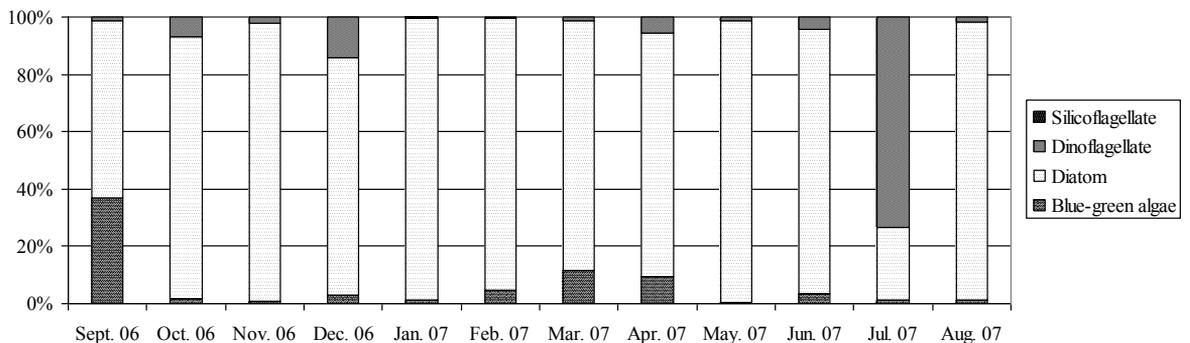


Figure 4. Temporal contribution percentage of phytoplankton in Si Racha Bay

Zooplankton showed no significant differences in abundance between stations. Total abundance of zooplankton varied from a minimum of 1,709 ind. m^{-3} in February 2007 to a maximum of 5,733 ind. m^{-3} in June 2007. The mean abundance was $3,368 \pm 1,183$ ind. m^{-3} (Figure 3). Two peaks in abundance were reached in June and August 2007, which coincided with the abundance of copepods and cirripede nauplii. Minimum values were found in January to February 2007. Copepods, mostly copepodid larvae and adults, dominated over other groups, contributing 46% to the total zooplankton abundance. The mean value was $1,548 \pm 943$ ind. m^{-3} (Table 3). Five subdominant groups were cirripede nauplii (10.4%), *Lucifer* sp. (4.4%), *Sagitta* spp. (4.1%), *Oikopleura* spp. (4.0%) and doliolids (3.2%) (Figure 5). Other groups had generally low abundance with < 3%

or were absent in some months.

Pearson correlation analyses between hydrographic conditions, nutrients and zooplankton abundance are shown in Table 1. The results indicate that zooplankton abundance was positively correlated to water temperature ($r = 0.705$, $P < 0.05$), pH ($r = 0.601$, $P < 0.05$), rainfall ($r = 0.580$, $P < 0.05$) and silicate ($r = 0.550$, $P < 0.05$), but showed negative correlation to salinity ($r = -0.398$, $P < 0.05$) and nitrate ($r = -0.394$, $P < 0.05$). Other hydrographical conditions (dissolved oxygen) and nutrients (nitrite, ammonia, orthophosphate, chlorophyll a concentration) were not correlated to zooplankton abundance. Zooplankton abundance showed no significant difference between months (Figure 2) although the average values of abundance tended to be high in May - August 2007.

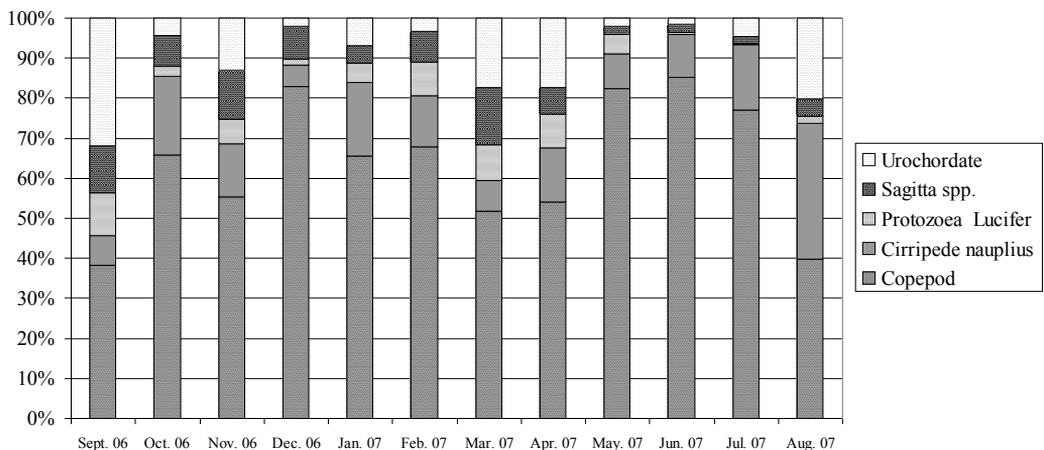


Figure 5. Temporal contribution percentage of zooplankton in Si Racha Bay

Table 3. Zooplankton diversity with mean, maximum and minimum values of abundance (ind.m⁻³), mean value for contribution (%) to total abundance of each taxa

Taxa	Abundance (unit L ⁻¹)			Mean %
	Mean	Max	Min	
Radiolaria	5	31	0	0.1
Hydromedusae	72	186	16	2.2
Siphonophoran	21	111	0	0.6
Cydippid larvae	8	36	0	0.2
Pilidium larvae	1	13	0	0
Polychaeta larvae	88	380	6	2.6
Gastropod veliger	38	181	13	1.1
<i>Creseis</i> sp.	9	27	0	0.3
Bivalve veliger	57	225	10	1.7
<i>Penilia avirostris</i> Dana	1	13	0	0
<i>Pseudevadne tergestina</i> Claus	60	362	0	1.8
Ostracoda	0	4	0	0
Copepod nauplii	68	502	0	2.0
Copepod	1548	3840	529	46.0
Cirrepede nauplii	350	1245	78	10.4
Cypris larvae	24	192	0	0.7
Amphipoda	8	38	0	0.2
Protozoa of <i>Lucifer</i>	96	298	3	2.9
<i>Lucifer</i> sp.	149	364	33	4.4
Protozoa of <i>Acetes</i>	16	53	0	0.5
Shrimp larvae	98	285	12	2.9
Brachyuran zoea	59	191	9	1.7
Brachyuran megalopa	5	23	0	0.1
Porcellanid larvae	3	13	0	0.1
Anomuran larvae	4	21	0	0.1
<i>Sagitta</i> spp.	138	320	51	4.1
Bipinnaria larvae	4	18	0	0.1
Echinopluteus larvae	11	58	0	0.3
Ophiopluteus larvae	96	317	0	2.8
Actinotrocha larvae	2	6	0	0.1
<i>Oikopleura</i> sp.	134	738	19	4.0
<i>Doliolum</i> sp.	108	752	0	3.2
Fish eggs	71	358	17	2.1
Fish larvae	16	36	6	0.5

DISCUSSION

The environmental factors and nutrients showed no significant differences between sampling stations because the tidal current only slightly changed within narrow ranges and also the water column well mixed (Anongponyoskun and Bundismith, 1998). Shallow depth (average < 5 m) and mixed tidal current are important factors that affect both horizontal and vertical water column mixing in this bay (Anongponyoskun, 2006). Moreover, the tidal current seems to be standing water being influenced by many aquaculture rafts. The area had no major transporter exchanging between the coastal water and the open sea. Also, this study area is probably restricted as a shallow bay excluding offshore areas.

There was seasonal variation of salinity and water temperature which was a result of precipitation. Salinity values were relatively high from November to April (the Northeast monsoon). The lowest value was recorded in July and October (the Southwest monsoon). In contrast, water temperature was fairly constant throughout the year with the low values recorded in December to February (the Northeast monsoon).

Nutrient loading to coastal waters is generally influenced by freshwater run-off from land and also available nutrients into the water column (Dame and Allen, 1996; McQuatters-Gollop et al., 2007; Philippart et al., 2000). In addition, the nutrient contents generally support primary production in terms of phytoplankton biomass (Bot and Colijn, 1996). Our study showed that the dissolved nutrient contents fluctuated in temporal variation with no noticeable trend with monsoon seasons excluding the chlorophyll a concentration. The chlorophyll a concentration showed two high peaks during the Southwest monsoon season and could be stated as an enrichment of this bay. This result showed a

moderate value of chlorophyll a concentration ($3.85 \pm 2.79 \text{ mg m}^{-3}$) but low value of $1.11 \pm 0.36 \text{ mg m}^{-3}$ in the Northeast monsoon and $1.77 \pm 0.8 \text{ mg m}^{-3}$ in summer. It can be explained by seasonal changes in coastal circulation patterns, phytoplankton density and nutrient loading in the raining season (Boonyapiwat, 1999). In this regard, this area was assumed to be a mesotrophic water during the Southwest monsoon but an oligotrophic coastal water in the Northeast monsoon and summer (Calbet and Landry, 2004; U.S. EPA, 2003). Our results agreed with previous findings by Yoosamran et al. (2004; 2006) that there were clear patterns of seasonal variations in salinity and chlorophyll a concentration in this bay. Additionally, the environmental parameters and nutrient values were at a normal level for Thai standard levels of seawater suitable for an aquaculture area (Department of Pollutant Control, 2006).

Species composition of phytoplankton and zooplankton were similar to previous studies by Chuchit et al. (2003) and Yoosamran et al. (2006). Diatoms mainly showed dominance in total abundance of phytoplankton and copepods were also a dominant group of zooplankton in this area. Total abundance of plankton community was related to monsoon seasons and showed a high peak during the Northeast monsoon. It can be explained by the variation of salinity that was influenced by heavy rainfall from May to October. Moreover, species composition of the plankton community was generally brackish species. In addition, a shift in the dominant group developed from diatoms to dinoflagellates in July 2007 in terms of a *Ceratium furca* bloom. This result agreed with previous findings by Chuchit (2004) and Chuchit and Yoosamran (2005, 2006). They found that *C. furca* increased in abundance during the Northeast monsoon season. However, Mardnui and Lirdwitayaprasit (2007) found that this phe-

nomenon was negatively correlated to salinity.

The combination of phytoplankton and zooplankton showed the characteristics of tropical coastal waters. The decreasing trend of phytoplankton biomass during the Northeast monsoon and summer months could be explained by mussel grazing in the area of aquaculture rafts. Our results showed two high peaks in abundance of bivalve veliger larvae in April and May. This might indicate a high reproductive period for mussels in this study area. The bivalve filtration highly affected the fluctuation in both composition and abundance of suspended seston (Hawkins et al., 1998; Norén et al., 1999). Other grazing on phytoplankton also comes from zooplankton across the trophic structure or food web (Landry et al., 1995; Turner, 2004). In addition to the temporal variation, there may be seasonal availability in food supply to the filtration activity of the mussels. However, the local food competition requires knowledge of the interactions between the environments and food supply on the mussel population (Dame and Prins, 1998; Prins et al., 1998). On the other hand, the amounts of inorganic nutrients released from mussel populations and sediment re-suspension may be a major source of nutrients for phytoplankton in this study area. Finally, an evaluation of relations between mussel growth and production and their environment is required to establish a model of the mussel role in the pelagic ecosystem.

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