ความสัมพันธ์ของปัจจัยสิ่งแวดล้อมทางน้ำและความหนาแน่นของแพลงก์ตอนพืชในปากน้ำปากเมง อำเภอสิเกา จังหวัดตรัง

RELATIONSHIP OF AQUATIC ENVIRONMENTAL PARAMETERS AND PHYTOPLANKTON DENSITY IN PARKMENG ESTUARY, SIKAO DISTRICT, TRANG PROVINCE

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บทคัดย่อ

ปากแม่น้ำปากเมงตั้งอยู่บริเวณ อำเภอสิเกา จังหวัดตรัง มีความสำคัญเป็นแหล่งอนุบาลสัตว์ทะเลหลายชนิด การก่อสร้างและกิจกรรมการท่องเที่ยวส่งผลกระทบต่อคุณภาพสิ่งแวดล้อมบริเวณนี้ จึงมีความจำเป็นในการศึกษาผลกระทบของกิจกรรมดังกล่าวต่อคุณภาพสิ่งแวดล้อมและด้านชีวภาพในบริเวณนี้การศึกษาความสัมพันธ์ระหว่างปัจจัยสิ่งแวดล้อมทางน้ำ (Aquatic Environment Parameters, AEP) กับความหนาแน่นของเพลงก์ตอนพืชในปากแม่น้ำนี้ใช้วิธี Canonical Correspondence Analysis (CCA) ผลการศึกษาพบว่า APE ของปากแม่น้ำปากเมง แบ่งได้เป็นสองฤดูกาลหลัก ๆ คือ ฤดูมรสุม (มิถุนายน-ตุลาคม) และ ฤดูร้อน (พฤศจิกายน-เมษายน) โดยมีค่าความคล้าย (similarity scores) ที่ระดับคะแนนร้อยละ 98.79 และ 98.18 ตามลำดับ ส่วนช่วงสลับฤดูกาลเป็นเดือนพฤษภาคมโดยมีค่าความคล้ายร้อยละ 99.54 พบแพลงก์ตอนพืชจำนวน 2 ดิวิชัน 11 วงศ์ 14 สกุล และ 17 ชนิด โดยดิวิชันโครโมไฟตา มีความหนาแน่นสูงสุด ร้อยละ 98.79 รองลงมาเป็นไซยาโนไฟตา

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ร้อยละ 26.04 แพลงก์ตอนพืช แบ่งได้สองกลุ่มคล้ายกับผลการศึกษา APE กล่าวคือแพลงก์ตอนช่วงฤดูฝนและฤดูมรสุม โดยมีค่า คะแนน CCA เท่ากับร้อยละ 74.2 และร้อยละ 55.00 ตามลำดับ ปริมาณฟอสเฟต การนำไฟฟ้า ปริมาณซิลิเกต ค่าความเป็นกรดด่าง (pH) และอุณหภูมิ มีความสัมพันธ์กับความหนาแน่นของแพลงก์ตอนพืชที่ระดับคะแนน CCA เท่ากับ 0.84, 0.75, 0.74, 0.72, และ 0.71 ตามลำดับ การศึกษานี้แสดงให้เห็นว่าไดอะตอม *Triceratium* sp., *Rhizosolenia* sp., *Odontella* sp., และ *Cyclotella stylorum* อาจใช้เป็นดัชนีทางชีวภาพสำหรับชี้วัดการผันผวนความเค็มและ pH ของน้ำในบริเวณปากน้ำนี้ได้

คำสำคัญ: แพลงก์ตอนพืช พารามิเตอร์ทางน้ำ ความสัมพันธ์ ปากน้ำ ทะเลอันดามัน

Abstract

Parkmeng Estuary is located in Siako District area, Trang Province, the estuary is an important nursery area for marine life; however, port construction and tourist activities affect the estuarine environmental quality. It is necessary to study effect of those activities on the environment and biological qualities in this area. The relationships between aquatic environment parameters (AEP) and phytoplankton density in this estuary were investigated using the canonical correspondence analysis (CCA) method. The AEP was classified for two main seasons, monsoon (July-October) and summer seasons (November-April) by the unweighted pair group method with arithmetic mean analysis with similarity scores of 98.79% and 98.18%. The inter-change period was May classified by CCA score at 99.54%. Two divisions, 11 families, 14 genera, and 17 species of phytoplankton were recorded in this study. The division Chromophyta showed the highest density (74.96%) followed by Cyanophyta (26.04%). Similar to AEP analysis, phytoplankton was classified as monsoon or summer species with CCA similarity scores of 74.28% and 55.00%, respectively. Phosphate, conductivity, silicates, pH, and temperature showed correlations to phytoplankton density with CCA variable scores of 0.84, 0.75, 0.74, 0.72, and 0.71, respectively. This study reveals that the density of *Triceratium* sp., *Rhizosolenia* sp., *Odontella* sp., and *Cyclotella stylorum* diatoms might be used as bio-indicators for the fluctuations of salinity and pH in this estuary.

Keywords: Phytoplankton, Aquatic parameter, Relationship, Estuary, Andaman Sea

Introduction

Estuaries are highly dynamic and productive parts of the coastal ecosystem. Under the influence of riverine waters and tidal currents, estuaries are fertile areas, nutrient reservoirs, and nursery habitats for marine animals (Llebot et al., 2010). However, estuaries are also used for anthropogenic activities such as harbor locations, tourist sites, and agricultural activities. Waste and pollutants from these activities drain into and accumulate in these reservoirs. The seasonal and geographical dynamics of phytoplankton and water quality are indicators for assessing the abundance and productivity of estuaries. Usually, estuarine studies are done by surveying the diversity of phytoplankton and assessing aquatic environmental quality. The relationship between these factors is then used as an indicator for productivity assessments of estuaries found in Indonesia, India, and Brazil (Li et al., 2019; Mishra et al., 2019; Wafa et al., 201). The diversity and densities of phytoplankton can be utilized as a biological index to assess the fertility of any estuary because the uptake capacities and sensitivities to dissolved chemicals in estuarine waters differ in phytoplankton species (Barinova & Krupa, 2017), for example, *Nephroselmis pyriformis* is an ammonia-sensitive species (Devaraj et al., 2014) while *Trichodesmium erythraeum*, which cause blooms in Indian estuaries, grow very well in the areas of high nitrogen concentrations (Mohanty et al., 2010). Parkmeng Estuary is located in Trang province on the west coast of southern Thailand (07° 18′ 54″ N, 99° 17′ 90″ E) (Figures 1 and 2), on the Andaman Sea coastline. The estuary is approximately 10 km^2 and is surrounded by mangrove forests, seagrass beds, and sandy beaches. It is a reservoir of river water and contaminated materials from anthropogenic activities. The quality of estuarine water and the surrounding environment has deteriorated due to tourism, commercial port construction, and anthropogenic pollutants. We also observed mass coral bleaching and death of the seagrass bed, phenomena indicating the impacts of anthropogenic activities. Therefore, it is required that the biology and environment of this estuary should be studied.

Figure 1 The Andaman Sea coast area

Material and methods

Study site and sampling design

Twelve sampling stations were assigned among the study area where was divided into two lines with 150 meters from each other as shown in Figure 2. Water and phytoplankton samples were collected for 10 months (once a month) during January to October (2018) in two tidal currents of a spring tide day.

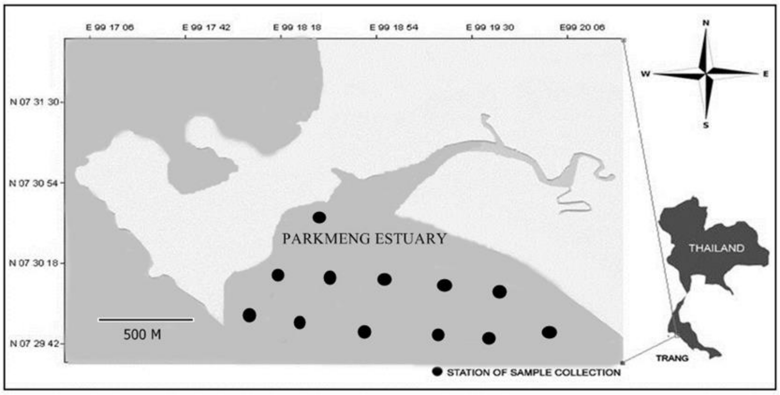

Figure 2 The study area, Parkmeng Estuary

Remark A black dot is sampling station

Aquatic environmental parameters (AEP) measurement

The physico-chemical parameters of the sea water, including temperature, dissolved oxygen, pH, and conductivity were determined using an in-situ instrument (YSI 60/10 FT; Ohio, USA). Salinity and transparency were measured using a refracto salinometer (ATAGO S/Mill-E, Japan) and a Secchi disc, respectively. Water sampling, dissolved silicate and phosphorus analysis were performed by following the method described by Strickland & Parson (1972).

Phytoplankton analysis

A plankton net (mesh size 53 μm, diameter 45 cm) was used to collect phytoplankton at a depth of 2–4 m. The samples were fixed with neutralized formaldehyde (0.8–1.6%) until analysis. The density determination was performed on 500 ml aliquots of the original samples using a Sedgewick-Rafter counter under an inverted microscope fitted with a phase contrast device (Olympus, Pennsylvania, USA). The phytoplankton was identified using the taxonomic guides to marine phytoplankton described by Kraberg et al. (2010). The relationships between phytoplankton density and AEP were obtained by canonical correspondence analysis (CCA) with the MultiVariate Statistical Package (MVSP) version 3.12d (freely available at http://www.kovcomp.com), where the raw data was transformed to log (X+1) and grouping by means of unweighted pair group method with arithmetic mean (UPGMA).

Results and Discussion

Aquatic environmental parameters

Mean values of aquatic environmental parameters (AEP) were calculated as shown in Table 1. All values were in range of the coastal water standard (Strickland & Parson, 1972) as shown in Table 1. Three groups of water qualities were characterized according to seasonal variation by UPGMA, as shown in Figure 3. These were the inter-change seasons (May), monsoon season (June–October), and the summer season (November–April), with similarity scores of 99.54%, 98.79%, and 98.18%, respectively. The alterations of the AEPs in Parkmeng estuary were caused by two main factors: first, the inputs of Sikao river water and anthropogenic material into the estuary reservoir; second, the nutrient carrying from open ocean by the Andaman Sea currents (Thawonsode et al., 2015).

Table 1 Aquatic environmental parameters of Parkmeng Estuary

Month	pH	Temperature	Salinity	DO	Transparency	Silicate	Conductivity	Phosphate	Ammonia	Silicate	Nitrite
1	8.61±0.23	31.43±0.21	30.00±0.00	7.75±0.17	2.53±0.06	0.56±0.02	54.02±0.04	0.43±0.03	0.67±0.11	0.54±0.02	0.03±0.01
2	9.36±0.01	30.56±0.15	30.66±0.58	6.55±0.02	1.20±0.10	0.55±0.01	53.92±0.02	0.30±0.01	0.84±0.03	0.72±0.02	0.03±0.01
3	7.66±0.01	31.6±0.10	31.16±0.21	8.53±0.01	1.46±0.06	0.55±0.03	54.53±0.03	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
4	7.67±0.03	31.26±0.23	30.20±0.26	8.43±0.01	0.76±0.05	0.37±0.06	52.76±0.02	0.13±0.01	0.08±0.01	0.20±0.01	0.36±0.01
5	7.60±0.05	31.16±0.15	31.06±0.11	8.74±0.36	0.86±0.06	0.45±0.02	52.08±0.07	0.13±0.00	0.11±0.01	0.19±0.01	0.37±0.02
6	7.79±0.07	29.50±0.10	28.66±0.58	8.79±0.06	0.86±0.06	0.66±0.02	45.55±0.01	0.12±0.02	0.85±0.02	0.13±0.01	0.13±0.02
7	7.59±0.06	31.5±0.17	31.33±0.58	8.79±0.06	1.30±0.10	0.48±0.07	41.78±0.02	0.16±0.03	0.73±0.03	0.12±0.02	0.12±0.02
8	8.58±0.12	30.33±0.58	30.33±0.58	7.84±0.01	1.33±0.06	0.63±0.02	45.95±0.01	0.13±0.01	0.72±0.02	0.13±0.02	0.13±0.02
9	8.54±0.10	30.33±0.58	30.33±0.58	7.83±0.02	2.53±0.06	0.58±0.12	45.86±0.02	0.13±0.02	0.74±0.02	0.12±0.01	0.12±0.01

Remark The data are shown as mean ± *S*. Month numbering 1-9 were January – October, 2018.

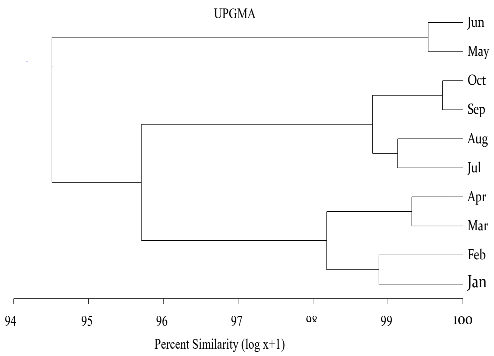

Figure 3 UPGMA phenogram showe water quality grouping according to seasons

Remark Jan=January, Feb=February, Mar=March, Apr=April, May=May, Jun=June, Jul=July, Aug=August, Sep=September, Oct=October

Summer season is November-April, Monsoon season July-October, and the inter-change period was May.

Phytoplankton density

Two divisions, eleven families and seventeen genera of phytoplankton (Table 2) in the Parkmeng Estuary were recorded during the studied period. The density and UPGMA analysis showed that the division Chromophyta had the highest density (74.96%) of all the discovered phytoplankton. Those phytoplankton were classified as summer species (*Bacteriastrum varians*, *Ceratium* sp., *C. microcuries*, and *C. deflexum*), and monsoon species (*Odontella* sp., *Triceratium* sp., *Rhizosolenia* sp., *Cyclotella stylorum*) with scores of 48.97% and 51.03% (Figure 4), respectively. Consideration of phytoplankton data on the Andaman coastal area from the Ranong to Satun Provinces since 1985 revealed the distributions and densities similar to our study; particularly, the division Chromophyta was the main group, with *Chaetoceros spp*., *Rhizosolenia spp*., and *Thalassiocera spp*. well distributed in this area (Thawonsode et al., 2015). Generally, the density and distribution of phytoplankton is related to topography, current, and nutrient flux. Parkmeng Estuary connects to the Sikao River in the east and opens to the Andaman Sea in the west (Figures 1 and 2), therefore water circulation and mixing in this area is under the influence of equatorial and local wind (monsoon) forces, creating a semidiurnal tide with a tidal period about 12 hours (Chatterjee et al., 2017). This estuary is nutrient-enriched by the Sikao River, especially in the monsoon season. The density and the relationships of phytoplankton to aquatic environment parameters (AEP) were analyzed by the CCA method, as shown in Figure 5.

Table 2 Phytoplankton taxa and density during the study period

Phytoplankton	Density (cells/ml)									
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Division: Chromophyta										
Class Bacillariophyceae	-	-	-	-	-	-	-	-	-	-
Order Biddulphiales (centric diatoms)	-	-	-	-	-	-	-	-	-	-
Suborder Biddulphiineae	-	-	-	-	-	-	-	-	-	-
Family Chaetoceraceae	-	-	-	-	-	-	-	-	-	-
Bacteriastrum varians	8	21	15	1	1	-	-	3	-	6
Chaetoceros sp.	26	5	8	-	-	-	-	-	-	-
Family Eupodiscaceae	-	-	-	-	-	-	-	-	-	-
Odontella sp.	-	-	-	-	-	6	4	2	3	1
Triceratium sp.	-	-	-	-	-	1	1	1	3	-
Family Thalassionematacea	-	-	-	-	-	-	-	-	-	-
Thalassionema sp.	17	35	28	2	1	31	18	20	25	21
Suborder Rhizosoleniineae	-	-	-	-	-	-	-	-	-	-
Family Rhizosoleniaceae	-	-	-	-	-	-	-	-	-	-
Rhizosolenia sp.			5			15	33	21	25	26
Order Bacillariales (pennate diatoms)	-	-	-	-	-	-	-	-	-	-
Suborder Bacillariineae	-	-	-	-	-	-	-	-	-	-
Family Bacillariaceae	-	-	-	-	-	-	-	-	-	-
Nitzschia longissima	12	15	9	6	10	8	18	9	4	21
Family Naviculaceae	-	-	-	-	-	-	-	-	-	-
Pleurosigma angulatum	21	14	18	13	17	36	26	18	12	19
Pleurosigma salinarum	35	27	20	10	15	26	20	14	13	6
Suborder Coscinodiscineae	-	-	-	-	-	-	-	-	-	-
Family Thalassiosiraceae	-	-	-	-	-	-	-	-	-	-

Table 2 Phytoplankton taxa and density during the study period (cont.)

Phytoplankton	Density (cells/ml)									
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cyclotella stylorum		3	4	1		15	24	12	7	13
Ditylum brightwellii	11	-	-	-	-	-	-	-	-	-
Class Dinophyceae	-	-	-	-	-	-	-	-	-	-
Order Gonyaulacales	-	-	-	-	-	-	-	-	-	-
Family Ceratiaceae	-	-	-	-	-	-	-	-	-	-
Ceratium sp.	18	101	89	1	5	5	-	-	-	19
Ceratium deflexum	9	10	7	1	4	-	-	-	-	-
Ceratium macroceros	7	15	8			-	-	-	-	-
Order Dinophysiales	-	-	-	-	-	-	-	-	-	-
Family Dinophysiaceae	-	-	-	-	-	-	-	-	-	-
Dinophysis caudata	13	1	-	-	9	-	-	-	-	-
Order Peridinales	-	-	-	-	-	-	-	-	-	-
Family Podolampaceae	-	-	-	-	-	-	-	-	-	-
Peridinium steinii	-	3	-	-	-	14	-	-	-	-
Division: Cyanophyta	-	-	-	-	-	-	-	-	-	-
Class Cyanophycea	-	-	-	-	-	-	-	-	-	-
Order Nostocales	-	-	-	-	-	-	-	-	-	-
Family Oscillatoriaceae	-	-	-	-	-	-	-	-	-	-
Oscillatoria sp.	-	22	9	-	4	20	-	-	-	-
Total	**181**	**283**	**222**	**42**	**70**	**183**	**159**	**106**	**92**	**150**

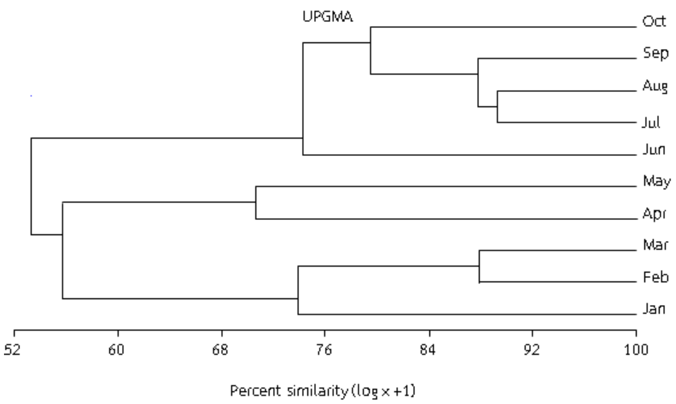

Figure 4 UPGMA phenogram showed phytoplankton classification according to seasons (Summer, monsoon season and inter-change period).

Remark Jan=January, Feb=February, Mar=March, Apr=April, May=May, Jun=June, Jul=July, Aug=August, Sep=September, Oct=October

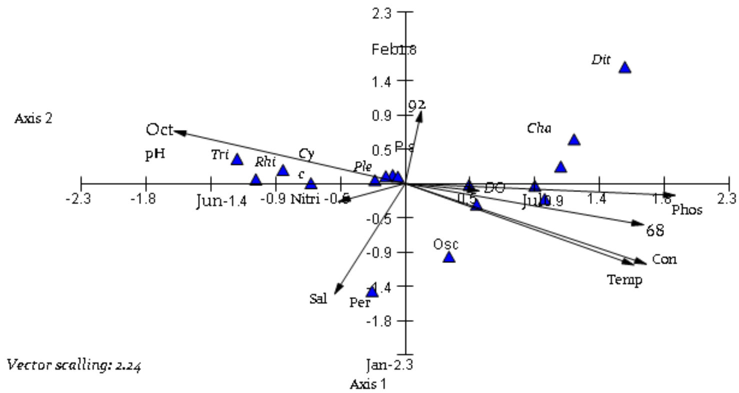

Figure 5 Diagram of canonical correspondence between phytoplankton density and AEP

Remark Tri = *Triceratium* sp., Rhi = *Rhizosolenia* sp., Cyc = *Cyclotella stylorum*,
Per = *Peridinium steinii*, Bac = *Bacteriastrum varians*, Ced = *Ceratium macroceros*,
Cha = *Chaetocerose* sp., Din = *Dinophysis caudata*, Dit = *Ditylum brightwelli*,
Osc = *Oscillatoria* sp., Sal = Salinity, Ammo = Ammonia, Phos = Phosphorus,
Con = Conductivity, Temp = Temperature, DO = Dissolve Oxygen, Nitri = Nitrite

The results showed that pH, phosphate, silicate, conductivity, and temperature parameters were related to the variations and densities of phytoplankton. *Triceratium* sp., *Rhizosolenia* sp., *Odontella* sp., and *Cyclotella stylorum* diatoms were recorded at high pH, but low for phosphate concentration, conductivity, dissolved silicate and temperature parameters; while a dinoflagellate, *Peridinium stenii*, was found in high salinity but low of ammonia concentrations. Under laboratory conditions, the optimum pH for phytoplankton growth ranges from 6.30-10.00, depending on the species (Medupin, 2011). Unlike a static laboratory setting, riverine water containing high levels of Ca^{2+} and HCO_{3-} flows into the Parkmeng Estuary, and is well mixed with sea water. This mix interferes in the carbonate buffer system so that the resulting pH is re-balanced and changed. In our study, the pH values in the monsoon season of Parkmeng Estuary were about 7.54-7.75, which may be suitable for the four diatoms growing there (Velsamy et al., 2013; Li et al., 2019). Dinoflagellates generally grow well in saline water in the range of 30–36 ppt, but do not grow below 30 ppt (Mishra et al., 2019). Our study recorded that a dinoflagellate, *Peridinium stenii*, showed high densities in the summer when the salinity was 30.00–31.16 ppt. Salinity in Parkmeng Estuary did not vary widely in the summer when there is no effect from riverine water; on the other hand, salinity drops to 28.66 ppt in the monsoon season. Hence, no *Peridinium stenii* was found (Table 2). The CCA analysis revealed that the populations of diatoms (*Ceratium* sp., *C. deflexum*, *C. macrocerose*, *Bacteriastrum varians*, and *Chaetoceros* sp.) and dinoflagellates (*Dinophysis caudate*, *B. varians*) corresponded to dissolved silica and phosphorus, respectively. Silica is an important element for diatoms as it is used for shell construction and growth but does not affect their diversity and community structure (Xiao et al., 2019). Furthermore, each species of diatom needs a different level of silica concentration. The suitable concentrations of phosphorus (P) are a limiting factor for dinoflagellates as it is involved in cell division, growth, and enzyme activity; too high or low concentrations of P in the water decrease growth (Li et al., 2016). Sikao River water, contaminated with P from agricultural fertilizers, anthropogenic material and silica from rock-weathering, will enrich the estuary in the monsoon season with excess nutrients (Snoeijs & Weckstrom, 2010). This is the reason that we found correspondence between phytoplankton density and AEP.

Parkmeng Estuary has an area of approximately 10 km^2 and is classified as a small, well-mixed estuary with an average depth of 1-5 meters. The maximum water temperature in the summer (March, 2018) was 32.15°C and the minimum in the monsoon season was 29.51°C (July, 2018). The maximum temperature and density of phytoplankton were recorded in March 2018, indicating that phytoplankton grows well in rising temperatures, possibly because their metabolic processes are activated (Trombetta et al., 2019). In addition, it might be suggested that the long period of light irradiation during the summer is also influential to phytoplankton growth because of the increased photosynthesis period. As the discussed data, those of phytoplankton were susceptible accorded to the fluctuation of phosphate, silicate and ammonia, pH, conductivity, and temperature in this estuary. Therefore, both waste material and heating water from boat engine were loaded into this estuary might be affected phytoplankton density. This information indicated that phytoplankton density should be used as a biological index of the aquatic environmental status of Parkmeng estuary. However, to assess the environmental quality of estuary by using phytoplankton density should collect long term data or setup an annual monitoring program for more precisely predicted.

Conclusions

The Parkmeng Estuary is a high biodiversity area where is used as a port harbor and tourism site. We investigated the density of phytoplankton and their relationships to aquatic environmental parameters to assess the biological status of this estuary. Chromophyta showed the highest density (74.96%), and the rest of the phytoplankton population was made up of Cyanophyta (25.04%). This phytoplankton can be classified as summer and monsoon plankton by CCA analysis. Micronutrients, pH, conductivity, and temperature were related to density of phytoplankton. Diatoms (*Peridinium stenii*, *Triceratium* sp., *Rhizosolenia* sp., *Cyclotella stylorum, B. varians*) and the dinoflagellate *D. caudata* can be used as a biomarker for changing AEP in this estuary. Based on the studied data, we proposed that the environmental status of Parkmeng estuary in the years of 2018 was in richness situation. However, the anthropogenic waste release should be controlled.

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