ORIGINAL PAPER

Diversity and Abundance of Phytoplankton in the Ports of Chonburi and Rayong Provinces, the Gulf of Thailand

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Received: 04 July 2021 / Revised: 29 August 2021 / Accepted: 29 August 2021

Abstract. Phytoplankton are the main component of food webs in marine and coastal ecosystems and can be used as a bioindicator to investigate water quality, ecosystem fertility, and ocean circulation, which are also crucial for the fisheries in Thailand. Phytoplankton communities reflect climate variability and changes that occur in coastal and marine ecosystems. Here, we aimed to study the diversity and density of phytoplankton in the Chonburi and Rayong ports. Phytoplankton were collected using a 20-micron mesh size plankton net with horizontal hauling from six study sites, including Ao Udom, Laem Chabang Port, and Ao Bang La Mung in Chonburi Province and the Hin Khong, Hat Nong Fab, and Ko Saket in Rayong Province. The results showed that a total of 68 taxa were found in this study. The highest abundance of phytoplankton was found in Bang Lamung in the summer season (39,400.23±773.31 ind./L), while the lowest was also found in Bang Lamung (3,288.35±16.38 ind./L) in the rainy season. The total abundance of phytoplankton in the vicinity of Chonburi ports in the summer season was significantly higher than that in the rainy season and those observed in both seasons in the vicinity of Rayong ports (p <0.05). The species composition in the vicinity of Chonburi ports was dominated by diatoms, while in the vicinity of Rayong port was dominated by diatoms and dinoflagellates. Our study provides baseline data of phytoplankton communities in the vicinity of Chonburi and Rayong ports.

Keywords: industrial port, phytoplankton, diatom, dinoflagellate, seasonal variation

1. Introduction

Phytoplankton are the main primary producer of marine ecosystems globally and play specific roles in biogeochemical cycling. Phytoplankton are an important component of the marine food chain because of their photosynthesis, which serves as the primary food source for various consumers (Waniek & Holliday, 2006). The abundance and distribution of phytoplankton vary spatially and locally (Matos et al., 2011). At the global scale, phytoplankton species diversity varied according to environmental variability and different latitudes (Barton et al., 2010). The population density and species composition of phytoplankton are susceptible to environmental changes inducing the changes in water quality characteristics (Salmaso et al., 2006; Chellappa et al., 2009; El-Sherbiny et al., 2011; Katsiapi et al., 2011).

Phytoplankton community in near-shore and coastal water is mainly influenced by several environmental factors such as nutrient availability, predator communities, and land-driven inputs (Bhaskar et al., 2011). Several anthropological factors can generate several impacts, such as coastal water quality (eutrophication), the introduction of non-native species from ship's ballast water, changes in predator community (overfishing). Concerns on the environmental impacts of ballast water from ships have been growing, particularly in areas with dense shipping industries. Various anthropogenic activities can affect water quality in harbor/port areas due to the release of toxic chemicals, untreated wastewater, oil pollutants, and biological agents that can potentially be invasive species (Zaiko et al., 2011). Invasive species are considered the major problems to our world's oceans (in addition to marine pollution and overused marine resource). Commercial transportation across oceanic or interoceanic ships are engendered non-native invasive phytoplankton species via the ballast water of ships (Zaiko et al., 2011; Liebich, 2012).

Invasive phytoplankton species blooming is significantly impacted the quality of seawater due to their toxic secondary metabolism, which is affected an organism's health. The toxics can be released into seawater or incorporated by the biota and transfer via the food web (Butrón et al., 2011; Costa et al., 2017). The most significantly affected from invasive phytoplankton species well known cause ecological and aquaculture on the coastal zone impacts all aquatic system types. Diatoms (*Coscinodiscus wailesii*) and several dinoflagellates species (*Gymnodinium catenatum*, *Alexandrium minutum*, *Ostreopsis* cf. *ovata*, *Prorocentrum minimum*) have been considered as invasive (Costa et al., 2017). Thirty potentially invasive phytoplankton species were identified to date around Bilbao harbor facilities. There could be a high risk of exporting at least *Alexandrium minutum*, *Dinophysis* sp., *Heterosigma aka-shiwo*, *Karlodinium* sp., *Ostreopsis* cf. *siamensis*, *Pfiesteria*-like, and *Prorocentrum minimum*. Those invasive phytoplankton species show the success of growth in the different oceans and varying salinity (Butrón et al., 2011).

Regarding the concerns, taxonomic studies and regular monitoring of the community structure and dynamics of phytoplankton are highly needed to understand community dynamics and functional groups, then mitigate the impacts of ballast water on marine environment (Gameiro et al., 2007; Baliarsingh et al., 2012). However, the available literature on a dynamic population of phytoplankton communities at the different harbors of the Gulf of Thailand is still limited, making it difficult to properly manage the ecological impacts of ballast water on marine ecosystems. In Thailand, such phytoplankton information is highly required for the management of ballast water. Therefore, this study aims to investigate the diversity and density of phytoplankton in the vicinities of industrial ports in Chonburi and Rayong Provinces, the Inner and Eastern Gulf of Thailand.

2. Materials and Methods

2.1 Location of study sites

A total of six study sites are located near major maritime ports in the Inner and Eastern Gulf of Thailand, including Ao Udom (13°02′53″N, 100°51′23″E), Laem Chabang Port (13°07′37″ N, 100°53″03″E), Ao Bang Lamung (13°01′57″ N, 100°53″11″E) in Chonburi Province and Hin Khong (12°40′05″ N, 101°05″57″E), Hat Nong Fab (12°40′41″ N, 101°06″49″E), Ko Saket (13°38′51″ N, 101°10″10″E) in Rayong Province (Figure 1).

2.2 Sample collection

This study was conducted in the summer and rainy seasons during May and October in 2020. Phytoplankton were collected by using a 20 µm mesh-size plankton net with horizontal hauling. The phytoplankton samples were preserved in 4% buffered formalin in seawater then transported to the Marine Biodiversity Research Group laboratory for further identification. The phytoplankton were identified to genus level and identified to species level, if possible.

2.3 Statistical analysis

The total abundance of phytoplankton was expressed in individuals/L. One-way Analysis of Variance (ANOVA) with Turkey HSD was used to analyze the difference of mean total densities of phytoplankton between sites and seasons, using R Version 3.5.0.

3. Results

A total of 68 phytoplankton taxa were recorded in this study. A total of 52 and 40 taxa were found in the study sites in Chonburi and Rayong, respectively (Table 1). The highest density of phytoplankton was recorded at Bang Lamung in the summer season (39,400.23±773.31 ind./L), whereas the lowest one was found at Hin Nong Fab in the summer season

(3,288.35±16.38 ind./L), as shown in Figure 2. The densities of phytoplankton found in Chonburi ports were significantly higher than those found in Rayong ports (p <0.05). The spatial variation among study sites within each province was not detected.

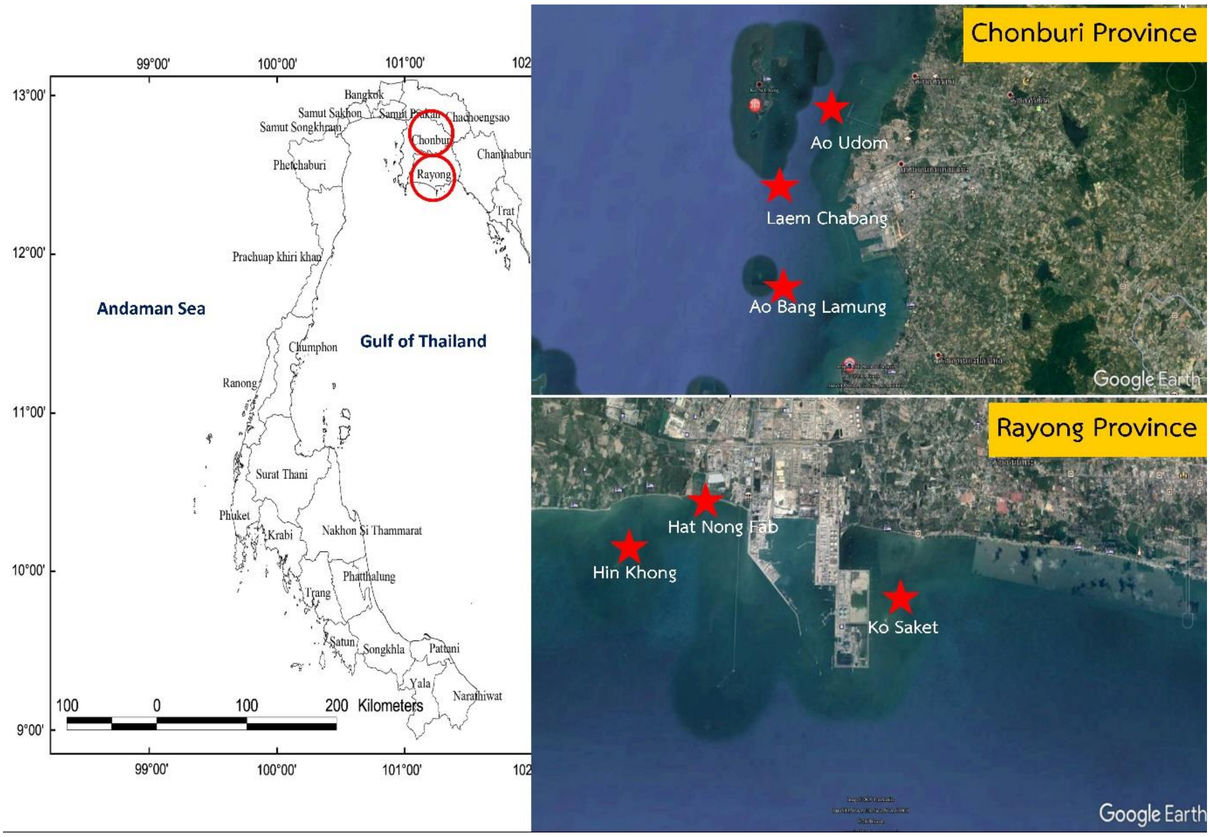


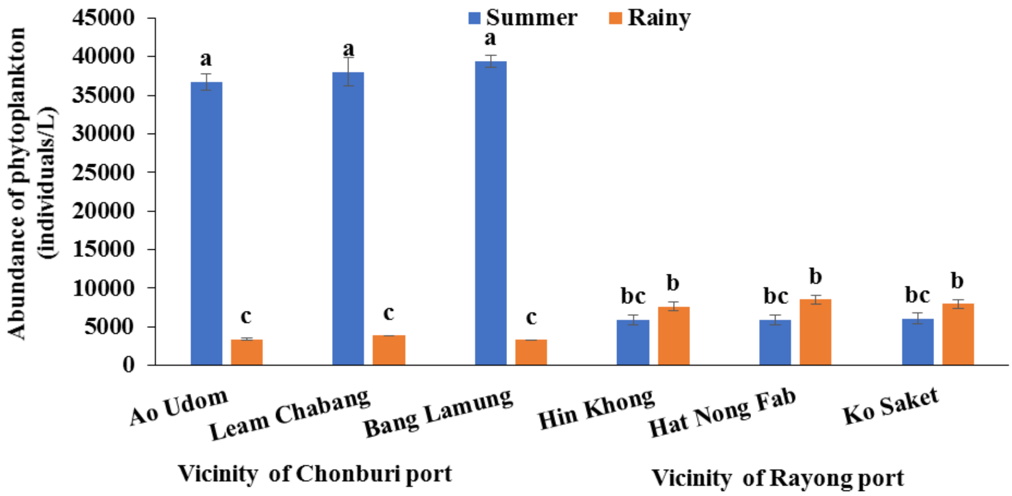
Figure 1. The location of study sites in Chonburi and Rayong Provinces

Table 1. Checklist of phytoplankton at the vicinities of Chonburi and Rayong ports

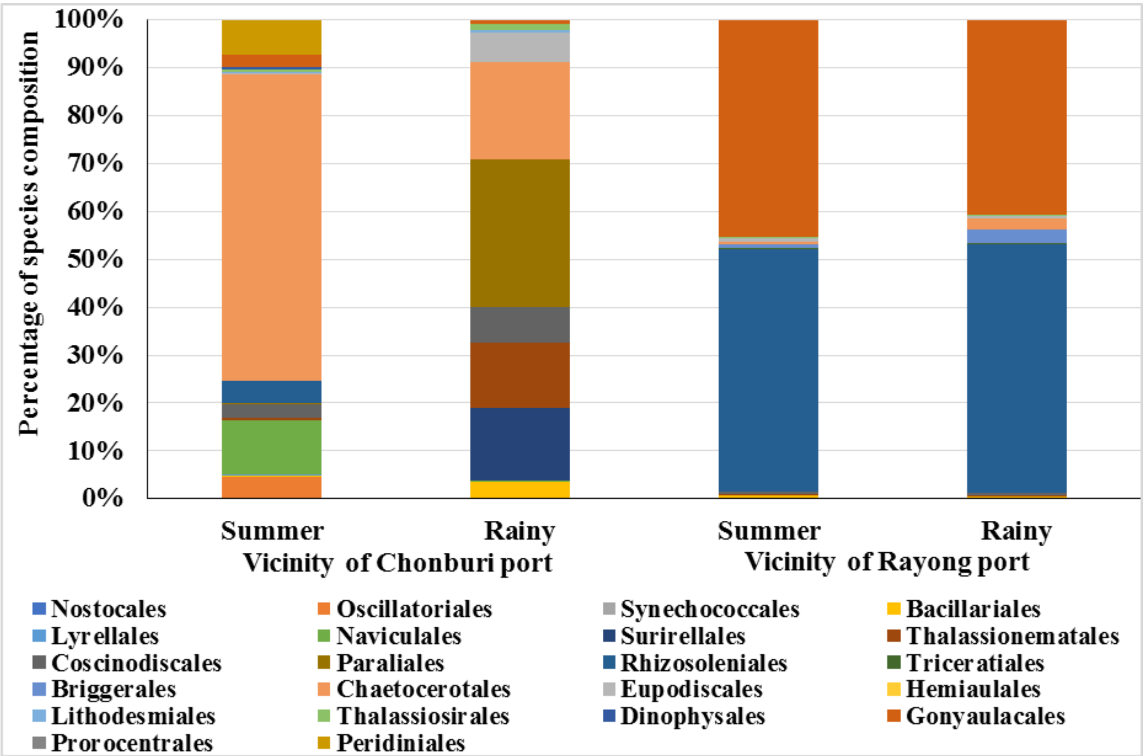
Classification	**Vicinity of Chonburi ports**		**Vicinity of Rayong ports**	
	Summer season	**Rainy season**	**Summer season**	**Rainy season**
Cyanobacteria				
Cyanophyceae				
Nostocales				
Nostocaceae				
Richelia intracellularis			✓	
Oscillatoriales				
Oscillatoriaceae				
Oscillatoria sp.	✓	✓		
Synechococcales				
Merismopediaceae				
Merismopedia punctata	✓	✓		
Bacillariophyta				
Bacillariophyceae				
Bacillariales				
Bacillariaceae				
Bacillaria paxillifera	✓	✓	✓	✓
Nitzschia lorenziana		✓		
Pseudo-nitzschia turgidula		✓		
Lyrellales				
Lyrellaceae				

Classification	Vicinity of Chonburi ports		Vicinity of Rayong ports	
	Summer season	Rainy season	Summer season	Rainy season
Lyrella sp.	✓			
Naviculales				
Naviculaceae				
Navicula sp.	✓			
Pleurosigmataceae				
Pleurosigma spp.	✓	✓		
Pleurosigma normanii		✓		
Surirellales				
Surirellaceae				
Stenopterobia sigmatella		✓	✓	
Thalassionematales				
Thalassionemataceae				
Thalassionema spp.	✓	✓		
Thalassionema bacillare	✓	✓	✓	✓
Thalassionema frauenfeldii	✓	✓		
Thalassionema nitzschoides	✓	✓		
Coscinodiscophyceae				
Coscinodiscales				
Aulacodiscaceae				
Aulacodiscus kittonii			✓	✓
Coscinodiscaceae				
Coscinodicus spp.	✓	✓	✓	
Palmeria sp.	✓			
Palmeria hardmaniana		✓	✓	
Hemidiscaceae				
Actinoptychus octonarius		✓	✓	✓
Paraliales				
Paraliaceae				
Paralia sulcata	✓			
Rhizosoleniales				
Probosciaceae				
Proboscia sp.	✓			
Proboscia alata			✓	✓
Rhizosoleniaceae				
Guinardia spp.	✓			
Guinardia cylindrus		✓	✓	✓
Guinardia flaccida		✓	✓	✓
Pseudosolenia calcar-avis		✓	✓	✓
Rhizosolenia spp.	✓	✓	✓	✓
Rhizosolenia alata	✓	✓	✓	✓
Rhizosolenia Formosa	✓	✓	✓	✓
Rhizosolenia hyaline			✓	✓
Rhizosolenia setigera	✓	✓	✓	✓
Rhizosolenia striatra	✓	✓	✓	✓
Rhizosolenia styliformis			✓	✓
Triceratiales				
Triceratiaceae				
Triceratium sp.	✓			
Triceratium favus			✓	✓
Mediophyceae				
Briggerales				
Streptothecaceae				
Streptotheca tamesis			✓	✓

Classification	Vicinity of Chonburi ports		Vicinity of Rayong ports	
	Summer season	**Rainy season**	**Summer season**	**Rainy season**
Chaetocerotales				
Chaetocerotaceae				
Bacteriastrum furcatum	✓		✓	✓
Chaetoceros spp.	✓	✓	✓	✓
Chaetoceros affinis	✓	✓	✓	✓
Chaetoceros avequatorialis	✓	✓		
Chaetoceros curvisetus	✓	✓	✓	✓
Chaetoceros didymus	✓	✓		
Chaetoceros lorenzianus	✓	✓		
Chaetoceros mitra	✓	✓	✓	✓
Eupodiscales				
Odontellaceae				
Odontella spp.	✓			
Odontella sinensis		✓	✓	✓
Hemiaulales				
Hemiaulaceae				
Eucampia zodiacus		✓	✓	
Lithodesmiales				
Lithodesmiaceae				
Ditylum sol	✓	✓	✓	
Tropidoneis sp.	✓			
Thalassiosirales				
Lauderiaceae				
Lauderia spp.	✓			
Thalassiosiraceae				
Thalassiosira thailandica		✓	✓	✓
Miozoa				
Dinophyceae				
Dinophysales				
Dinophysaceae				
Dinophysis sp.	✓			
Gonyaulacales				
Ceratiaceae				
Ceratium spp.	✓	✓	✓	✓
Ceratium breve			✓	✓
Ceratium deflexum	✓	✓	✓	✓
Ceratium furca			✓	✓
Ceratium fusus			✓	✓
Ceratium macroceros	✓	✓	✓	✓
Ceratium trichoceros	✓	✓	✓	✓
Ceratium tripos	✓	✓	✓	✓
Cladopyxidaceae				
Cladopyxis brachiolata			✓	
Pyrocystaceae				
Pyrophacus steinii	✓	✓	✓	✓
Prorocentrales				
Prorocentraceae				
Prorocentrum sp.	✓			
Peridiniales				
Oxytoxaceae				
Oxytoxum sp.	✓			
Protoperidiniaceae				
Protoperidinium spp.	✓			

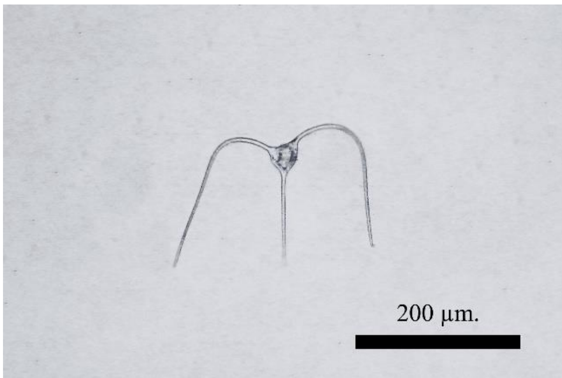


Figrue 2. The abundance of phytoplankton in the study sites at the vicinities of Chonburi and Rayong ports

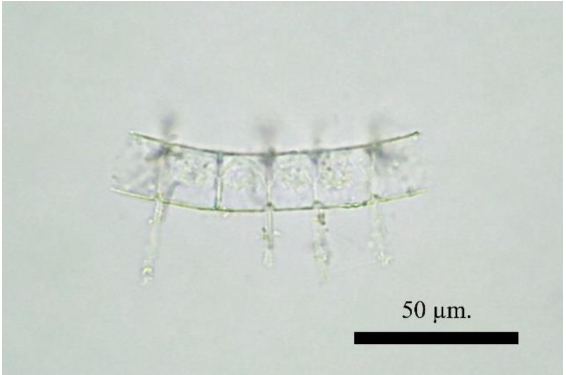


Figrue 3. Seasonal composition of phytoplankton in sampling areas at the vicinities of Chonburi and Rayong ports

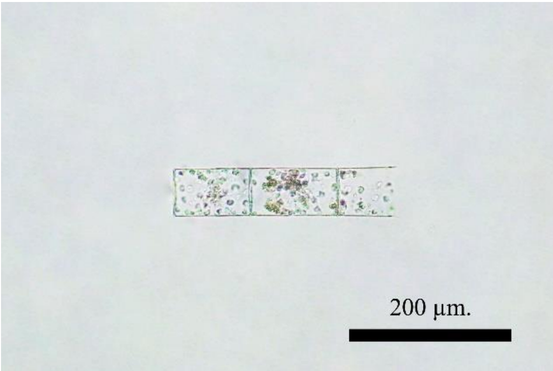
In the vicinities of Chonburi port, the phytoplankton belonging to order Rhizosoleniales, Chaetocerotales, and Briggerales were found as the dominant groups, including *Guinardia flaccida*, *Chaetoceros curvisetus*, and *Streptotheca tamesis.* In contrast, the phytoplankton communities observed in the study sites in the vicinities of Rayong port were dominated by *Proboscia alata*, *Guinardia flaccida* (order Rhizosoleniales), and *Ceratium trichoceros* (order Gonyaulacales) (Figure 3).



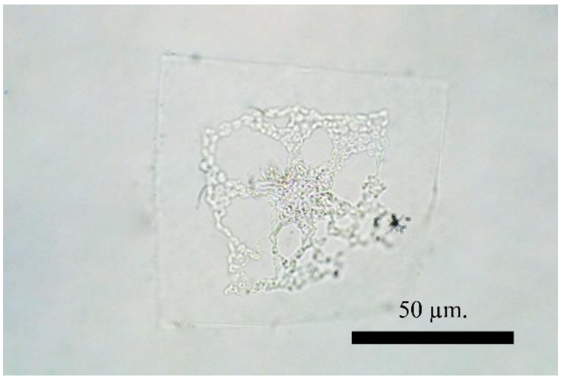
Ceratium trichoceros



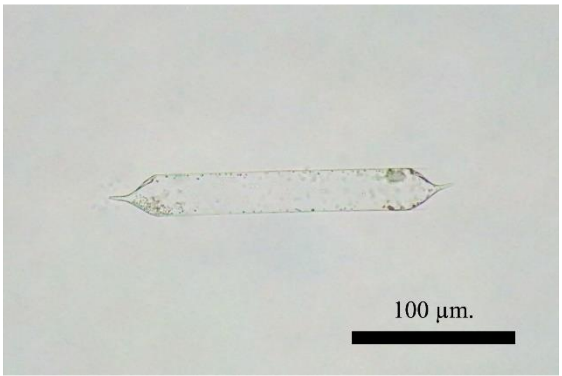
Chaetoceros curvisetus



Guinardia flaccida



Streptotheca tamesis



Proboscia alata

Figrue 4. Some major phytoplankton found in the vicinities of Chonburi and Rayong ports.

4. Discussion

Our results showed that the abundance and diversity of phytoplankton are similar to previous studies of Jitchum et al. (2012) and Taleb et al. (2016) that reported the phytoplankton density during the southwest monsoon was higher than the average abundance of phytoplankton during the northeast monsoon. The spatial variation of phytoplankton densities across the study sites may be influenced by currents, availability of nutrients, and coastal human activities (Mackey et al., 2002; Liebich, 2012; Costa et al., 2017). In the summer season, the mean densities of phytoplankton observed in Chonburi ports were higher than those in the vicinity of Rayong ports. This is because genus *Chaetoceros* were shown dominant phytoplankton groups in the summer season in the vicinity of Chonburi port. This might be due to influences of nutrients from the estuary, which is located close to Chonburi port, approximately

3.3 km. The nutrients from an estuarine environment are an important control on the magnitude and succession of phytoplankton density increases and the ecosystem structure in the coastal zone (Arndt et al., 2011).

Species composition of phytoplankton corresponds to previous studies of Yoosamran et al. (2006) and Jitchum et al. (2012). Overall, diatoms are dominant phytoplankton observed at most study sites. Dinoflagellates also showed high dominance in the total abundance of the phytoplankton at the vicinity of Rayong ports. The total abundance of the plankton community was influenced by the season, showing the peak during the summer season. It can be explained that it is due to the salinity and nutrient concentration in seawater change induced by the amount of rainfall from May to October. Moreover, the species composition of the phytoplankton community was generally marine species that may be susceptible to salinity change. In terms of a *Ceratium trichoceros* (order Gonyaulacales) was dominant group in the visibility of Rayong port. This result agreed with previous findings that the number of *Ceratium furca* increased during the northeast monsoon season (Chuchit, 2004; Chuchit and Yoosamran, 2005; 2006). However, this phenomenon is negatively correlated with salinity (Mardnui and Lirdwitayaprasit, 2007). In fact, the composition and density of phytoplankton changed have not been attributed to a single salinity but to a combination of temperature, solar irradiation, and nutrient input, etc. Therefore, although there is a nutrient gradient related to land inputs, phytoplankton abundance also greatly responds to temperature and irradiance as well (Paches et al., 2019). The diversity and abundance of phytoplankton change were occurring, when nutrients are available along the coastal area, phytoplankton dynamics change, especially the invasive phytoplankton species from ballast water.

Our study provides baseline data of phytoplankton communities in the vicinities of Chonburi and Rayong ports. Moreover, the diversity of phytoplankton in this study can support baseline data for managing invasive species from ship's ballast water. Further work should focus on the study of environmental factors related to phytoplankton growth and the importance of phytoplankton in the marine food web in the study areas.

Acknowledgments

We are most grateful to the staff of Marine Biodiversity Research Group, Faculty of Science, Ramkhamhaeng University, for their assistance in the field. This study was funded by a budget for research promotion from the Thai Government awarded to Ramkhamhaeng University and Marine Department, Ministry of Transport.

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