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Temporal and spatial dynamics of phytoplankton in the Palian river, Trang province, southern west coast of Thailand

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Abstract A study on species compositions, distribution of phytoplankton and water quality in the Palian river, Trang province was carried out. The results showed that a total of 82 phytoplankton species were which diatom was dominant in both season. The total cell density of 20,504 unit/L was found in summer, highest in Palian estuary. The dominant species found in the summer were *Cyclotella* sp., *Thalassiosira* sp., *Chaetoceros diversus*, *Chaetoceros lorenzianus*, *Bellerochea horologicalis*, *Thalassionema frauenfeldii*, *Thalassionema nitzschioides*. And the total cell density of 20,138 unit/L was found in rainy season highest in Palian estuary. The dominant species found in the rainy season were *Oscillatoria thiebautii*, *Amphora* sp., *Pleurosigma* sp. and *Bacillaria paxillifer*. The concentrations of ammonia-nitrogen, nitrate-nitrogen and orthophosphate-phosphorus were higher in summer season (0.056±0.014, 0.081±0.045 and 0.082±0.011 mg/L, respectively). The diversity index, evenness index and richness index were in the range of 2.460-3.720, 0.344-0.506, and 1.279-2.135, respectively. The results can be used to evaluate primary production, including the production of aquatic animals in water sources which is used as an index to measure the abundance of the water source ecosystem in the Palian river, Trang province.

Keywords: Species compositions, Distribution of phytoplankton, Palian river, Trang province

Introduction

The Palian river is formed by the Banthat mountain range in the provinces of Phatthalung and Satun. It is 58 kilometers long and has seven major streams that flow through 4 districts (Yan Ta Khao, Palian, Kan Tang and Hat Sumran districts) in Trang province to the Andaman Sea at the Palian estuary in the Hat Sumran districts. According to the flow of the streams, these areas are rich in biodiversity and natural resources. Particularly important are the mangrove forests in the Palian basin, which cover over 20,000 hectares and serve as habitats

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for juvenile aquatic animals and endemic species. More than 2,000 households in the Palian basin rely on mangrove forests and aquatic resources in the Palian river area. Clams and oysters are the most prominent aquatic animals in the Palian basin. Although the mangrove forest along the Palian river remains a rich mangrove ecosystem, over the past decade, the area's resources have been exploited for various purposes, including fishing activities such as oyster farming, mussel farming, and cage fish farming. Additionally, wastewater from aquaculture has been discharged into the river, directly impacting the ecosystem, leading to a decline in aquatic resources (Ramarn *et al*., 2017).

Phytoplankton are small organisms that float in water bodies carried by waves and wind. They contain pigments in their cells, allowing them to absorb light energy and use it, along with carbon dioxide, in the process of photosynthesis to produce organic substances. They play a crucial role in aquatic ecosystems as primary producers in the food chain. Phytoplankton can photosynthesize and create organic matter to serve as food for other aquatic animals. They can be found in freshwater, brackish water, seawater and are usually distributed only in areas where light penetrates (Wongrat, 1999). The spread of phytoplankton can also be used as an index to measure the fertility of aquatic ecosystems. Phytoplankton are an important factor and determine the growth rate and survival rate of aquatic animals because they serve as food for the nursery stage of young aquatic animals and filter feeders such as shrimp, crabs, and mollusks (Yusuk, 1998), which are considered phytoplankton as the basic natural food for living organisms (primary producer) in aquatic environments. If phytoplankton undergoes changes, it will inevitably affect the consumers in the next trophic level in the aquatic ecosystem (Gunbua *et al*., 2014).

The study of temporal and spatial changes in phytoplankton aimed to examine aspects of water quality by collecting both physical and chemical water quality data, and phytoplankton samples in the Palian river, Trang province.

Materials and methods

Study area

Sampling points along the entire stretch of the Palian river were determined which based on ecological characteristics with different environments as follows: Station 1 (ST1) upper river; Thung Khai subdistrict, Yan Ta Khao district, Trang province, Coordinates 47N 568263N 822815E UTM. Station 2 (ST2) upper river; Thung Krabue subdistrict, Yan Ta Khao district, Trang province, Coordinates 47N 566788N 818211E UTM. Station 3 (ST3) middle river; Ban Na

subdistrict, Palian district, Trang province, Coordinates 47N 565811E 812292E UTM. Station 4 (ST4) Palian estuary; Had Samran subdistrict, Had Samran district, Trang province, Coordinates 47N 557579E 801781E UTM (Figure 1).

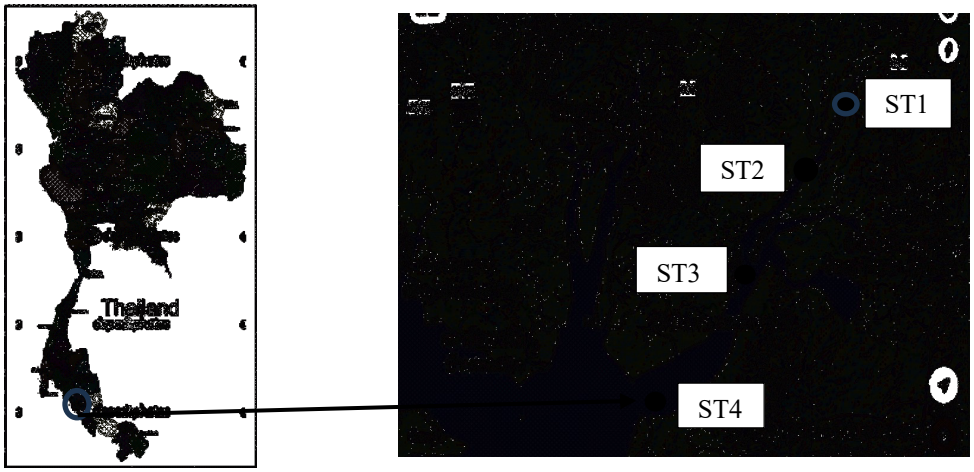

Figure 1. Location of study site and sampling stations in the Palian river, Trang province (Source: https://www.google.co.th/maps/place/ Palian river)

Study of certain water quality parameters in the Palian river, Trang province

Measurement of water quality parameters and water sampling in the Palian river, Trang province, was conducted in 4 areas (which are the same areas where phytoplankton samples were collected) in April 2023 (summer) and August 2023 (rainy season). Water temperature, salinity, pH, and dissolved oxygen (DO) levels were measured at a water depth of approximately 30 cm from the water surface using a Horiba 1U-52 field water quality meter. Water transparency was measured using a Secchi disc and water samples were collected using a vertical type water sampler at a mid-water depth of 1,000 mL. The water was collected in plastic bottles and all samples were placed in a cooling storage box for laboratory analysis of nutrient levels. For nutrient analysis in water, ammonia was measured using the Koroleff's Indophenol blue method, nitrite using the Colorimetric method, nitrate using the Cadmium reduction method, orthophosphate using the Ascorbic acid method (APHA, AWWA and WEF, 2017), and silicate in water using the Molybdosilicate method (Parsons *et al*., 1992). For water quality data analysis, the average water quality data for each month was analyzed, and the statistical differences in the average water quality parameters between the sampling months were analyzed using the Analysis of Variance (ANOVA) method with SPSS for Windows version 23.0.

Classification of phytoplankton

Phytoplankton species were classified by verifying taxonomic accuracy according to Wongrat (1999), Chatmongkolkul and Chantangsee (2005) and Peerapornpisan (2015). A count of the number of phytoplankton was conducted in the laboratory using the Natural Unit Count method with a high-power compound microscope, randomly sampling 3 replicates per station and calculating the phytoplankton density. Then, the data to calculate the Diversity Index, Evenness Index, and Richness Index were analysed using Primer 5 software.

Study on species compositions, distribution and density of phytoplankton in the Palian river, Trang province

Phytoplankton samples were collected in 4 areas (which are the same areas where water samples were collected) at a depth of approximately 30-50 cm from the water surface in April 2023 (summer) and August 2023 (rainy season) using the daytime filtering method using a two-liter plastic beaker to scoop water to a volume of 50 L, filtering the water through a plankton net with a mesh size of 20 microns and storing the filtered water samples in plastic bottles. The samples were preserved with neutral formaldehyde at a final concentration of 2% before returning the samples for analysis to identify species down to the lowest taxonomic rank at the Faculty of Science, Ramkhamhaeng University, Huamark, Bang Kapi, Bangkok.

Study of the relationship between water quality parameters and the density of phytoplankton in the Palian river, Trang province

The average density of phytoplankton and water quality were analysed in each season using the Pearson's correlation coefficient between the density of all phytoplankton and water quality.

Results

Physical and chemical water quality parameters in the Palian river, Trang province

The water quality in the study area was found to have an average water temperature ranging from 28.53±0.84 to 31.25±1.55 ^{o}C. The average salinity ranged from 3.75±7.50 to 24.75±4.11 ppt. The average pH value of the water

ranged from 5.48±0.50 to 6.27±0.95. The dissolved oxygen (DO) levels averaged between 7.17±0.48 and 7.28±0.51 mg/L. The average transparency ranged from 0.24±0.08 to 1.15±0.82 m. In terms of nutrient levels in the water sources, including ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, orthophosphate-phosphorus and silicate, it was found that the average concentrations of nitrate-nitrogen and orthophosphate-phosphorus exceeded the thresholds suitable for aquatic life. The average nitrate-nitrogen levels were higher than the standard seawater quality for natural resource conservation in both seasons. The average orthophosphate-phosphorus levels exceeded the standard seawater quality for natural resource conservation only in the summer season (April 2023). The average silicate concentration varied between 1.134±0.239 to 3.293±1.213 mg/L. The water quality in most factors showed significant statistical differences ($P<0.05$) when comparing the averages in each season (Table 1). However, the water quality in nearly all factors showed no significant statistical differences ($P>0.05$) when comparing the averages at each station. (Table 2)

Table 1. Average seasonal water quality in the Palian river, Trang province between April 2023 and August 2023

Water quality parameter	April 2023 (summer season)	August 2023 (rainy season)	p-value
Temperature (°C)	31.25±1.55	28.53±0.84	0.021
Salinity (ppt)	24.75±4.11	3.75±7.50	0.003
pH	5.48±0.50	6.27±0.95	0.193
Dissolved oxygen (mg/L)	7.28±0.51	7.17±0.48	0.764
Transparency (m)	1.15±0.82	0.24±0.08	0.070
Total ammonia (mg/L as nitrogen)	0.056±0.014	0.005±0.003	0.000
Nitrite (mg/L as nitrogen)	0.002±0.001	0.006±0.006	0.263
Nitrate (mg/L as nitrogen)	0.081±0.045	0.078±0.042	0.925
Orthophosphate (mg/L as phosphorus)	0.082±0.011	0.006±0.001	0.000
Silicate (mg/L)	1.134±0.239	3.293±1.213	0.013

Table 2. Average water quality at each sampling area in the Palian river, Trang province between April 2023 and August 2023

Water quality parameter	upper river (ST1)	upper river (ST2)	middle river (ST3)	Palian estuary (ST4)	p-value
Temperature (°C)	28.89±1.38	29.16±1.41	30.03±2.47	31.48±2.43	0.606
Salinity (ppt)	12.50±17.68	12.00±16.97	10.00±14.14	22.20±10.61	0.841
pH	4.84±0.16	6.24±0.71	6.00±0.37	6.42±0.99	0.202
Dissolved oxygen (mg/L)	7.61±0.14	7.49±0.19	7.26±1.13	6.53±0.11	0.006
Transparency (m)	0.62±0.45	0.72±0.73	1.25±1.34	0.19±0.05	0.646
Total ammonia (mg/L as nitrogen)	0.030±0.040	0.028±0.028	0.024±0.029	0.040±0.049	0.975
Nitrite (mg/L as nitrogen)	0.002±0.000	0.002±0.001	0.002±0.001	0.009±0.009	0.495
Nitrate (mg/L as nitrogen)	0.066±0.024	0.084±0.047	0.089±0.023	0.078±0.086	0.972
Orthophosphate (mg/L as phosphorus)	0.045±0.056	0.049±0.064	0.044±0.053	0.038±0.043	0.997
Silicate (mg/L)	2.797±2.350	2.380±1.414	2.470±1.782	1.206±0.560	0.792

The species compositions, distribution and density of phytoplankton in the Palian river, Trang province

A total of 82 species from 55 genera of phytoplankton were found, including 4 species of blue-green algae (Division Cyanophyta), accounting for 4.88%, 6 species of green algae (Division Chlorophyta), accounting for 7.32%, and 72 species of golden-brown algae (Division Chromophyta), accounting for 87.80% (59 species of diatoms; 71.95% and 13 species of dinoflagellates 15.85%). The total density of phytoplankton was 40,642 unit/L, with the highest average density at the Palian estuary (ST4). The dominant phytoplankton species found included *Oscillatoria thiebautii*, *Cyclotella* sp., *Thalassiosira* sp., *Chaetoceros diversus*, *Chaetoceros lorenzianus*, *Bellerochea horologicalis*, *Thalassionema frauenfeldii*, *Thalassionema nitzschioides*, *Amphora* sp., *Pleurosigma* sp. *Bacillaria paxillifer* and *Cylingdrotheca closterium* account for 70.49% of the total phytoplankton. The phytoplankton found at all stations in both seasons include the diatom species *Thalassiosira* sp. and *Pleurosigma* sp. (Table 3).

When considering the species composition and density of phytoplankton by season, it was found that in summer, a total of 53 species from 40 genera were identified, including 2 species of blue-green algae, 6 species of green algae, and 45 species of golden-brown algae (39 species of diatoms and 6 species of

dinoflagellates). The total phytoplankton density was 20,504 unit/L, with the highest density recorded at the mouth of the Palian River (Figure 2). The dominant phytoplankton species found included *Cyclotella* sp., *Thalassiosira* sp., *Chaetoceros diversus*, *Chaetoceros lorenzianus*, *Bellerochea horologicalis*, *Thalassionema frauenfeldii*, *Thalassionema nitzschioides* and *Cyclotella closterium*, which accounted for 59.43% of the total phytoplankton. The phytoplankton species found at all stations in summer included the diatoms *Cyclotella* sp., *Thalassiosira* sp., *Melosira dubia*, *Leptocylindrus danicus*, *Coscinodiscus gigas*, *Pleurosigma* sp., *Surirella* sp. and *Protoperidinium* sp. (Table 3) In the rainy season, a total of 69 species and 49 genera of phytoplankton were found, including 4 species of blue-green algae and 65 species of brown algae (56 species of diatoms and 9 species of dinoflagellates). The total phytoplankton density was 20,138 unit/L, with the highest density at the station near the Palian estuary (Figure 2). The dominant phytoplankton species found were *Oscillatoria thiebautii*, *Amphora* sp., *Pleurosigma* sp. and *Bacillaria paxillifer* accounts for 61.39% of the total phytoplankton. The phytoplankton found at all stations during the rainy season include the blue-green algae; *Oscillatoria thiebautii*, the diatoms; *Thalassiosira* sp. and *Pleurosigma* sp. and the dinoflagellate species *Alexandrium* sp. (Table 3).

Table 3. Dominant species and average amount of phytoplankton during summer and rainy season in the Palian river, Trang province between April 2023 and August 2023

Season	Dominant species	Average amount (unit/liter)	Total amount (%)
Summer	*Cyclotella* sp.	1,856	9.05
	Thalassiosira sp.	2,439	11.90
	Chaetoceros diversus	945	4.61
	Chaetoceros lorenzianus	810	3.95
	Bellerochea horologicalis	1,890	9.22
	Thalassionema frauenfeldii	2,270	11.07
	Thalassionema nitzschioides	1,233	6.01
	Cylingdrotheca closterium	743	3.62
Rainy season	*Oscillatoria thiebautii*	7,960	39.53
	Amphora sp.	957	4.75
	Pleurosigma sp.	1,311	6.51
	Bacillaria paxillifer	2,135	10.60

For phytoplankton density, when comparing the upper river stations (ST1 and ST2), the middle river station (ST3), and the Palian estuary (ST4), it was found that the upper river stations (ST1 and ST2) had a higher total phytoplankton density in the summer than in the rainy season. For the middle river station (ST3) and the Palian estuary (ST4), the total phytoplankton density

was higher in the rainy season than in the summer. The station at the the Palian estuary (ST4) had the highest total phytoplankton density (33,875 unit/L), followed by the upper river station (ST1) (3,472 unit/L), the middle river station (ST3) (2,025 unit/L), and the upper river station (ST2) (1,270 unit/L), respectively (Figure 2).

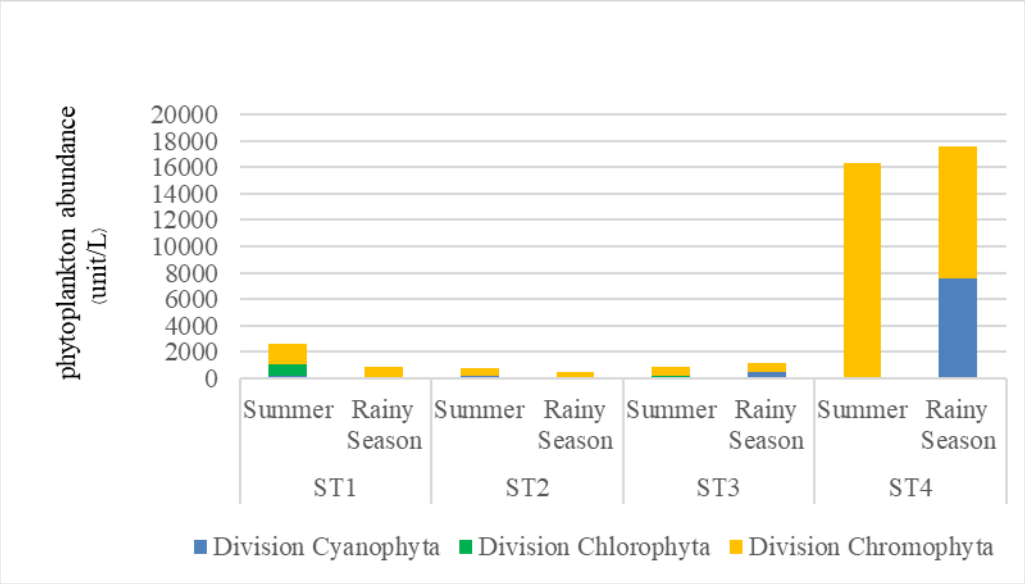

Figure 2. Phytoplankton abundance in the Palian river, Trang province between April 2023 and August 2023 (ST1: upper river, ST2: upper river, ST3: middle river and ST4: Palian estuary)

The ecological index of phytoplankton shows that the diversity index ranges from 1.79 to 2.85, with the highest values being the same in summer at the mid-river station (ST3) and the mouth of the Palian estuary (ST4). The lowest values were found in the rainy season at the upper river station (ST1). The evenness index ranges from 0.54 to 0.91, with the highest value in summer at the upper river station (ST2) and the lowest value in the rainy season at the upper river station (ST1). The richness index ranges from 2.39 to 5.94, with the highest value at the mid-river station (ST3) in the rainy season and the lowest value in summer at the upper river station (ST2) (Table 4).

The relationship between water quality and phytoplankton density in the Palian river, Trang province

The relationship between the total density of phytoplankton and water quality factors in the Palian river, Trang province, during April 2023 (summer) and August 2023 (rainy season) showed that the total density of phytoplankton had a very high negative correlation (r=-0.908) with dissolved oxygen, which was statistically significant (P<0.01). For other water quality factors, there was no statistically significant correlation (P>0.05) (Table 5).

Table 4. Univariate indices of phytoplankton in each area in the Palian river, Trang province between April 2023 and August 2023

Location	Diversity index		Evenness index		Richness index	
	Summer	Rainy season	Summer	Rainy season	Summer	Rainy season
ST1	2.73	1.79	0.82	0.54	3.44	3.97
ST2	2.57	2.73	0.91	0.87	2.39	3.59
ST3	2.85	2.46	0.89	0.65	3.55	5.94
ST4	2.85	2.48	0.83	0.70	3.09	3.48

Remark: ST1 : upper river, ST2 : upper river, ST3 : uiddle river ST4 : Palian estuary

Table 5. Correlation coefficience (r) between water quality factors and average phytoplankton abundance (unit/L) in the Palian river, Trang province between April 2023 and August 2023

Water quality parameter	Correlation coefficience (r)
	Average phytoplankton abundance (unit/liter)
Temperature	0.512 (p=0.194)
Salinity	0.424 (p=0.295)
pH	0.386 (p=0.345)
Dissolved oxygen	-0.908** (p=0.002)
Transparency	-0.425 (p=0.293)
Total ammonia	0.203 (p=0.630)
Nitrite	0.679 (p=0.064)
Nitrate	0.022 (p=0.959)
Orthophosphate	-0.079 (p=0.852)
Silicate	-0.462 (p=0.249)

Remark: ** indicates a significant difference at P<0.01

Discussion

The water quality in the Palian river, Trang province, when considered seasonally, shows that the average values of temperature, salinity, dissolved oxygen, transparency, average concentration of ammonia-nitrogen, average concentration of nitrate-nitrogen and average concentration of orthophosphate-

phosphorus are higher in the summer (April 2023). On the other hand, the average values of pH, average concentration of nitrite-nitrogen and average concentration of silicate are higher in the rainy season (August 2023). The average concentration of most nutrients in the Palian River during the summer is higher than in the rainy season, possibly because the water temperature in the summer is suitable for the decomposition of organic matter into nutrients (Khan and Siddique, 1971). But in most areas, the water quality is suitable for the survival of aquatic life throughout the year. The National Environmental Board's announcement on the sea water quality standards for natural resource conservation stipulates that the dissolved oxygen level must not be less than 4 mg/L (Pollution Control Department, 2023). The average pH level of the water is found to be quite acidic in all areas, mostly at levels unsuitable for aquatic life. According to the sea water quality standards for natural resource conservation, the pH level of sea water should be between 7.0-8.5. It was found that the average concentration of nitrate-nitrogen and orthophosphate-phosphorus exceeds the sea water quality standards for natural resource conservation (Pollution Control Department, 2023). The average concentration of nitrate-nitrogen in the water is higher than the sea water quality standards for natural resource conservation in both seasons, which stipulates that the concentration of nitrate-nitrogen in sea water should not exceed 0.02 mg/L. The average concentration of orthophosphate-phosphorus in the water exceeds the sea water quality standards for natural resource conservation only in the summer season (April 2023), which stipulates that the concentration of orthophosphate-phosphorus in sea water should not exceed 0.015 mg/L (Pollution Control Department, 2023). The presence of nitrogen and phosphate concentrations in the water in the area of the Palian river, Trang province, exceeding the standards indicates a deteriorating environmental condition.

The species composition, distribution and density of phytoplankton in the Palian river, Trang province, revealed a total of 82 species from 55 genera. This includes 4 species of blue-green algae (Division Cyanophyta), accounting for 4.88%, 6 species of green algae (Division Chlorophyta), accounting for 7.32% and 72 species of golden-brown algae (Division Chromophyta), accounting for 87.80% (59 species of diatoms; 71.95% and 13 species of dinoflagellates 15.85%). Consistent with the research of Naik *et al*. (2009), which studied phytoplankton in the estuaries along the eastern coast of India, it was found that diatoms were the dominant group. Additionally, this is similar to the findings of phytoplankton studies in the Trat estuaries, Chanthaburi estuaries and Rayong estuaries, where diatoms were also the most prevalent group. The dominant species found in all three estuaries included *Chaetoceros* spp., *Skeletonema costatum*, *Bacteriastrum furcatum* and *Lauderia* sp. (Pransin *et al*., 2014)

Additionally, this is consistent with the study by Paibulkichakul, *et al*. (2015) in the mangrove forest of Bang Sakaeo village, Chanthaburi province, which found a total of 63 genera of phytoplankton from 3 divisions: Division Chromophyta, Division Chlorophyta and Division Cyanophyta, comprising 49, 11, and 3 genera respectively. Throughout the study, it was found that phytoplankton in Division Chromophyta were the dominant group, accounting for 98.5% of the total. And it was also similar to the study results on the plankton community structure in the Trat Bay area, Trat province, which found phytoplankton in three divisions and 4 classes in Division Chlorophyta, Division Cyanophyta and Division Chromophyta. It was found that Division Chromophyta: Class Bacillariophyceae (diatoms) had the highest diversity (Sathienwongnusa, 2020) because these phytoplankton groups can adapt to constantly changing environments. Additionally, in this study, the total phytoplankton density was 40,642 unit/L, with the highest average density at the Palian estuary. The prominent phytoplankton species found included *Oscillatoria thiebautii*, *Cyclotella* sp., *Thalassiosira* sp., *Chaetoceros diversus*, *Chaetoceros lorenzianus*, *Bellerochea horologicalis*, *Thalassionema frauenfeldii*, *Thalassionema nitzschioides*, *Amphora* sp., *Pleurosigma* sp. *Bacillaria paxillifer* and *Cylingdrotheca closterium* accounting for 70.49% of the total phytoplankton. The phytoplankton found at all stations in both seasons included the diatom species *Thalassiosira* sp. and *Pleurosigma* sp. which is consistent with the study by Taleab and Noiraksa (2005) that examined the estuarine area of the eastern coastal region during the dry season (March 2005) and the rainy season (October 2005). They found 75 genera of phytoplankton, including 5 genera of blue-green algae, 11 genera of green algae, 47 genera of diatoms, 1 genus of golden-brown algae, 1 genus of silicoflagellates and 10 genera of dinoflagellates. The most widely distributed genera of phytoplankton were *Thalassiosira, Chaetoceros*, *Navicula* and *Pleurosigma*, respectively. This is consistent with the study of phytoplankton in the estuary of the Maeklong river, Samut Songkhram province, which found that the class Bacillariophyceae had the highest number of species and was the dominant group throughout the year. The most abundant phytoplankton species were *Chaetoceros pseudocurvisetus*, *Thalassiosira* spp., *Skeletonema costatum*, and Cylindrotheca closterium. Blue-green algae were found in slightly lower quantities, with the most abundant species being *Microcystis aeruginosa*, *Oscillatoria limnetica* and *Spirulina platensis* (Boondao, 2006). Additionally, it was found that the results were similar to the study on the seasonal changes of phytoplankton primary production in the lower Songkhla lake area, where a total of 5 divisions and 39 genera of phytoplankton were identified. The month with the highest abundance of phytoplankton was October 1993. The groups of

phytoplankton that were frequently found and quite abundant included blue-green algae and diatoms (Pholpanthin, 1995).

When considering the species composition, distribution, and density of phytoplankton by season, it was found that in the summer, a total of 53 species from 40 genera of phytoplankton were identified. These include 2 species of blue-green algae, 6 species of green algae, and 45 species of brown algae (39 species of diatoms and 6 species of dinoflagellates). The total density of phytoplankton was 20,504 unit/L (349 unit/L of blue-green algae, 1,077 unit/L of green algae and 19,078 unit/L of golden-brown algae). The highest density of phytoplankton was found at the Palian estuary. The dominant phytoplankton species included *Cyclotella* sp., *Thalassiosira* sp., *Chaetoceros diversus*, *Chaetoceros lorenzianus*, *Bellerochea horologicalis*, *Thalassionema frauenfeldii*, *Thalassionema nitzschioides* and *Cyclotella closterium*, which accounted for 59.43% of the total phytoplankton. The phytoplankton species found at all stations in the summer included the diatoms *Cyclotella* sp., *Thalassiosira* sp., *Melosira dubia*, *Leptocylindrus danicus*, *Coscinodiscus gigas*, *Pleurosigma* sp., *Surirella* sp. and *Protoperidinium* sp. During the rainy season, a total of 69 species from 49 genera of phytoplankton were found, including 4 species of blue-green algae and 65 species of brown algae (56 diatom species and 9 dinoflagellate species) with no green algae detected. The total phytoplankton density was 20,138 unit/L (8,175 unit/L of blue-green algae and 11,964 unit/L of golden-brown algae). The highest phytoplankton density was found at the Palian estuary. The dominant phytoplankton species included *Oscillatoria thiebautii*, *Amphora* sp. *Pleurosigma* sp. and *Bacillaria paxillifer*, accounting for 61.39% of the total phytoplankton. The phytoplankton found at all stations during the rainy season include the blue-green algae *Oscillatoria thiebautii*, the diatoms *Thalassiosira* sp., *Pleurosigma* sp. and the dinoflagellate species *Alexandrium* sp. It can be seen that the number of phytoplankton species during the rainy season is greater than in the summer, which is consistent with the study by Boondao (2006) in the Mae Klong estuary, Samut Songkhram province. The study found that the number of phytoplankton species was highest in May 2005 (rainy season) and lowest in April 2005 (summer). And from the data of both seasons, it was found that the total density of phytoplankton was slightly higher in the summer than in the rainy season. This is because in the summer, there is a higher amount of light and longer duration of light, with transparency suitable for photosynthesis and the growth of phytoplankton. Additionally, in the summer, the water temperature is suitable for the decomposition of organic matter into nutrients for phytoplankton. In contrast, during the rainy season, there are strong water currents and a large amount of sediment is washed from the land into the river, causing phytoplankton to photosynthesize and grow less, resulting

in a decrease in the amount of phytoplankton in the water source (Khan and Siddique, 1971). Furthermore, this study also found that the density of diatoms (Division Chromophyta) in the summer was higher than in the rainy season. In the rainy season, when salinity decreases, the density of blue-green algae was higher than in the summer. This is consistent with the study by Piumsomboon *et al*. (2003) in the Trat estuary, which found that during the dry season when the water is highly saline, diatoms are the dominant microplankton group. However, during the rainy season when the water is less saline, blue-green algae are the dominant phytoplankton group. For the overall density of phytoplankton compared by sampling stations, which include the upper river, the middle river, and the Palian estuary, it was found that the Palian estuary had the highest overall density of phytoplankton in both seasons. This is consistent with the study by Ramarn *et al*. (2017), which examined zooplankton in the Palian river area, Trang province, and found that zooplankton were most abundant at the Palian estuary. Zooplankton play an important role in the ecosystem as consumers of phytoplankton in aquatic environments. Therefore, when zooplankton are most abundant at the Palian estuary, it can be said that the phytoplankton density is also highest in that area during that time. The current study found that phytoplankton had the highest average density at the Palian estuary in both seasons, possibly because the estuary accumulates nutrients flowing from the land and during low tide, a variety of nutrients in large quantities are transported to the shore and sea. This leads to high abundance and diversity of aquatic resources around the estuary (Paibulkichakul *et al*., 2017). This is also consistent with the report by Eyre and Twigg (1997), which stated that the estuary is an important ecosystem as it is the starting point of energy transfer in the ecosystem and a crucial process in the exchange of nutrients between land and sea.

In terms of the ecological index of phytoplankton, it was found that the diversity index during the summer ranged from 2.57 to 2.85 and during the rainy season from 1.79 to 2.73. This differs from the report by Taleab and Noiraksa (2005), who studied the estuary area along the eastern coastal region and found that the diversity index of phytoplankton during the dry and rainy seasons ranged from 0.04 to 2.42 and 0.43 to 2.69, respectively. The diversity index of living organisms ranged from 1 to 3, indicating that the water source is still suitable for the survival of living organisms. However, if it is below 1, it indicates that the water source is unsuitable for the habitation of living organisms. If it exceeds 3, it indicates that the water source is suitable for the growth of living organisms (Tudorance *et al*., 1975). The results of this study suggest that the Palian river has moderate suitability for the survival of phytoplankton and aquatic life. The evenness index during the summer ranged from 0.82 to 0.91 and during the rainy season from 0.54 to 0.87. The richness index during the summer ranged from

2.39 to 3.55 and during the rainy season from 3.48 to 5.94. The relationship between the overall density of phytoplankton and environmental water quality factors in the Palian river, Trang province, found that the dissolved oxygen quality of the water influences the overall density of phytoplankton. This is consistent with a study conducted in the estuarine areas of the eastern coastal region, which found that the water quality factors most influencing the structure of phytoplankton communities are salinity, followed by dissolved oxygen, water transparency, pH, and temperature, respectively (Taleab and Noiraksa, 2005).

The information from the study can be used as a baseline for assessing and monitoring water quality. Furthermore, it serves as data for evaluating primary productivity and aquatic animal productivity in the water source, which are indicators of the ecosystem's fertility in the Palian river, Trang province. Additionally, it can assess the area's potential to support various future activities and can be used as a guideline for sustainable resource use.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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