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Effect of physico-chemical conditions on the phytoplankton community in the Sago Palm Wetlands, Nakhon Si Thammarat province, the Peninsular East Coast of Thailand

Chankaew, S.[1*], Chunta, S.[1], Baimai, V.[2] and Kiriratnikom, S.[3]

[1]Department of Interdisciplinary Management of Biodiversity, Faculty of Science and Technology, Chiang Rai Rajabhat University, Chiang Rai, Thailand; [2]Biodiversity Research Cluster, Department of Biology, Faculty of Science, Mahidol University, Bangkok, Thailand; [3]Department of Biological and Environmental Science, Faculty of Science, Thaksin University, Phatthalung, Thailand.

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Abstract A total of 30 genera of phytoplankton belonging to four divisions were identified. The highest of Shannon Wiener diversity index of phytoplankton were 2.463 in dry season of Trang River basin (TR4). The second-most abundant genera were *Euglena* and *Pandorina*. The water quality of all sampling sites were not clearly differed and classified as oligotrophic-mesotrophic status. Canonical correspondence analysis (CCA) after analyzed the relationship between the physico-chemical parameters and the phytoplankton. Among the environmental parameters, hardness and pH found to be the most important factors for *Bacillaria* and *Gomphonema* in the dry season. While, the wet season, *Eudorina*, *Pleurosigma* and *Synedra* were positively correlated with dissolved oxygen. *Fragilaria* was positively correlated with the ammonia content but *Bacillaria* was negatively correlated with total dissolved solids and conductivity.

Keywords: Phytoplankton, Sago Palm Wetlands, Water quality

Introduction

Microalgae or phytoplankton have numerous advantages that make them suitable for biodiversity and environmental monitoring studies**.**The productivity of the aquatic ecosystem depends on the phytoplankton (Parmar *et al*., 2016). The microalgae are one of the most rapid bio-indicator of water quality changes due to their short lifetime, instantaneous response to pollutants and easy to determine their numbers.Phytoplankton or microalgae as a lower plant that contains chlorophyll for photosynthesis. Microalgae are important for food, and agricultural crop production in fixing nitrogen, drug to treat various diseases,

[*] **Corresponding Author**: Chankaew, S.; **Email:** suriya_cha@nstru.ac.th

and wastewater disposal. Ecosystems are classified as producers and as a part of the primary food chain of aquatic organisms (Peerapornpisan *et al.*, 2007). Phytoplankton is sensitive to environmental change and has been used as water bio-indicator (Palmer, 1969). Some species go along in eutrophic water, while some species thrive in oligotrophic water. Some genera of phytoplankton are concerned as the most organic pollution-tolerant such as *Oscillatoria*, *Scenedesmus*, *Euglena*, *Nitzschia* and *Navicula* (Palmer, 1969). Peerapornpisal *et al.* (2007) using AARL-PP score method with dominant specie for evaluation water quality in freshwater bodies. Many researchers are interested in phytoplankton in terms of biodiversity in many areas and used as bio-indicators (Palmer, 1969; Sakset and Chankaew, 2013; Bellinger and Sigee, 2015; Prasertsin and Peerapornpisal, 2015).

Nakhon Si Thammarat province is one of the most biodiversity provinces in Thailand as an important watershed because of the mountain areas. There are many aquatic ecosystems in canal and stream flowing through the areas. In this area, a large variety of wetland plants are found as the endemic plants in the southern of Thailand is "Sago" (Sago palm, *Metroxylon* sp.). "Sago Palm" is a plant that plays an important role as the main plant in the wetlands because of the high biodiversity in sago forest ecosystem. In Malaysia, the sago palm is grown in the freshwater swamps, especially in the state of Sarawak (Phang *et al*., 2000).

This study focused on phytoplankton diversity in term of abundance, species compostion, seasonal distribution and its correlations with the water quality based on physical and chemical parameters in Sago plam wetland, Nakhon Si Thammarat, Thailand. The obtained data provided basic information and assessing aquatic resources of Sago plam wetland. It can be developed for aquatic animal and Sago palm resources management for sustainable utilization.

Materials and methods

Study sites

Data on phytoplankton diversity were collected which based on spatial and seasonal variability in the areas of the sago palm wetlands of the peninsular east coast basins of Thailand in Nakhon Si Thammarat province. It was obtained from sampling freshwater fishes in four river basins, namely the upper Pak Phanang River basin (UP), the lower Pak Phanang River basin (SP), the Trang River basin (TR) and the Tapi River basin (TP). Each of the river basins was included five survey stations in the total of twenty survey stations (Figure

1). The samples were collected during two seasons in 2020, summer (March to May) and the rainy season (September to November).

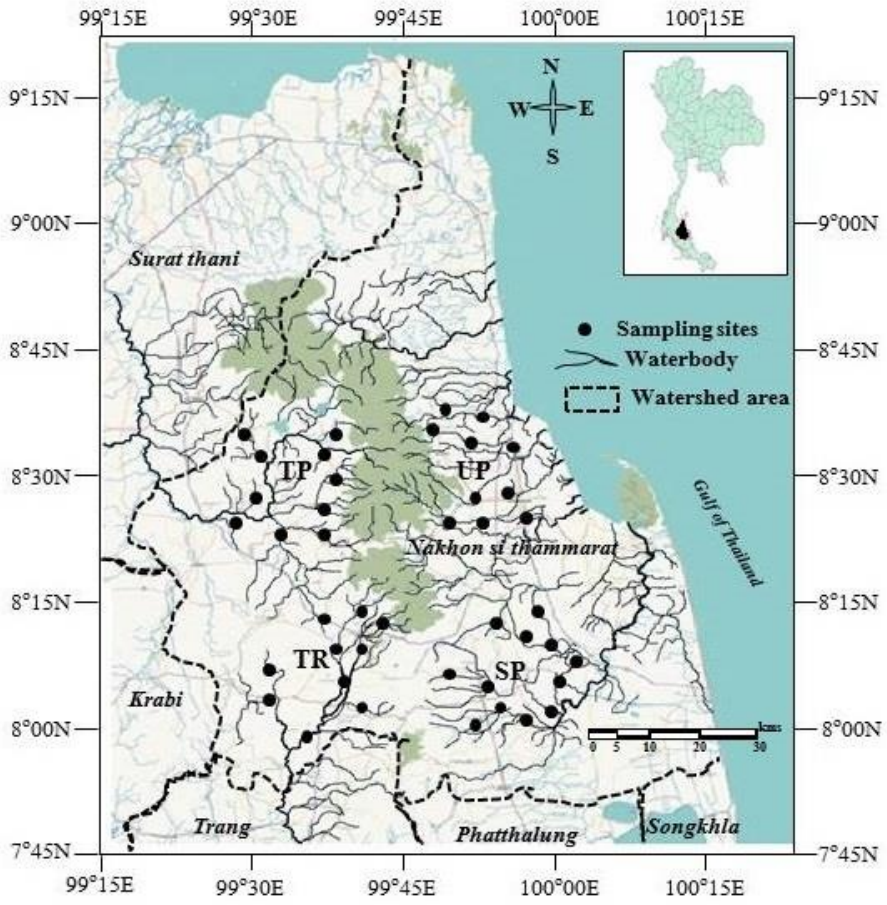

Figure 1. Map of sampling stations locates in the Upper Pak Phanang River Basin (UP), LowerPak Phanang River Basin (LP), Trang River Basin (TR), and Tapi River Basin (TP), Nakhon Si Thammarat province, Thailand
Source: Adapted from National Hydroinformatics Data Center (2020)

Samplings

The samples were collected from the sago forest wetland at 20 stations by in 2 seasons, dry and rainy seasons, 3 replications per site using phytoplankton net with pore size of 22 micron. Phytoplankton samples were collected vertically down from the water dept along with water quality measurement. The samples were filtered and preserved in Lugol's solution (Wongrat and

Boonyapiwat, 2003).The samples were then transported to the laboratory for identification into species. Phytoplankton was counted by using a Sedgewick rafter chamber following the methods in APHA, AWWA and WPCE (1989). The water quality was tested in terms of its physical and chemical during the fieldwork, using a fieldwork Lovibond 600 water quality gauge.

Phytoplankton identification, diversity index and data analysis

The phytoplankton species were classified according to morphology according to Presscott (1978), Lewmanomont *et al*., (1995), Wongrat (1995), John *et al*., (2002) and Peerapornpisan (2006). The Shannon-Wiener diversity index was done according to the method of Brower *et al*., (1997).

Statistical analyses were performed using software the multivariate statistical package (MVSP) for Windows. In order to identify interrelationships among sampling sites, the cluster analysis was presented as the percent similarity. The MVSP was used for Canonical Correspondence Analysis (CCA). The trophic status of water was evaluated from the main parameters such as dissolved oxygen (DO), conductivity, ammonia-nitrogen, nitrate-nitrogen and soluble reactive phosphorus by the Applied Algal Research Laboratory Physical and Chemical score (AARL PC score) (Peerapornpisal *et al*., 2004). The cluster and CCA data were transformed to square root and the axes extracted by Kaiser's rule.

Results

Phytoplankton community

A total of 30 genera of phytoplankton were found from 20 sampling sites of sago plam wetland, Nakhon Si Thammarat province, Thailand. It is classified into 4 divisions. The chrysophyte (11 genera) was the highest of phytoplankton, followed by the green algae (10 genera) while, euglenoid was lowest diversity with 4 genera. According to the numbers of phytoplankton, *Euglena* was the dominant genera, with 24.0±27.1 units/L. Freshwater diatom was the dominant group of Lower Pak Phanang River Basin (LP) and Tapi River Basin (TP) with *Navicula* were 21.6±1.7 units/L and 16.4±8.6 units/L, respectively, while the dominant group of the Trang watershed was *Euglena*, *Strombomonas* 22.8±13.2 units/L (Table 1).

Table 1. Number of species, density (units/L), distribution and AARL-PP score, of phytoplankton in the sago palm wetlands of Nakhon Si Thammarat province, Thailand

Division / genus	Dry season				Wet season			
	Sampling site				Sampling site			
	UP	SP	TR	TP	UP	SP	TR	TP
CYANOPHYTA								
Anabaena	7.8±15.6	5.2±5.2	1.2±2.4	12.4±17.9	0	0	0	0
Arthrospira	0	0	2.4±2.9	0	0	0	0	0
Lyngbya	1.2±1.5	0	2.8±3.4	0.6±1.3	0	0	0	0
Merismopedia	0.8±1.6	0	0	0.8±1.8	0	0	0	0
Oscillatoria	13.6±5.9	2.2±4.9	3.2±3.9	7.4±7.1	0	2.9±2.7	21.6±15.2	10.6±9.6
CHLOROPHYTA								
Closterium	0.6±2.8	2.4±3.6	20.6±21.6	1.4±3.1	4.3±8.7	0	0	0
Cosmarium	0	0	0	0	15.4±15.0	0	0	0
Eudorina	0.4±2.4	0.4±0.9	2.4±2.1	2.2±2.0	0	0	3.2±7.2	2.6±3.6
Gonium	0.4±0.8	0	0	0	0.8±1.2	0	0	0
Pandorina	24.0±11.2	2.8±6.3	5.2±3.2	0	8.3±9.0	85.1±62.5	0	36.9±36.1
Pediastrum	8.8±2.1	0.4±0.9	6.6±5.5	1.8±2.5	4.5±6.6	0	0	0
Pleurotaenium	0	0	0	0	0.5±0.8	1.8±3.6	7.4±16.5	7.3±6.7
Scenedesmus	6.6±0	0.4±0.9	0	0	3.5±5.1	0	0	0
Spirogyra	21.0±3.6	0.4±0.9	0.8±1.6	0.5±0.4	0.9±1.9	0	8.7±3.2	3.0±4.4
Staurastrum	0	2.2±4.9	0.4±0.8	0	1.7±2.5	0	0	0
Staurodesmus	22.4±0	1.4±1.9	0.6±1.2	0	0	0	0	0
Synedra	17.0±4.4	0.4±0.9	0	2.2±4.9	0	0	0	0
EUGLENOPHYTA								
Euglena	24.0±27.1	16.0±6.3	14±11.5	9.0±7.2	34.2±29.1	104.7±61.7	16.1±6.5	47.3±29.5
Phacus	0	3.4±7.6	2.4±3.5	0	15.6±5.6	95.5±57.9	7.5±4.8	41.4±29.9
Strombomonas	8.8±8.7	12.6±19.5	22.8±13.2	5.4±5.5	0	0	0	0
Trachelomonas	21.0±13.1	18.0±18.2	20.0±9.8	9.8±8.9	2.8±3.4	42.6±34.7	0	19.3±20.1
CHRYSOPHYTA								
Amphora	0.6±1.2	1.8±1.6	0	0	1.5±2.9	0	0	0
Bacillaria	2.2±4.4	0.6±1.3	0	2.2±4.9	2.0±4.0	0	0	0
Caloneis	0	0	0	0	0.9±1.3	0	0	0
Cymbella	1.6±3.2	0.6±1.3	0.6±1.2	0	0	0	0	0
Diatoma	0	0.4±0.9	0.4±0.8	0	0	0	0	0
Diatomella	6.6±9.5	8±8	10.0±5.8	0.4±0.9	0	0	0	0
Euastrum	0	0	0	0	0	0	1.8±4.0	1.5±2.0
Fragilaria	0	0	0	0	0.8±1.6	0	5.6±5.4	2.8±3.2
Gomphonema	0.4±0.8	0.4±0.9	0	0	0	0	0	0
Gyrosigma	2.4±3.5	0.8±1.3	0	0	2.8±5.6	0	0	0
Navicula	22.4±5.0	21.6±1.7	17.2±6.9	16.4±8.6	18.4±12.3	20.1±2.9	30.7±3.2	14.2±16.0
Neidium	0	0.4±0.9	0	0	0	0	0	0
Nitzschia	0.4±0.8	1.2±2.7	0.6±1.2	0	4.6±6.6	4.6±3.8	2.1±3.5	3.5±0.9
Melosira	0.8±1.6	0	0	0	0		0	0
Pinnularia	0	0	0	0	0	12.8±11.7	26.9±8.2	14.9±10.0
Rhopalodia	0	0	0	0	0	0	6.7±7.4	3.5±4.1
Surirella	0	0	0	0	0	11.3±9.5	0	5.2±5.5
Number of genus	25	25	20	15	18	10	12	15
AARL score	7.0	7.0	6.33	7.33	6.67	8.0	8.33	8.0
Trophic status	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic	eutrophic	eutrophic	eutrophic
Classified of water quality	Class 4	Class 4	Class 4	Class 4	Class 4	Class 5	Class 5	Class 5

In the dry season, distribution of phytoplankton was found 4 divisions in 25 genera. The chrysophyte were the dominant group (17 genera). The highest of number was found in the UP and LP (Table 1). Ten genera were found in all areas such as *Anabaena*, *Oscillatoria*, *Closterium*, *Eudorina*, *Pediastrum*, *Euglena*, *Trachelomonas*, *Strombomonas*, *Diatomella* and *Navicula*. Distribution of phytoplankton in 4 areas of the rainy season was 4 divisions of phytoplankton which 25 genera were found, in the dry season which the green algae and the chrysophyte were the dominant group (11 genera) and the lowest was found in blue green algae, *Oscillatoria*. Upper Pak Phanang found the highest number of species (18 genera) while the lower Upper Pak Phanang was the lowest of number (10 genera). There were found five genera in all selected areas such as *Pleurotaenium*, *Euglena*, *Phacus*, *Navicula* and *Nitzschia* (Table 1).

Phytoplankton diversity index in SagoPalm wetland is shown in Figure 2. In the summer, the most sampling site of the diversity index was higher than the rainy season. The highest diversity index found in the Trang River tributary area (TR4) of 2.463 while in the rainy season, the highest value was in the upper Pak Phanang River tributary area (UP2) which was 2.443. The lowest of phytoplankton diversity index was found in the rainy season at the lower Pak Phanang River tributary (SP1) which was 1.33 (Figure 2).

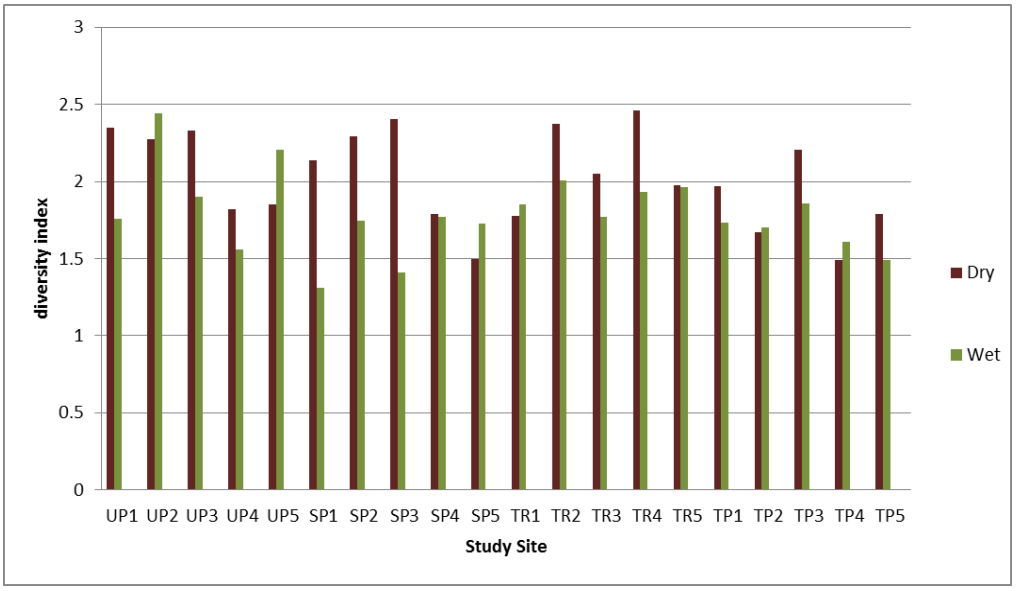

Figure 2. Shannon Wiener diversity indices in site and season of phytoplankton in the sago palm wetlands of Nakhon Si Thammarat province, Thailand

The evenness index of phytoplankton in two seasons were similarity. The summer and rainy seasons were ranged of 0.74-0.936 and 0.718-0.945, respectively. The highest of evenness index was found in the summer season at the upper Pak Phanang River tributary (UP4) and the rainy season found in the lower Pak Phanang River tributary watershed (SP1) which were 0.936 and 0.945, respectively (Figure 3).

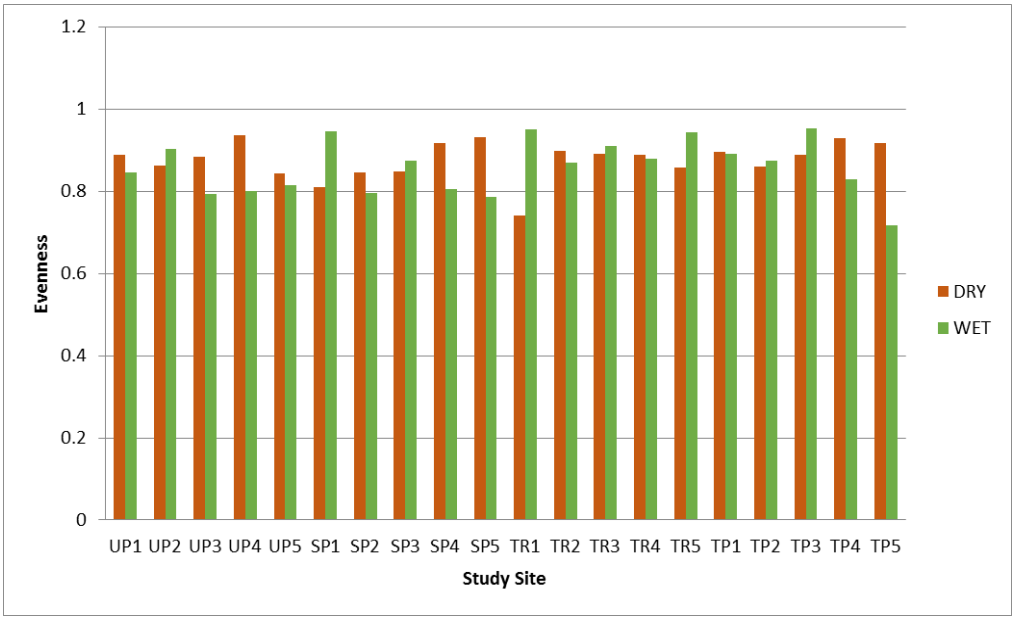

Figure 3. Evenness indices in site and season of phytoplankton in the sago palm wetlands of Nakhon Si Thammarat province, Thailand

The water quality in Sago were evaluated by AARL PC Score. Most of the sampling sites showed similarity trophic status in each season due to similarity locations in Nakhon Si Thammarat province. The most sampling sites were classified in the meso-eutrophic status, except at SP, TR and TP sites during the wet season which shown eutrophic status. The TR site in dry season was the highest clean water, and being meso-eurotrophic status because this area was small site which surrounded by deciduous forests, there was not much contaminated from tourists and agricultural activities. The change in water quality and trophic status were not much in both sites and seasons.

The UGPMA dendrogram was classified into 2 groups at the percent similarity of 50 based on phytoplankton diversity which demonstrated from 20 sampling sites in dry season. The first group was found at all sampling sites except the upper Pak Phanang River tributary areas (UP4) and the River Basin 4 (TP4). In the rainy season, the similarity of phytoplankton distribution was 50

percent which classified into 6 groups. There were found 4 groups in sampling sites namely, UP4, TP5, SP1 and UP3 (Figure 4 and 5).

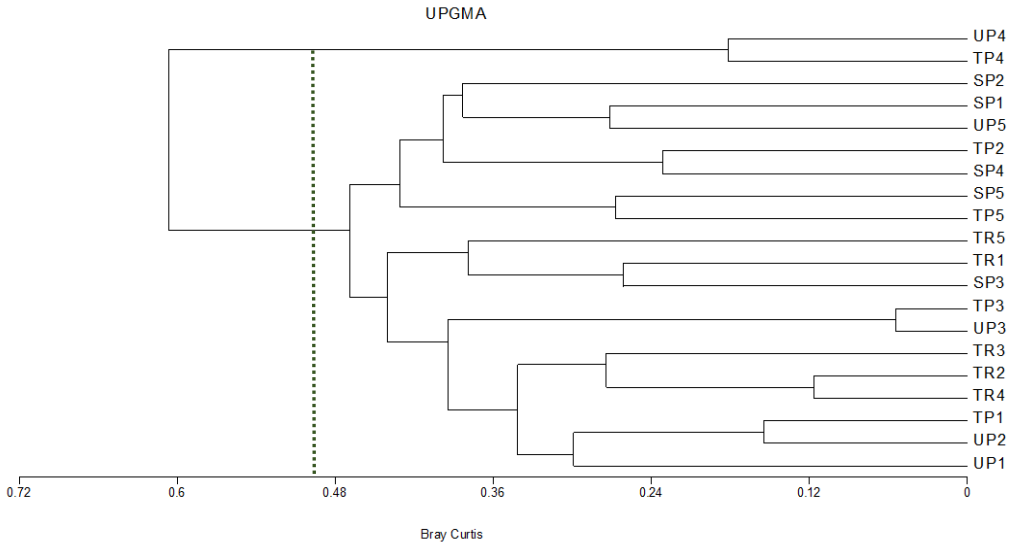

Figure 4. Dendrogram for clustering of sampling site based on physico-chemical parameter in the dry season

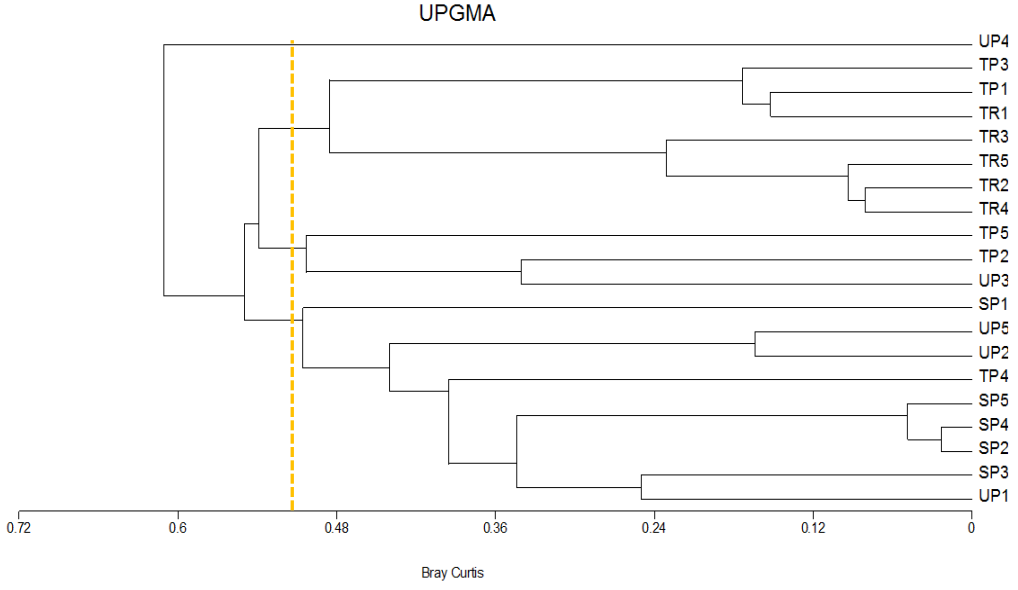

Figure 5. Dendrogram for clustering of sampling site based on physico-chemical parameter in the wet season

Phytoplankton distribution and water quality were correlated by Canonical corresponding analysis (CCA) that in the summer season revealed to be low correlation. The *Bacillaria* (Bac) was positively correlated with pH, while *Gomphonema* (Gom) was negatively correlated with pH (Figure 6).The rainy season, *Eudorina* (Eudr), *Pleurosigma* (Pleu) and *Synedra* (Syn) were positively correlated with dissolved oxygen (DO), *Fragilaria* (Fra) was positively correlated with ammonia (Amm).Whereas, *Bacillaria* (Bac) was negative correlated with total dissolved solids (TDS) and conductivity (Cond). *Trachelomona*s (Tra) and *Gonium* (Gon) were negative correlated with nitrite (Nitri) and nitrate (Nitra) (Figure7).

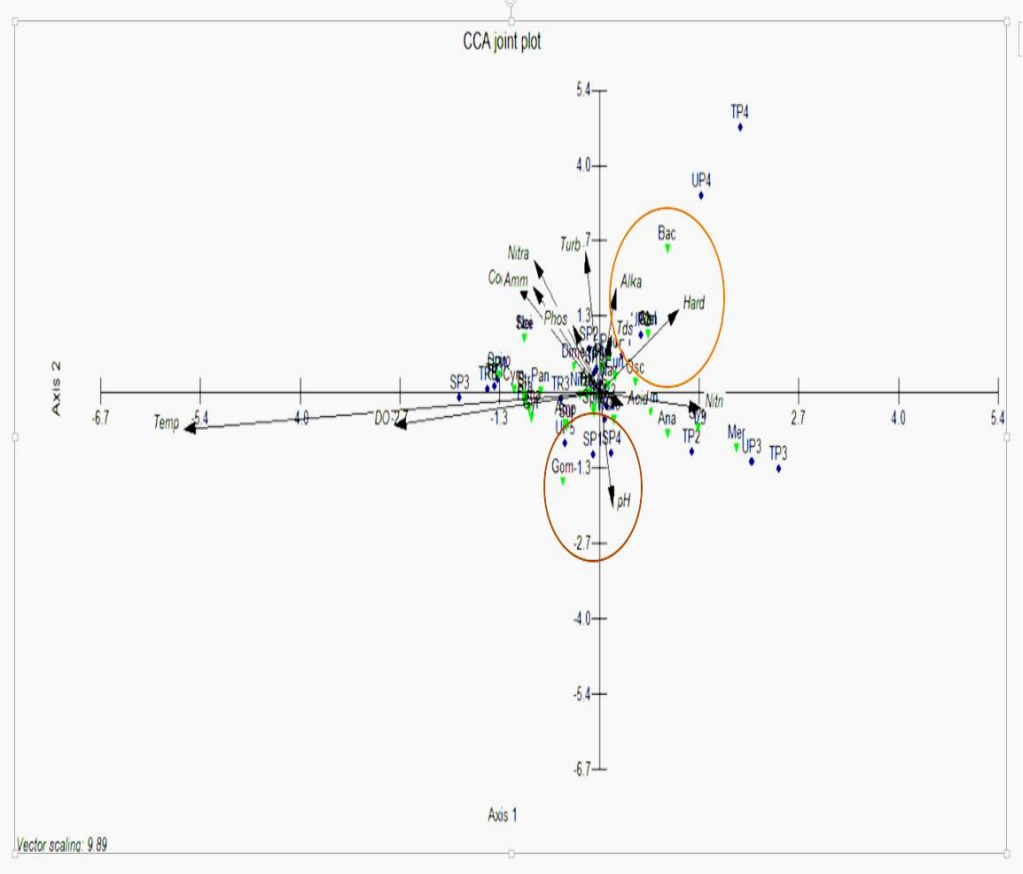

Figure 6. Canonical Correspondence Analysis ordition of phytoplankton distribution based on the correlation of physico-chemical water quality in dry season

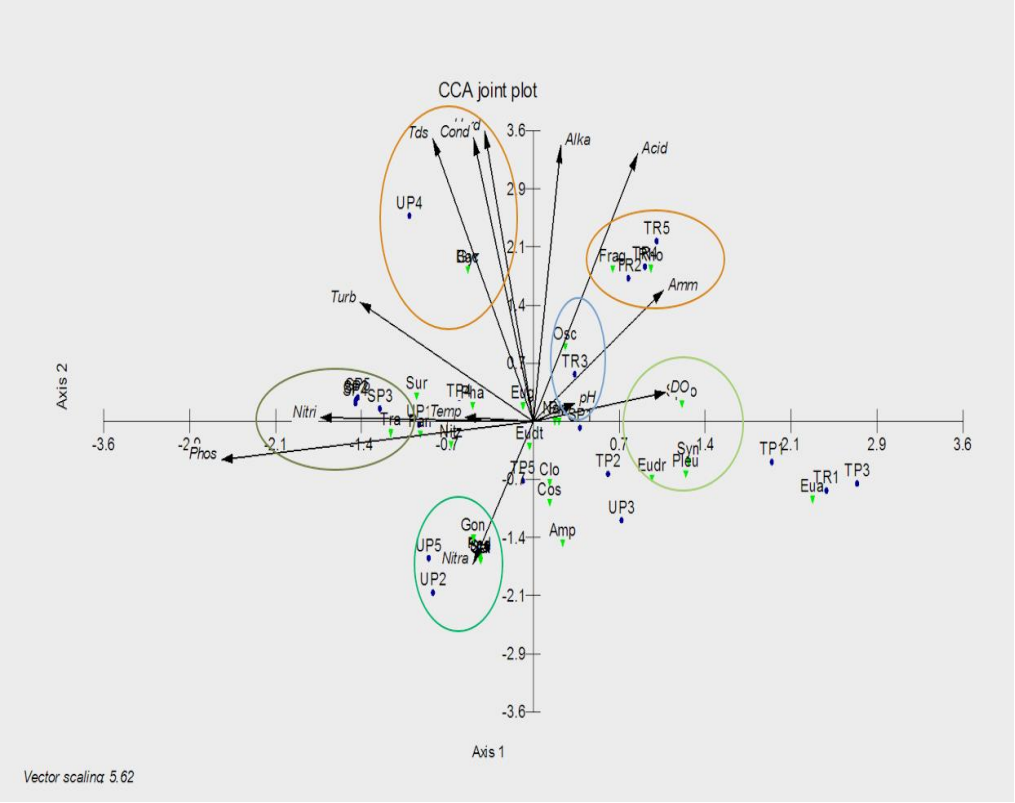

Figure 7. Canonical Correspondence Analysis ordition of phytoplankton distribution based on the correlation of physico-chemical water quality in wet season

Discussion

Phytoplankton community

From the results of Canonical Correspondence Analysis (CCA), a few species of phytoplankton were related with each physico-chemical parameter. *Bacillaria* was a high hardness tolerant species. However, phytoplankton was sensitive to the physical and chemical properties. In Sago Palm wetland, Nakhon Si Thammarat province, 30 genera were found, the appropriate conditions for phytoplankton are normally found in high nutrient water bodies with mesotrophic–eutrophic status (Peerapornpisal *et al*., 2004). Due to the wetland of sago palm is small area. Chrysophytes was found to be the most diverse because it possed a wide range of environmental variables (Mooser *et al*., 1996). Phytoplankton diversity depends on the key ecological process such

as succession, predation and competition, and changes in these processes can alter the diversity through changes in evenness (Sterling *et al*., 2001).

There were found 30 genera of phytoplankton in this study which revealed less than the number of phytoplankton genera reported in Sago plam forest of Nakhon Si Thammarat province, which consisted of 100 genera of 6 divisions in 2013 (Weeraphong *et al*., 2016). The phytoplankton richness showed the highest in UP and SP site followed by TR. While, the lowest species richness was SP site which lower in diversity when compared the phytoplankton community reported in the lower part of the Tapee River basin, where the higher value of species richness was 63 genera (Sakset and Preecha, 2021). When comparison the study of Promana (2002) who reported toxic algae distribution and water quality in Kwan Phayao that was similar group in this study which were blue green algae, green algae, chrysophyte and euglenoids, due to phytoplankton are commonly found in freshwater and eutrophic water bodies.

Phytoplankton distribution and physico-chemical parameters

AARL-PP score showed 6.67 overall of both seasons, indicating that the trophic status was meso-eutrophic to eutrophic status level (Table 1). The water quality of Sago palm wetland in this study was classified to Class 4-5 of surface water quality standard of Thailand (Pollution Control Department, 2016) (Table 1), resulted inconsistent with reported in Pak Phanang river basin (Sakset, 2011) and the lower part of the Tapee river basin, Surat Thani province (Sakset and Preecha, 2021). It is suggested that the amount of water bodies in this wetland was less than those area due to the small areas and high nutrients in the water bodies.

As results, it was showed the range of physico-chemical water parameters which related with distribution of phytoplankton in all sampling sites. The major factors that influenced the distribution of phytoplankton in the dry season such as alkalinity, pH and hardness. In the rainy season, the number of phytoplankton was significantly decreased, except in TP. In the SP site, the distribution of phytoplankton was found 25 genera which appeared in dry season whereas only 10 genera occurred in wet season. Due to the wet season in this area is moderate current velocity that impacted to the phytoplankton distribution. The changing of water temperature in each season directly affected the succession of phytoplankton. In the dry season, the average water temperature was 28.05 ± 0.71 $^{\circ}$C. *Anabaena*, *Lyngbya*, *Merismopedia*,

Arthrospira, *Surirella*, *Synedra*, *Strombomonas* and *Diatomella* were found to be the dominant species in all sites but not found in the rainy season, when the water temperature was lower. However, many chrysophyte species (diatom), *Euastrum, Fragilaria, Pinnularia, Pluerosigma* and *Rhopalodia* were found in only the wet season.

Fluctuation in nitrogen and phosphorus ratios represent significant as limiting growth factors to most algal species in aquatic ecosystems (Mohamed *et al.*, 2017). As the result, in the sago palm wetland in Nakhon Si Thammarat province, the nutrients were slightly increased in the rainy season which high concentration of nutrient because of nitrogen in the soil, agricultural fertilizer and human waste diluted to the wetland. The high nutrient concentration had a negative correlated with phytoplankton diversity. Nutrient which effect the growth of phytoplankton are nitrate and phosphate which are found in natural water bodies. Phosphate (soluble reactive phosphorus) is considered as one of the important nutrient limiting phytoplankton growth (Welch *et al*., 1978).

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References

APHA, AWWA, WPCE. (1989). Standard methods for the examination of water and wastewater. American Public Health Association, Washington DC.

Bellinger, E. G. and Sigee, D. C. (2015). Freshwater algae identification and use as bioindicator. 2nd Ed. Wiley-Blackwell, New Jersey.

Brower, J. E., Zar.J. H. and Ende, C. N. (1997).Field and laboratory methods for general ecology,4th ed. WCB:McGraw-Hill Education, Iowa.

John, D. M., Whitton, B. A. and Brook, A. J. (2002). The Freshwater algae flora of British Isles. Cambridge: Cambridge University Press, UK.

Lewmanomont, K., Wongrat, L. and Supanwanid, C. (1995). Algae in Thailand. Office of Environment Policy and Planning, Bangkok.

Mohamed, A. N., Kader, M. O. A., Nor, N. M., Osman, N., Shohaimi, S., Zulkifly, S..Omar, H. and Ismail, A. (2017).Comparison of phytoplankton diversity and succession between two small non-made lakes in Serdang, Selangor.Tropical Ecology, 58:485-496.

Mooser, K. A., Macdonald, G. M. and Smol, J. P. (1996). Applications of freshwater diatoms to geographical research, Progress in Physical Geography, 20:21-52.

National Hydroinformatics Data Center. (2020). Monitor the water situation and water quality in Thailand. Retrieved from https://www.thaiwater.net/water/quality

Palmer, M. C. (1967). A composite rating of algae to tolerating organic pollution.Phycologia, 5:78-82.

Parmar, T. K., Rawtani, D. and Agrawal, Y. K. (2016). Bioindicator: the natural indicator of environmental pollution. Frontiers in life science, 9:110-118.

Peerapornpisal, Y., Chaiubol, C., Pekoh, J., Kraibut, H., Chorum, M., Wannathong, P., Ngenpat, N., Jusakul, K., Thammathiwat, A., Chuananta, J. and Inthasotti, T. (2004). The monitoring of water quality in AngKaew Reservoir of Chiang Mai University by using phytoplankton as bioindicator from 1995-2002. Chiang Mai Journal of Science, 31:85-94.

Peerapornpisal, Y. (2006). Phycology. Department of Biology, Faculty of Science, Chiang Mai University, Chiang Mai.

Peerapornpisal, Y., Pekkon J., Powangprasit, D., Tonkhamdee, T., Hongsirichat, A. and Kunpradid, T. (2007). Assessment of water quality in standing water by using dominant phytoplankton AARL-PP score). Journal Fisheries Technology Research, 1:71-81.

Phang, S. M., Miah, M. S., Yeoh, B. G. and Hashim, M. A. (2000). *Spirulina* cultivation in digested sago starch factory wastewater. Journal of Applied Phycology, 12:395-400.

Pollution Control Department (2016). Notification of pollution control department. Retrieved from http://hydrolaw.thaiwater.net.accessed

Prasertsin, T. and Peerapornpisal, Y. (2015). Diversity and phytoplankton and water quality in some freshwater resources in Thailand.International Journal of Applied Environmental Sciences, 10:1101-1123.

Presscott, G. W. (1978). How to know freshwater algae. The picture key Nature Series W.M.C. Brown Company Publishers, Dubuque. Iowa.

Promana, R. (2002). Distribution of toxic algae and water quality in Kwan Phayao, Phayao province in 1999-2000. (Masters thesis). Chiang Mai University, Thailand.

Sakset, A. (2011). Biophysical and Socio-economic assessment for fisheries management in the freshwater fishing area in Pak Phanang River Basin, Nakhon Si Thammarat province. (Ph.D. Thesis). Asian Institute of Technology, Thailand.

Sakset, A. and Chankaew, W. (2013). Phytoplankton as a bio-indicator of water quality in the freshwater fishing area of Pak Phanang River Basin (Southern Thailand). Chiang Mai Journal of Science, 40:344-355.

Sakset, A. and Preecha, C. (2021). Variations of phytoplankton in the lower part of the Tapee river basin (TRB), Surat Thani province, Thailand. Khon Kaen Agriculture Journal, 49:763-778.

Sterling, G. and Wilsey, B. (2001). Empirical relationships between species richness evenness and proportional diversity. The American Naturalist, 158:286-299.

Weeraphong, M., Jariyapong, M. and Jaihowweerapong, D. (2016). The study of algae diversity in Sago Palm forests, Nakhon Si Thammarat. Princess of Naradhiwas University Journal, 8:134-141.

Welch, E. B., Sturtevant, P. and Perkins, M. A. (1978). Dominance of phosphorous over nitrogen as a limited of phytoplankton growth rate. Hydrobiologia, 57:209-215.

Wongrat, L. (1995). Phytoplankton. Section of Fisheries of Fishery: Kasetsart University, Bangkok.
Wongrat, L. and Boonyapiwat, S. (2003). Manual of sampling and analytical methods of plankton. Kasetsart university press, Bangkok.

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