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Original Article

Distribution of aquatic plants in Nong Han wetland, Thailand

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Abstract

Aquatic plants are regarded as primary producers that play a significant role in the ecosystem. Thus, the distribution of aquatic plants has a substantial impact on aquatic organisms. The purpose of this research was to study the spatio-temporal variation of the distribution of aquatic plants in Nong Han wetland, Thailand. According to the results, there were 31 species and 22 families of aquatic plants in Nong Han wetlands with the mean biomass of 13,991.44 g m^{-2}; where by *Potamogeton malaianus* Miq was the dominant species with highest biomass. In addition, the central wetland to the east had the highest amount biomass, and the period between February and April had the greatest influence on the biomass of aquatic plants. Moreover, the mean value of chlorophyll-a was found to be 0.021±0.014 mg l^{-1}, indicating a high eutrophic level. *Eichhornia crassipes* and *Salvinia cucullatas* were invasive species with the tendency to cause damage to the water body in the future. Accordingly, to maintain ecological balance and sustainable output, stakeholders should implement preventive measures, eliminate invasive plants, and reduce the discharge of organic substances which are the source of plant nutrients into the water body.

Keywords: aquatic plants, biomass, distribution, Nong Han wetland

1. Introduction

Nong Han wetland is the largest freshwater lake in the northeastern region of Thailand and is regarded as one of the natural lagoons of international importance, covering a total area of 123 km^2 (Office of Environmental Policy and Planning, 2002). Nong Han wetland provides multiple benefits to the surrounding communities by serving as a water storage area for agriculture and livestock farming, a source of water supply, a tourist attraction, and a site for aquaculture. In addition, Nong Han wetland also accommodates fishery activities that provide income and food security to the communities (Kunlapapuk, Kulabtong, & Soontornkit, 2014; Pengsangsee & Kaewnern, 2014; Rayan, Chartchumni, Kaewdonree, & Rayan, In Press). Aquatic plants are considered an important resource of fishery on account of the fact that they are primary producers and fundamental components of the food chain in an aquatic ecosystem. Indeed, aquatic plants play a significant role in both physical and chemical processes; they serve as habitats, sources of food, hiding sites, and breeding sites for aquatic organisms (Nagmsnae, 2011). The distribution patterns of aquatic plants tend to vary over time. Meanwhile, the variability of nutrients and waterbed materials significantly contribute to the variation of aquatic plant species in a water body (Pieczynska, 1990). Furthermore, an appropriate amount of aquatic plants is essential for maintaining ecological balance of a water body, hence creating suitable habitats for aquatic organisms and enabling humans to fully utilize the water body (Sripen, 1999). Aquatic plants are highly sensitive to the effects of human activities imposed on aquatic ecosystems, whereby the variation of aquatic plants is negatively correlated with the number of human activities in a water body (Nagmsnae, 2011). Concerning the fact that the topography of Nong Han wetland is flat and surrounded by communities, it is directly affected by human activities such as intrusion of humans in the wetland for agriculture, soil surface erosion in the agricultural areas, and drainage of wastewater from the surrounding communities – all of which directly affect the type and amount of aquatic plants in the wetland. Although

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human activities may be conducive to the wetland in terms of providing sources of food and hiding sites for aquatic animals, they may contribute to the death of aquatic plants that subsequently results in the deterioration of water quality and inhabitability of the wetland. Accordingly, this research aims to study the spatio-temporal variation of the distribution of aquatic plants in Nong Han wetland in order to use the results thereof to improve the management of water resources in the future.

2. Materials and Methods

2.1 Study area

With respect to the study area of this research, six sampling sites in Nong Han wetland were selected, consisting of (Figure 1): (1) S1, at 17°24’31.364”N, 104°20’94.386”E, Baan Tha Rae, which is located in the upper region to the west with a moderately low water level and high number of inhabitants, whereby the area has been developed as a tourist attraction and is therefore highly affected; (2) S2, at 17°20’ 71.057”N, 104°19’86.239”E, Baan Paen, which is located in the upper region to the east with a moderately low water level and small number of inhabitants; (3) S3, at 17°21’18.61”N, 104°18’15.436”E, Don Sakham, which is located in the central region to the west with a high population density and is therefore the most affected; (4) S4, at 17°20’66.138”N, 104°18’10.286”E, Don Sawan, which is located in the central region to the east with the highest water level and a very low number of inhabitants, and is therefore the least affected; (5) S5, at 7°15’33.131”N, 104°19’63.923”E, Pak Narmpung, which is located in the lower region to the west and is the main watercourse flowing into Nong Han, whereby the area has a moderately low water level and small number of inhabitants; and (6) S6, at 17°17’78.025”N, 104°21’24.212”E, Pak Narmkam, which is located in the lower region to the east with a moderately high water level and high number of inhabitants, whereby valves have been constructed to control water levels in the area that connects Nong Han to Lam Narmkam (Rayan *et al.*, 2020).

2.2 Sampling period

Sampling was carried out in Nong Han wetland during November 2016 to October 2017, and was divided into four intervals based on the changes in water levels and the hydrological data of the area, as follows: (1) T1 – the period of transition from rainy to dry season, which is during November to January (this is the period when water storage level is at the highest and starts to decline, water temperature is low, and water is clear due to sedimentation); (2) T2 – the period of dry season, which is during February to April (this is the period when water storage level is at the lowest and water temperature starts to rise); (3) T3 – the period of transition from dry to rainy season, which is during May to July (this is the period when water storage level starts to increase, water temperature is at the highest, and water is turbid due to the flushing of sediments into the water body); and (4) T4 – the period of rainy season, which is during August to October (this is the period when rainfall is at the highest, water storage level starts to increase, and water has high turbidity) (Rayan *et al.*, 2020).

2.3 Sampling method

Aquatic plant samples were collected by using a wooden quadrat of 1x1 m in size. The quadrat was placed along nine transects, which were 100 m apart. After that, three samples were collected along each transect for a total of three rounds. The obtained samples were classified into types, and the weights of the samples were recorded based on the species of aquatic plants found in the sampling sites, according to Sripen (1999), Rodloy, Nukwan, and Saichan (2010), and Pooma and Suddee (2014).

2.4 Analysis of water quality

Water samples were collected concurrently with aquatic plant samples. The depth of water was measured by using a plummet and tape line. In addition, the transparency of water was measured by using the Secchi disc and the

Figure 1. Map and location of six sampling sites in Nong Han wetland, Sakon Nakhon province

conductivity of water was obtained from Mettler Toledo's FB-30 conductivity meter. The pH of water was measured by using Mettler Toledo's FB-20 pH meter and the level of dissolved oxygen in water was obtained from Hanna Instruments' HI-2400 DO meter. Titrimetric analysis was employed to analyze the hardness and alkalinity of water in accordance with the method proposed by Clesceri, Grenberg, and Eaton (1998). Moreover, chlorophyll-a values were analyzed using trichromatic method, and the levels of orthophosphate were analyzed using PhosVer method and Shimadzu's UV-1800 spectrophotometer in accordance with the procedures of Clesceri *et al.* (1998).

2.5 Data analysis

Data concerning the species and biomass of aquatic plants were calculated as a percentage. The Shapiro-Wilk test was conducted to test for the normality of biomass data, whereafter the analysis of variance was performed based on the sampling site and period. The differences between the sample means were then tested using Turkey's HSD (honest significant difference) test. After that, the parameters of water quality that influenced the distribution of aquatic plant biomass were identified by using co-inertia analysis (Dray, Chessel, & Thioulouse, 2003) and analyzed with R-statistic Version 3.4.2 (R Development Core Team, 2009).

3. Results and Discussion

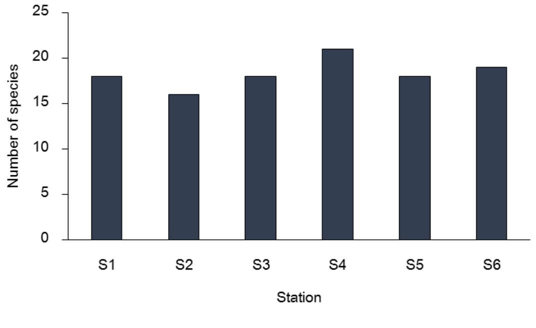
According to the results obtained from November 2016 to October 2017, there were 31 species and 22 families of aquatic plants in Nong Han wetland, Sakon Nakhon Province. The sampling site where the highest number of species was found was Site 4, totaling 21 species, followed by Site 6, Site 1, Site 3, Site 5, and Site 2, whereof 19, 18, 18, 18, and 16 species were found, respectively. Regarding the sampling period, the highest number of species was found in T1, totaling 24 species, followed by T2, T4, and T3, in which 21, 20, and 16 species were found, respectively (Figure 2). The mean biomass of aquatic plants was 13,991.44 g m^{-2}. The top five species with highest biomass were *Potamogenton malaianus*, *Eichhornia crassipes*, *Hydrilla verticillata*, *Salvinia cucullate*, and *Ceratophyllum demersum*, of which the mean value of biomass was 7,556.21 (54.10%), 2,088.79 (14.93%), 1,211.85 (8.66%), 990.19 (7.08%), and 409.67 (2.93%) g m^{-2}, respectively (Table 1).

Upon the analysis of variance, it was found that there were no statistically significant differences in the biomass of aquatic plants between each sampling site (P>0.05). Moreover, it was evident that Site 4 had the highest biomass of 16,094.25 g m^{-2}, followed by Site 2, Site 6, Site 3, Site 1, and Site 5, of which the mean value of biomass was 15,442.42, 14,903.25, 13,858.17, 12,033.17, and 11,617.42 g m^{-2}, respectively. Nonetheless, there were statistically significant differences in the biomass of aquatic plants between each sampling period (P<0.05); the mean values of biomass at T2 and T4 (17,002.22 and 15,727.61 g m^{-2}, respectively) were significantly different from the mean values of biomass at T3 (9,442.44 g m^{-2}) but were not significantly different from the mean value of biomass at T1 (13,793.50 g m^{-2}) (Figure 3).

According to the study of water quality in Nong Han wetland, the mean values were found to be as presented in Table 2. Upon the analysis of variance based on the sampling period, it was found that there were no statistically significant differences in the mean values of depth, transparency, pH, alkalinity, dissolved oxygen, and ammonia in water (P>0.05). Alternatively, there were statistically significant differences in the mean values of conductivity, hardness, orthophosphate, and chlorophyll-a in water (P<0.05).

Upon analysis of the correlation between the distribution of aquatic plants and water quality parameters that were significantly different between each sampling period, it was found that: (1) *Potamogeton crispus*, *Spirogyra sp.*, *Commelina benghalensis*, *Azolla pinnata*, *Colocasia esculenta*, and *Nymphaea lotus* were directly correlated with the hardness of water; (2) *Ipomoea aquatic*, *Jussiaea repens*, *Polygonum tomentosum*, and *Polygonum hydropipen* were directly correlated with the conductivity of water; and (3) *Neptunia oleracea* was directly correlated with the level of orthophosphates in water (Figure 4).

According to the results of this research, there were 31 species of aquatic plants in Nong Han wetland. The aquatic plant species found in this research were consistent with the research of Kasetsart University, Chalermphrakiat Sakon Nakhon Province Campus (KUCS, 2017), in which a total of 42 aquatic plant species were found. Moreover, Kownaruemit, Sanitchon, & Upakarat (2014) reported that 73 aquatic plant species were found; whereby all 31 species of aquatic plants found in this research were aquatic plants that are prevalently distributed in Thailand (Rodloy *et al.*, 2010). In addition, this research found that *Potamogenton malaianus*, *Eichhornia crassipes*, *Hydrilla verticillata*, *Salvinia cucullate*, and *Ceratophyllum demersum* were the top five species of aquatic plants with highest biomass. These results were consistent with the research of Kownaruemit *et al.* (2014), which reported that *Potamogenton malaianus*, *Hydrilla verticillata*,



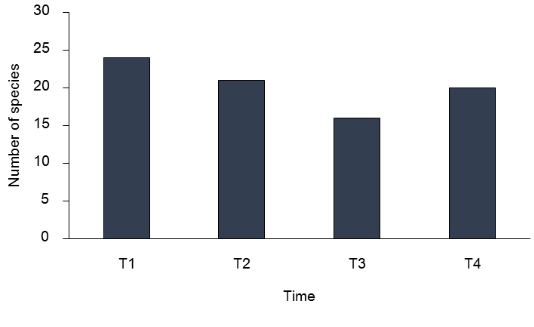


Figure 2. Aquatic plant species collected from each sampling site and period in Nong Han wetland, Sakon Nakhon Province, Thailand

Table 1. Biomass of individual aquatic plant species collected from each sampling temporal (g m^{-2})

Scientific Name	Abbrev.	T1	T2	T3	T4	Mean
1. *Potamogeton malaianus* Miq.	POMA	8177.00	10338.17	2902.00	8807.67	7556.21
2. *Eichhornia crassipes* (Mart.) Solms	EICR	2312.33	3092.83	1220.17	1729.83	2088.79
3. *Hydrilla verticillata* (L.f.) Royle	HYVE	390.67	486.67	788.00	3182.06	1211.85
4. *Salvinia cucullata* Roxb.	SACU	630.83	1376.33	1241.11	712.50	990.19
5. *Ceratophyllum demersum* L.	CEDE	152.33	54.17	1079.17	353.00	409.67
6. *Nelumbo nucifera* Gaertn.	NENU	326.44	407.67	810.50	0.00	386.15
7. *Pistia stratiotes* L.	PIST	92.17	60.50	1151.00	147.39	362.76
8. *Leersia hexandra* Sw.	LEHE	410.50	531.00	0.00	87.33	257.21
9. *Cyperus pilosus* Vahl.	CYPI	437.67	81.00	47.00	245.33	202.75
10. *Thelypteris interrupta* (Willd.) K. Iwats.	THIN	142.67	166.00	0.00	0.00	77.17
11. *Utricularia aurea* Lour.	UTAU	75.33	138.17	43.00	10.00	66.63
12. *Spirogyra* sp.	SPSP	190.00	43.67	29.17	0.00	65.71
13. *Jussiaea repens* Linn.	JURE	25.33	37.56	28.83	70.17	40.47
14. *Vallisneria gigantea* Graebn.	VAGI	22.67	16.67	44.67	73.00	39.25
15. *Hygroryza aristata* (Retz.) Nees	HYAR	0.00	0.00	0.00	150.33	37.58
16. *Typha angustifolia* L.	TYAN	97.50	0.00	0.00	33.50	32.75
17. *Nymphoides parvifolia* (Griseb.) Kuntze.	NYPA	120.17	2.50	4.17	0.00	31.71
18. *Colocasia esculenta* (L.) Schott	COES	4.67	93.00	0.00	0.00	24.42
19. *Polygonum tomentosum* Willd.	POTO	20.83	19.00	0.00	39.17	19.75
20. *Trapa bispinosa* Roxb.	TRBI	50.17	0.00	7.67	2.67	15.13
21. *Najas greminea* Del.	NAGR	31.00	0.00	0.00	20.67	12.92
22. *Ipomoea aquatica* Forsk.	IPAQ	11.00	21.33	0.00	17.50	12.46
23. *Trapa quadrispinosa* Roxb.	TRQU	0.00	16.67	25.83	0.00	10.63
24. *Nymphaea lotus* Linn.	NYLO	32.00	0.00	0.00	3.33	8.83
25. *Neptunia oleracea* Lour.	NEOL	0.00	0.00	0.00	34.67	8.67
26. *Eleocharis dulcis* (Burm.f.) Trin ex Henschel	ELDU	33.17	0.00	0.00	0.00	8.29
27. *Neptunia* sp.	NESP	0.00	0.00	20.17	0.00	5.04
28. *Commelina benghalensis* L.	COBE	0.00	17.67	0.00	0.00	4.42
29. *Polygonum hydropiper* L.	POHY	0.00	0.00	0.00	7.50	1.88
30. *Potamogeton crispus* L.	POCR	7.06	0.00	0.00	0.00	1.76
31. *Azolla pinnata* R.Br.	AZPI	0.00	1.67	0.00	0.00	0.42

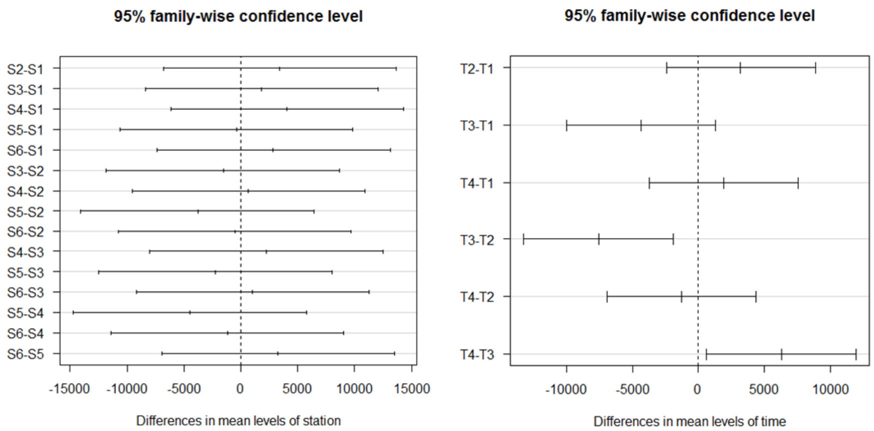


Figure 3. Results of the distribution of biomass in Nong Han wetland, Sakon Nakhon Province, Thailand by sampling site and period

Najas graminea, and *Utricularia aurea* were species of aquatic plants that were most commonly found. With respect to the sampling sites of this research, it was evident that the water turbidity was moderately low, and the water transparency was high. These observations were consistent with the research of KUCS (2017), which found that there were a high number of submerged plant species in Nong Han wetland, hence indicating a high level of water transparency; in other words, sunlight was able to penetrate through the water mass and reach the water bed.

Results of this research suggested that there were statistically significant differences in the biomass of aquatic plants between each sampling period. This conformed to the research of Rayan, Rungsiwiwat, Kumla, & Chartchumni (2017), which found that there was a seasonal variation in the distribution of aquatic plant biomass in Nam Oun Dam, Sakon Nakhon Province. According to this research, the mean value of aquatic plant biomass was 13,991.44 g m^{-2}, which was higher than the results of previous studies: (1) Duangsawasdi, Boonparote, and Prasatpornchai (1992) reported 4.02 kg m^{-2}

Table 2. Average water quality in Nong Han wetland, Sakon Nakhon Province, Thailand

Parameter	Times				Mean±SD
	T1	T2	T3	T4	
Depth (m)	2.34	2.18	2.19	2.25	2.24±0.08
Transparency (m)	1.66	1.56	1.43	1.44	1.52±0.11
Conductivity* (µs cm^{-1})	91.65^{b}	92.08^{b}	96.20^{b}	119.24^{a}	99.79±13.13
pH	8.18	7.43	7.19	7.40	7.55±0.43
DO (mg l^{-1})	7.38	7.82	7.05	7.31	7.39±0.32
Alkaline (mg l^{-1} as $CaCO_3$)	25.43	24.08	30.08	23.73	25.83±2.93
Hardness* (mg l^{-1} as $CaCO_3$)	36.36^{a}	35.15^{a}	42.61^{a}	12.06^{b}	31.54±13.40
Ammonia (mg l^{-1})	0.11	0.17	0.08	0.12	0.12±0.03
Orthophosphate* (mg l^{-1})	0.011^{b}	0.017^{b}	0.023^{b}	0.090^{a}	0.036±0.04
Chlorophyll a* (mg l^{-1})	0.015^{b}	0.015^{b}	0.015^{b}	0.042^{a}	0.021±0.014

$*^{abc}$ means different superscripts within a row differ significantly (P<0.05)

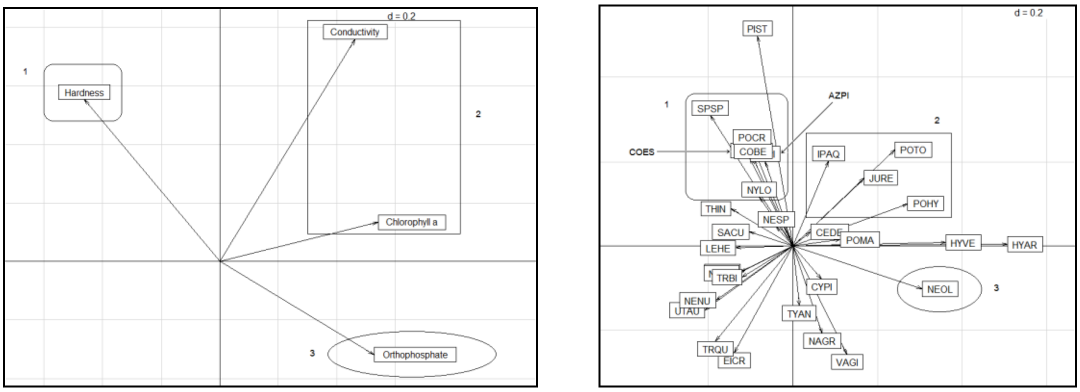


Figure 4. Results of co-inertia analysis of (A) water quality to (B) aquatic plants found in the study

of fresh weight biomass; (2) Duangsawasdi, Leeranont, Sricharoendham, and Rattanachamnong (1994) reported 6.42 kg m^{-2} of fresh weight biomass; (3) Ruekaewma, Ngoichansri, Thongphant, Rayan, and Sutti-arj (2005) reported 4.09 kg m^{-2} of fresh weight biomass; (4) Kownaruemit *et al.* (2014) reported 1.11 kg m^{-2} of fresh weight biomass; and (5) KUCS (2017) reported 4.50 kg m^{-2} of fresh weight biomass. Differences in these results could be attributable to the differences in the sampling methods, sampling locations, and number of sampling sites. Likewise, the differences in the sampling periods could contribute to the differences in the results due to changes in the conditions of Nong Han wetland, which may arise from the expansion of surrounding communities. It was reported that 22,600 m^3 of wastewater were released from the communities per day, whereby there were two wastewater treatment sites that could accommodate 18,000 m^3 of wastewater per day before discharging them to Nong Han wetland (KUCS, 2017). In addition, 583 km^2 of areas in Nong Han wetland were exposed to rainfall and, on average, 49,080 tons of sediments were deposited on Nong Han wetland per year (KUCS, 2005). These sediments served as a source of nutrients for aquatic plants and therefore contributed to their growth. At present, Nong Han wetland is encountering the problem of invasion by aquatic plants. The death of these aquatic plants causes the water body to become shallower, whereby the accumulation of dead aquatic plants in Nong Han wetland covers a total area of 14.51 km^2 or 16.12% of total area of water surface (89.97 km^2) (KUCS, 2017).

According to the results of this research, the highest amount of aquatic plant biomass was found at T2 (February - April), owing to the fact that submerged plants thrive well in shallow and transparent water. Results corresponded to the physical characteristics of the water body at T2, which was the period of dry season during which the water storage level started to decrease, water temperature began to increase, and water became less turbid due to sedimentation – all of which were conducive to the growth of submerged plants, specifically *Potamogenton malaianus*, *Hydrilla verticillata*, and *Ceratophyllum demersum*. Meanwhile, the second highest amount of aquatic plant biomass was found at T4 (August - October), which could be accounted for by the biomass of floating aquatic plants, namely *Eichornia crassipes* and *Salvinia cucullate*, that thrive well in high water conditions. These results were consistent with the research of Kownaruemit *et al.* (2014), which found that the changes in water levels affected the distribution of aquatic plants in Nong Han wetland. Specifically, high water levels during the rainy season contributed to the rapid growth of floating aquatic plants (*Eichornia crassipes*) and to the death of shoreline plants due to submergence. In addition, this research found that the amount of orthophosphates in water was the highest at T4 and were in the form of dissolved phosphorous that can be taken up by aquatic plants for growth. This conformed to the research of Duangsawasdi *et al.* (1992), which reported a high amount of phosphorous during May to September. Such high amount of phosphorous could be due to the flushing of nutrients from the catchment area to Nong Han wetland by rainfall. Likewise, in the year when this research was conducted, there was an occurrence of flood in Mueang District, Sakon Nakhon Province during late July to August 2017 (New mthai, 2018), which could be one of the major causes of the flushing of organic substances into Nong Han wetland.

Regarding the correlation between the distribution of aquatic plants and water quality, this research found that *I. aquatic*, *J. repens*, *P. tomentosum*, and *P. hydropipen* were correlated with water conductivity and chlorophyll-a values in water; whereby conductivity is directly related to the concentration of ions, particularly of calcium and magnesium, in water (Hem, 1970). Meanwhile, chlorophyll-a represents the biomass of planktons in water since it is the one of the photosynthetic pigments found in planktons (Peerapornpisal, 2006, Pithakpol, Soontornprasit, & Valunpian, 2014). Pithak pol *et al.* (2014) reported that the values of chlorophyll-a varied between each sampling site and period. Alternatively, Permsirivanich, Meksumpun, & Petpiroon (2005) found that the increase in chlorophyll-a was attributable to the increase in nutrients, namely ammonium-nitrogen and orthophosphate-phosphorous, which were flushed from the soil. This corresponded to the results of this research with respect to the distribution of aquatic plants, in which these plants were plant species that thrive well along the shoreline. Moreover, the biomass of each aquatic plant species was the highest at T4, which was the period of rainy season when nutrients from the catchment area were flushed into the water body. It was also evident that *N. oleracea* was correlated with orthophosphate values and was prevalent only at T4 – the period of which there was a high level of rainfall. These results were similar to the results of the research conducted by Shardendu , Sayantan , Sharma , & Irfan (2012), which examined the accumulation of phosphorous in aquatic plants, namely *Eleocharis plantaginea*, *E. crassipes*, *Pistia stratiotes*, and *H. verticillata*. The researchers found that all four species of aquatic plants had the highest level of phosphorous accumulated during the period towards the end of summer and during the rainy season, whereby *Pistia stratiotes* had the highest level of phosphorous accumulated among the four species. Their results were in line with the research of Ambastha, Hussain, & Badola (2007), which reported that circulation of plant nutrients in wetlands was influenced or controlled by the fundamental processes of transformation, storage, discharge, and transport of nutrients. Although the mean water quality obtained from this research was at the level inhabitable by aquatic animals, the mean value of orthophosphates was 0.036 mg l^{-1}, indicating excessive nutrients (Duangsawasdi & Somsiri, 1985). Likewise, the mean value of chlorophyll-a was 0.021 mg l^{-1}, which implied that the water body was under eutrophication (Wetzel, 1983).

This research and previous studies showed that Nong Han wetland underwent a rapid invasion by an increasing number of aquatic plants. Such invasion can pose adverse effects to the water body, such as the shallowing of the water body and obstruction to the navigation channels. Furthermore, the death of aquatic plants can further affect the quality and inhabitability of the water body, as well as the quality of water supply. It was also reported that *Eichornia crassipes* – an invasive plant species – was highly prevalent in Nong Han wetland (Doydee, 2016) and served as micro-habitats for insects or other disease carriers such as snails (carrier of schistosomiasis) and marsh mosquitoes (carrier of malaria) (Masifwa, Twongo, & Denny, 2001; Plummer, 2005; Rakotoarisoa, Waeber, Richter, & Mantilla-Contreras, 2015). Other major problems of *Eichornia crassipes* include obstructtions to the watercourse and damages to the fishing equipment (Rakotoarisoa *et al.*, 2015). Meanwhile, the invasion of Nong Han wetland by aquatic plants could arise from a lack of awareness of the potential consequences of human invasion for agriculture, expansion of agricultural areas that contributes to the flushing of sediments, and expansion of communities that discharge wastewater into the water body. All of these factors, along with the high level of light availability in the area (Ndimele, Kumolo-Johnson, & Anetekhai, 2011), pose direct effects to Nong Han wetland, resulting in eutrophication and contributing to the rapid growth of aquatic plants.

4. Conclusions

This research found that there were a total of 31 species of aquatic plants in Nong Han wetland with a mean biomass of 13,991.44 g m^{-2}. Moreover, the dominant species found in Nong Han wetland was *P. malaianus*, while *E. crassipes* and *S. cucullata* were invasive species that adversely affected the habitats of aquatic animals. This research also showed that rainfall had an effect on the increase in nutrients and the degree of distribution of aquatic plants. In addition, the water body in Nong Han wetland was found to have a high eutrophic level, which contributed to the invasion by certain aquatic plant species. Accordingly, it is necessary to implement measures on the utilization of Nong Han wetland, through collaboration between the public and private sector, to serve as a guideline for preventing adverse changes of aquatic plant communities that affect the deterioration of the water body. For instance, wastewater treatment plants should be expanded to support the increasing number of communities, and wastewater should be properly treated before being discharged into the water body. Likewise, preventive measures on the invasion of humans for agricultural practices should be implemented, since human activities directly contribute to the increase in nutrients. Meanwhile, measures on the control of invasive species can be achieved through mechanical methods, such as using machinery to remove invasive species and dredging nutrient-rich sediments from the water body, and biological methods such as releasing herbivorous fish into the water body to feed on aquatic plants. In addition, the private sector or communities should establish measures on the utilization of water bodies, as well as monitoring the epidemic of invasive species and eliminating them from the water bodies on a regular basis. Furthermore, communities should exhibit environmental awareness and consciousness in the utilization of Nong Han wetland so as to maintain ecological balance and achieve sustainable output.

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