การเปลี่ยนแปลงการแพร่กระจายเชิงพื้นที่และฤดูกาลของพรรณไม้น้ำในอ่างเก็บน้ำเขื่อนน้ำอูน จังหวัดสกลนคร ประเทศไทย

Spatial Distribution and Seasonal Variations of Aquatic Plants in Nam Oun Reservoir, Sakon Nakhon Province, Thailand

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บทคัดย่อ

การเปลี่ยนแปลงการแพร่กระจายเชิงพื้นที่และฤดูกาลของพรรณไม้น้ำในอ่างเก็บน้ำเขื่อนน้ำอูน จังหวัดสกลนคร ระหว่างเดือนพฤศจิกายน 2556-เดือนตุลาคม 2557 โดยแบ่งเป็น 4 ฤดูกาล ตามการเปลี่ยนแปลงทางอุทกวิทยาใน 3 เขตพื้นที่ จำนวน 6 สถานี พบพรรณไม้น้ำ 57 ชนิด 31 วงศ์ จำแนกตามประเภทลอยน้ำ โผล่พ้นน้ำ ใต้น้ำ และชายน้ำ พบจำนวน 8, 3, 7 และ 39 ชนิด ตามลำดับ การเปลี่ยนแปลงการแพร่กระจายของชนิดและปริมาณพรรณไม้น้ำในแต่ละครั้งของการสำรวจ (สถานี*ฤดูกาล) พบว่า ฤดูกาลมีอิทธิพลต่อการแพร่กระจายของพรรณไม้น้ำด้านมวลชีวภาพแตกต่างอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) พรรณไม้น้ำที่พบได้บ่อยครั้งและมีมวลชีวภาพสูงสุด ได้แก่ ไมยราบยักษ์ (*Mimosa pigra* L.) สาหร่ายข้าวเหนียว (*Utricularia aurea* Lour.) และ แห้วทรงกระเทียม (*Eleocharis dulcis* (Burm.f.) Trin ex Henschel) ตามลำดับ โดยฤดูฝน (T4) มีความหลากหลายของพรรณไม้น้ำมากที่สุด ส่วนฤดูปรับเปลี่ยนจากฝนสู่แล้ง (T1) มีมวลชีวภาพสูงสุด เมื่อทำการจัดกลุ่มความคล้ายคลึงกันตามองค์ประกอบของมวลชีวภาพตามฤดูกาล สามารถแบ่งพรรณไม้น้ำชนิดเด่นได้เป็น 3 กลุ่ม โดยพรรณไม้น้ำประเภทชายน้ำเป็นชนิดเด่นสามารถพบได้ทั้งพื้นที่อ่างเก็บน้ำ

คำสำคัญ : พรรณไม้น้ำ ความหลากหลาย การแพร่กระจาย การวิเคราะห์ตัวแปรแบบพหุ

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Abstract

Spatial and seasonal variations of aquatic plants were investigated from November, 2013 to October, 2014 in Nam Oun reservoir, Sakon Nakhon province, Thailand. Samplings of aquatic plants were conducted in 4 hydrological seasons, total of 6 stations, within 3 zones. Altogether, 57 species and 31 families were recorded and categorized into floating, emergent, submerged and marginal (8, 3, 7, and 39 species, respectively). Variations of species and abundance of macrophytes were surveyed (station*season). The seasons had significantly affected on biomass of aquatic plants ($p<0.05$). *M. pigra* L., *U. aurea* Lour. and *E. dulcis* Burm.f. were the most commonly found aquatic plants and had the highest biomass. The rainy season (T4) had the most diverse species. However, the highest biomass was observed during rainy to dry season (T1). Cluster analysis was used to determine biomass on seasons, which resulted in 3 major clusters. Marginal type of aquatic plants can be found in all groups, and reservoir area.

Keywords : aquatic plant, diversity, distribution, multi-variation analysis

Introduction

Nam Oun dam is built to preserve water from Nam Oun River, which is a tributary of the Songkhram River, originates in Phu Phan Range in Kut Bak district, Sakhon Nakhon province. The dam is located in Nong Bua village, Moo 4, Rae sub-district, Phang Khon district, Sakon Nakhon province. This earth dam is 3,330 m in height, 8 m in crest length, 1,100 m^2 of catchment area, 520 million m^3 of storage capacity, 53,000 rai (84.4 km^2) of water surface area, and 6.4 m in depth (Department of Fisheries, 1974; 1975). The irrigation from the dam would be useful in agriculture and fisheries to community use. Basically, aquatic plants are the primary producers and form the basis of food chain in aquatic ecosystems. Aquatic plants play an important roles in physical and chemical processes such as habitats, hiding places, and breeding of living organisms in water (Ngamsnae, 2011). Composition and abundance of macrophytes had greatly affected on aquatic ecosystem (Carpenter and Lodge, 1986). Abundance of aquatic plants must maintain the appropriate amount for living organisms in the water and for human used (Sripen, 1999). However, human activities are a major cause of decreasing the diversity of aquatic plant species, in which, the lower disturbance from human, the higher diversity of the plants (Ngamsnae, 2011). The aim of this study was to investigate the spatial and seasonal variations of aquatic plants on biodiversity, distribution, and abundance in Nam Oun reservoir which indicated the habitats of living organisms, a relevant indicator for water resources, and a management of aquatic plants in the reservoir.

Methods

Study area

Nam Oun reservoir in Sakon Nakhon province was studied and divided into 3 zones, based on morphology; 1) water outlet zone (S1: 17°17'27.86"N 103°45'49.90"E and S2: 17°16'32.50"N 103°41'44.05"E); 2) middle zone (S3: 17°13'48.96"N 103°44'31.48"E and S4: 17°14'12.72"N 103°41'05.76"E); and 3) water inlet zone (S5: 17°11'53.69"N 103°44'41.66"E and S6: 17°09'15.13"N 103°48'03.33"E). Total of 6 stations and 2 points of each zone were conducted as followed:

Water outlet	S1	Ban Kok Sa-ad, Rae sub-district, Phang Khon district
(Zone 1)	S2	Ban Dong Kumpho, Waritchaphum district
Middle	S3	Ban Na Tun, Nanai village, Phanna Nikhom
(Zone 2)	S4	Ban Kudtakab, Kudtakab village, Waritchaphum district
Water inlet	S5	Ban Nong Pling, Nong Pling village, Nikhom Nam Oun district
(Zone 3)	S6	Ban Kok Sung, Nong Bua village, Nikhom Nam Oun district

Sampling of aquatic plants

Aquatic plants were randomly sampled between November 2013 and October 2014 which divided in to 4 hydrological seasons (Table 1). The sampling locations were surveyed using transactional point sampling throughout of the reservoir in 6 stations and 9 points along each station. The samples were collected by 1x1 m quadrat in 3 replications follow transaction line in each point. Samples were identified and wet weighed (g/m^2) by types of the aquatic plants in each survey area. Macrophytes were counted within 1,600 m^2 and classified by Sripen (1999), Rodloy *et al*. (2010), Kohanantakul (n.d.), AICAF (1996), and Han (2002), Pooma and Suddee (2014).

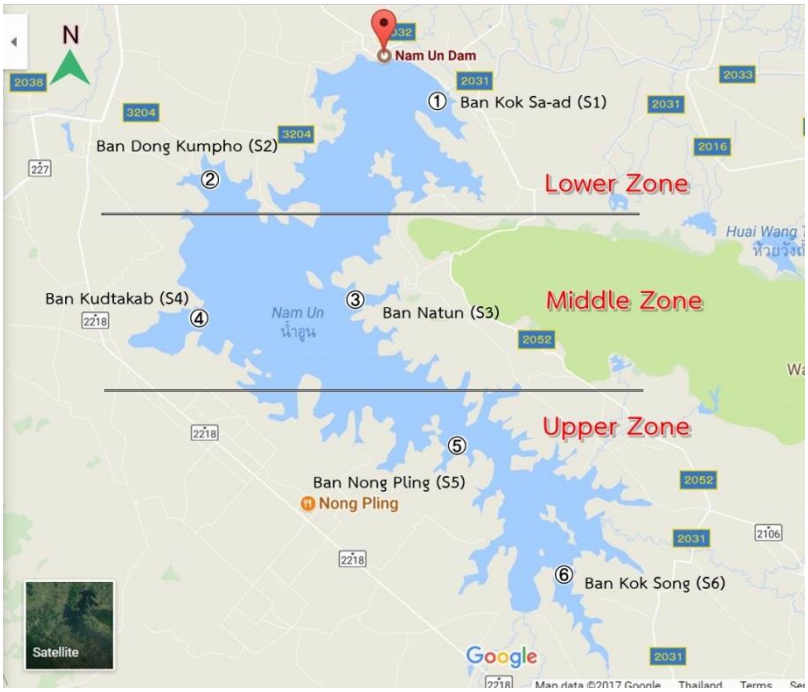

Figure 1 Map and location of sampling station (S1-S6) in Nam Oun reservoir, Sakon Nakhon province, Thailand. (Modified from Google maps, 2017)

Table 1 Patterns and details of hydrological seasons in Nam Oun reservoir, Sakon Nakhon province, Thailand, during November 2013 to October 2014. (Modified from Wudneh, 1998)

Period	Month	Details
Rainy to Dry: T1	Nov-Jan	End of the rainy season, highest in water volume and water body is extremely expanded.
Dry: T2	Feb-Apr	The water level at the lowest end storage, because of lowest water level, water temperature in dry season should be high.
Dry to Rainy: T3	May-Jul	End of storage period at low water level, when rain starts to precipitate, the water temperature is quite high.
Rainy:T4	Aug-Oct	The period of heavy precipitation, the water level starts to rise and turbidity increase.

Data Analysis

The differences between species and abundance of aquatic plants (each station and each season) were determined. The data were statistically analyzed by ANOVA using R-statistic version 2.9.0 software (R Development Core Team, 2009). Data were transformed to logarithm when data was non-normal distribution prior to analysis. The

Fisher's Least- Significant Different (LSD) test was used to compare and separate means when main effects were significant ($p<0.05$). Hierarchical cluster for multi-variance analysis was performed to classify types and abundance of macrophytes by Ward (1963). Principle Component Analysis (PCA) was then used for classification and comparison of the samples (Chatfield and Collins, 1980).

Results and Discussion

The distribution of species and abundance of aquatic plants in Nam Oun reservoir were reported. Total of 57 species and 31 families were found. Zone 1, zone 2 and zone 3 had 44, 40 and 44 species, respectively. As of survey stations, the highest and lowest number of species were recorded in S2 (39 species) and S3 (27 species), respectively. Aquatic plants were categorized into marginal (39 species; 68.42%), floating (14.04%), submerged (12.28%), and emergent (5.26%) (Table 2).

This study was similar to those reported by Rodloy *et al*. (2010), who surveyed 67 species and 77 families of aquatic plants in the Upper Northeast of Thailand, including Sakon Nakhon province. Rayan *et al*. (2014) revealed that 50 species and 29 families were identified with different in duration of the study. Nong Han Lake, Sakon Nakhon province, were surveyed and 44 species of aquatic plants were found (Ruekaewma *et al*., 2005). Bueng Khong Long in Nong Khai province had 75 species and 38 families of aquatic plants (Chaiya *et al*., 2005). When compared to nearby Nam Oun reservoir's areas, the Nam Oun Dam had a wide variety of aquatic plant species.

The aquatic plant species on frequency of occurrence in Nam Oun reservoir were *Mimosa pigra* (70.83%), *Hydrilla verticillata* (66.67%), *Eleocharis dulcis* (62.50%), *Utricularia aurea* (62.50%), and *Cynodon dactylon* (62.50%). Biomass of macrophyte which divided by species, were *M. pigra* (1,114.45 g/m^2), *Leersia hexandra* (993.44 g/m^2), *U. aurea* (359.31 g/m^2), *Nymphaea lotus* Linn. (266.61 g/m^2), and *E. dulcis* (208.06 g/m^2).

The most commonly found and largest biomass of macrophytes in Nam Oun reservoir were *M. pigra* , *U. aurea* and *E. dulcis*. However, Nong Han Lake contained *Potamogeton malaianus* L., *H. verticillata*, and *Eichornia crassipes* (Mart.) Solms. (Ruekaewma *et al*., 2005). Hui Kvang, Kanchanaburi province had species richness of *Najas graminea*, *U. aurea*, and *H. verticillata* (Kulabtong and Kunlapapuk, 2010). The species of *P. malaianus* Miq., and *Alternanthera sessilis* (L.) R. Br. DC. were found with highest biomass in Srinakarin Dam, especially, in the middle part of the dam where was rich in water sources (Kodsup, 2007). Related to this study, the middle zone (Zone 2) of Nam Oun reservoir had peaked of biomass during rainy to dry season (November-January). Because of these time of the year, the water level and storage were maximum. So, aquatic plants can be increased their maximum growth during that time.

Table 2 Total of aquatic plant species collected from each sampling station in Nam Oun reservoir, Sakon Nakhon province, Thailand, during November 2013 to October 1014.

Scientific Name	Common Name	Abbrev.	Zone 1		Zone 2		Zone 3		Type*
			S1	S2	S3	S4	S5	S6	
1. Family AMARANTACEAE									
1. *Alternanthera sessilis* (L.) R. Br. DC.	Alligator weed	ALSE	+	+	+	+	+	+	M
2. Family ARACEAE									
2. *Pistia stratiotes* L.	Water lettuce	PIST	-	-	+	-	-	-	F
3. Family ASTERRACEAE									
3. *Eclipta prostata* L.	White head	ECPR	-	+	-	+	+	+	M
4. *Enydra fluctuans* Lour.	Marsh herb	ENFL	+	-	-	+	-	-	F
5. *Grangea maderaspatana* (L.) Poir	-	GRMA	+	+	+	+	-	-	M
4. Family BUTOMACEAE(LIMNOCHARITACEAE)									
6. *Limnocharis flava* (L.) Buch.	Yellow sawah lettuce	LIFL	-	-	+	+	-	-	M
5. Family CARYOPHYLLACEAE									
7. *Drymaria diandra* BL.	Whitesnow	DRDI	+	+	-	+	+	+	M
6. Family COMMELINACEAE									
8. *Commelina benghalensis* L.	Dayflower	COBE	-	+	-	-	-	+	M
7. Family COMPOSITAE									
9. *Ageratum conyzoides* (Linn.)	Billygoat-weed	AGCO	-	+	+	+	+	+	M
10.*Chromolaena odorata*	Siam weed	CHOD	-	+	+	+	+	+	M
8. Family CONVOLVULACEAE									
11. *Ipomoea aquatica* Forsk., I. reptans Poir. (Syn.)	Swamp morning glory	IPAQ	-	-	-	+	-	+	F
9. Family CYPERACEAE									
12. *Cyperus casteneus* Wild.	-	CYCA	-	+	-	-	-	+	M
13. *Cyperus haspan* L.	Sheathed cyperus	CYHA	+	+	-	-	-	+	M
14. *Cyperus imbricatus* Retz.	Shingle flatsegde	CYIM	+	+	-	-	-	-	M
15. *Cyperus pilosus* Vahl.	Fuzzy flatsedge	CYPI	+	+	-	-	-	+	M
16. *Cyperus kyllingia* Endl.	Java grass	CYKY	+	+	-	-	-	+	M
17. *Eleocharis dulcis* (Burm.f.) Trin ex Henschel	Spike rush	ELDU	+	+	-	+	+	+	M
18. *Cyperus rotundus* (Linn.)	Nutgrass	CYRO	+	+	+	-	+	-	M
19. *Eleocharis vivipara* Link (1827)	Hair grass	ELVI	+	+	-	-	-	-	M
10. Family ERIOCAULACEAE									
20. *Eriocaulon setaceum* L.	-	ERSE	+	-	-	-	-	+	M
11. Family FABACEAE									
21. *Aeschynomene americana* L.	American jointvech	AEAM	-	-	-	-	-	+	M
12. Family GENTIANACEAE									
22. *Nymphoides parvifolia* (Griseb.)Kuntze.	Water snowflake	NYPA	+	+	+	+	+	-	F

Table 2 (Continued)

Scientific Name	Common Name	Abbrev.	Zone 1		Zone 2		Zone 3		Type*
			S1	S2	S3	S4	S5	S6	
13. Family HYDROCHARITACEAE									
23. *Hydrilla verticillata* (L.f.) Royle	Hydrilla	HYVE	+	+	+	+	+	+	S
24. *Ottelia alismoides* (L.) Pers.	Duck-lettuce	OTAL	+	-	-	+	-	-	S
25. *Vallisneria spiralis* L.	Tapeglass	VASP	+	+	-	-	-	-	S
14. Family LENTIBULARIACEAE									
26. *Utricularia aurea* Lour.	Leafy bladderwort	UTAU	+	+	+	+	+	+	S
15. Family MARSILEACEAE									
27. *Marsilea crenata* Presl.	Water clover	MACR	+	+	-	+	-	-	M
16. Family MIMOSACEAE									
28. *Mimosa pigra* L.	Giant mimosa	MIPI	+	+	+	+	+	+	M
29. *Mimosa pudica*	Mimosa	MIPU	+	+	+	-	+	+	M
30. *Senna tora* (L.) Roxb.	Sickle senna	SETO	-	-	+	+	+	+	M
17. Family MIMOSACEAE(LECUMIMOSAE)									
31. *Neptunia oleracea* Lour.	Water mimosa	NEOL	-	-	-	-	+	-	F
18. Family NAJADACEAE									
32. *Najas greminea* Del.	Bushy pond weed	NAGR	+	+	+	+	-	-	S
19. Family NYMPHAEACEAE									
33. *Nelumbo nucifera* Gaerth.	Lotus	NENU	-	-	-	+	-	+	E
34. *Nymphaea lotus* Linn.	Water lily	NYLO	+	+	-	+	+	+	E
35. *Nymphaea stellata* Willd.	Water lily	NYST	+	-	-	+	+	+	E
20. Family ONAGRACEAE									
36. *Jussiaea linifolia* Vahl.	Water primrose	JULI	+	+	+	-	-	+	M
37. *Jussiaea repens* Linn.	Creeping water primrose	JURE	+	+	+	+	+	+	M
21. Family POACEAE									
38. *Brachiaria mutica* (Forsk.) Stapf	Paragrass	BRMU	-	-	-	+	+	+	M
39. *Hymenachne pseudointerrupta* C. Muell	Marsh grass	HYPS	+	+	+	+	+	-	M
40. *Leersia hexandra* Sw.	Southern cutgrass	LEHE	+	+	+	+	+	+	M
41. *Paspalum conjugatum* Berg.	Sour grass	PACO	-	-	+	-	+	+	M
22. Family POACEAE (GRAMINEAE)									
42. *Cynodon dactylon* (L.) Pers.	Bermuda grass	CYDA	+	+	+	+	+	+	M
43. *Ischaemum rugosum* Salisb., I. alkoense Honda	Wrinkle duck-beak	ISRU	-	+	-	+	-	+	M
23. Family POLYGONACEAE									
44. *Polygonum glabrum* Willd.	Common marsh buckwheat	POGL	+	+	+	+	+	+	M
45. *Polygonum tomentosum* Willd.	Knot weed	POTO	-	+	+	+	+	+	M
24. Family PONTEDERIACEAE									
46. *Eichornia crassipes* (Mart.) Solms.	Water hyacinth	EICR	-	-	+	-	-	-	F
47. *Monochoria hastata* (L.) Solms.	Monochoria	MOHA	+	+	-	-	+	+	M
48. *Monochoria vaginalis* (Burm.f.) Presl.	Monochoria	MOVA	-	-	-	-	+	-	M
25. Family POTAMOGETONACEAE									
49. *Potamogeton malaianus* Miq.	Curly pondweed	POCR	+	+	+	+	+	+	S

Table 2 (Continued)

Scientific Name	Common Name	Abbrev.	Zone 1		Zone 2		Zone 3		Type*
			S1	S2	S3	S4	S5	S6	
26. Family SCROPHULARIOACEAE									
50. *Bacopa monnieri* (L.) Pennell.	Dwart bacopa	BAMO	-	+	-	+	-	-	S
51. *Lindernia crustacean* (L.) F. Muell	Malaysian false pimpernel	LICR	-	+	-	-	-	+	M
27. Family SPHENOCLEACEAE									
52. *Sphenoclea zeylanica* Gaertn.	Gooseweed	SPZE	-	+	+	-	+	+	M
28. Family TRAPACEAE									
53. *Trapa bispinosa* Roxb.	Water chestnut	TRBI	-	-	+	+	+	-	F
54. *Trapa quadrispinosa* Roxb.	Water chestnut	TRQU	-	-	-	-	+	-	F
29. Family TYPHACEAE									
55. *Typha angustifolia* L.	Narrow leaved cattait	TYAN	-	+	-	-	-	+	M
30. Family VERBENACEAE									
56. *Lippia nodiflora* L.	Frog fruit	LINO	-	+	+	+	+	+	M
31. Family XYRIDACEAE									
57. *Xyris difformis* Chapman.	Yellow-eyed grass	XYDI	+	-	-	-	-	-	M
Total species of stations			32	39	27	33	31	37	
Total species of zones			44		40		44		

* F: floating (8 species), E: emergent (3 species), S: submerged (7 species), M: marginal (39 species)

Result of analysis of variance in species diversity and logarithm regression in the estimation of aquatic plant biomass had no significantly differed between the stations ($p>0.05$). However, seasonal had a statistical effect on biomass of aquatic plants ($p<0.05$) (Table 3). Macrophytes, during rainy to dry season, had significantly higher biomass compared to those macrophytes during dry, and dry to rainy seasons ($p<0.05$). No differences were found during rainy season (Table 4).

Table 3 Results of ANOVA in spatial and seasonal contributions of species richness and log biomass.

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Species richness					
Season	3	11.240	3.747	2.010	0.156
Station	5	3.831	0.766	0.411	0.834
Residuals	15	27.963	1.864		
Log biomass					
Season	3	2.739	0.913	11.751	0.000***
Station	5	1.040	0.207	2.676	0.063
Residuals	15	1.165	0.0777		

* p value<0.05 with differences statistically significant.

Seasonal and macrophytes biomass composition were clustered either similar or different and divided into 3 groups (Figure 2A) and biomass of aquatic plants found in each season were shown in Figure 2B. Group 1 contained submerged plants; *Vallisneria spiralis* L. (VASP; 346.68 g/m^2) and *Na. greminea* Del. (NAGR; 217.78 g/m^2), and marginal plant; *Cyperus pilosus* Vahl. (CYPI; 53.32 g/m^2) in the water outlet (Zone 1) and the middle (Zone 2) zones during rainy to dry season (T1). Group 2 consisted of floating plants; *Ny. lotus* Linn. (NYLO; 1,066.45 g/m^2) and marginal plants; *Cynodon dactylon* (CYDA; 746.67 g/m^2), and *Alternanthera sessilis* (L.) R. Br. DC. (ALSE; 19.137 g/m^2) in the middle zone (Zone 2) during rainy to dry season (T1). Group 3 had marginal plants; *Drymaria diandra* BL. (DRDI; 80.00 g/m^2), *Paspalum conjugatum* Berg. (PACO; 46.66 g/m^2), and *Lindernia crustacean* (L.) F. Muell (LICR; 33.34 g/m^2) in the water inlet zone (Zone 3) during rainy season (T4).

Table 4 Summary of ANOVA result on seasonal contribution of biomass of aquatic plants.

Season	Log biomass
T1	2.930 ± 0.413^{a}
T2	2.465 ± 0.378^{b}
T3	2.047 ± 0.198^{c}
T4	2.777 ± 0.294^{ab}

^{abc}Means within a column with difference superscripts differ significantly ($p<0.05$).

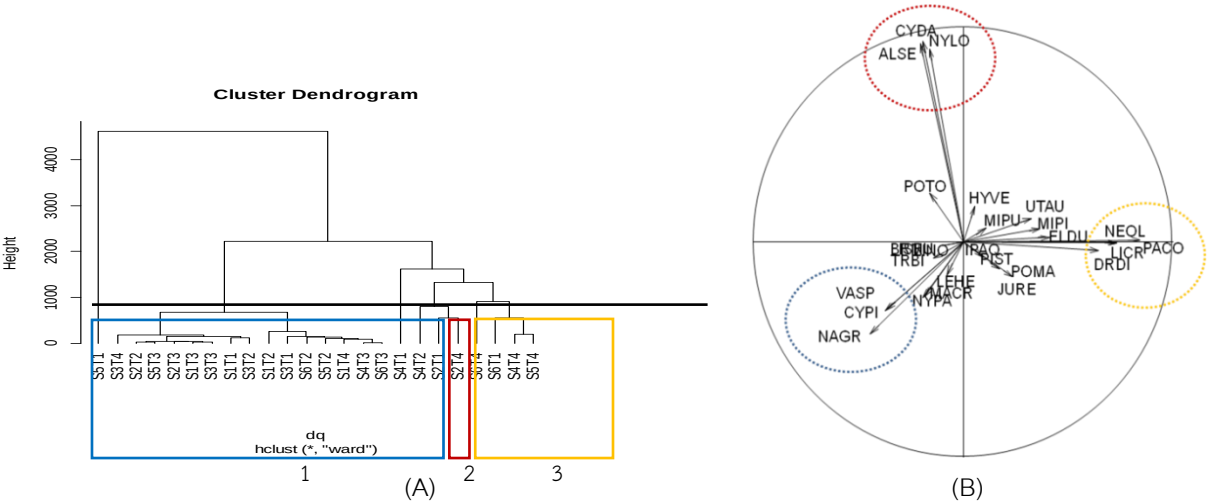

Figure 2 Results of hierarchical cluster (A), principle component analysis (B), of aquatic plant biomass related to the survey.

From the results of hierarchical cluster, diversity and richness of aquatic plants (Figure 2), richness of floating plants were *Trapa bispinosa* Roxb. (TRBI) and found in every seasonal survey. Meanwhile, *Ny. lotus* L. (NYLO) which is an economic aquatic plant was detected and had lowered biomass in the middle zone (Zone 2) during rainy to dry season (T1). The middle (Zone 2) and the water outlet (Zone 1) zones had the most diversity of aquatic plants. The largest biomass were found in the middle zone (Zone 2) of the reservoir during rainy to dry season (T1). This would be explained by Adwubi *et al*., (2009) and Royal Irrigation Department (2011). The middle zone of reservoir during rainy season had the maximum deposit of sediments which accumulated nutrient availability for aquatic plants. In the other hands, Duangsawasdi *et al*., (1992) reported that abundance and distribution of aquatic plants in Nong Han Lake were lowered because of high water level during rainy season. Marginal plants were the most common and had normal growth during rainy season (T4).

Conclusions

The total aquatic plants were 57 species, 31 family which categorized into floating, emergent, submerged and marginal (8, 3, 7, and 39 species, respectively). Seasons had an influence on distribution and biomass of aquatic plants. The most commonly found and largest biomass were *M. pigra*, *U. aurea* and *E. dulcis*. In term of seasonal distribution and area, the most diverse species were observed in the middle and water outlet zones during dry to rainy season. While the highest biomass were detected in the middle zone during rainy and dry to rainy seasons. By grouping the similarity of aquatic plants, marginal plants were the dominant in this reservoir area.

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