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Relationship between Vegetation Composition and Dissolved Nitrogen in Wetlands of Higashi-Hiroshima, West Japan

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ABSTRACT: Twenty-four wetlands located in Higashi-Hiroshima City in West Japan were selected for this study in order to investigate both the relationship between aquatic plant composition and environmental conditions; and the relationship between changing land use patterns in the catchments and the concentration of different forms of nitrogen in the wetlands. The dominant and subdominant species which comprised the principal vegetation were determined based on a vegetation census conducted in each wetland during the growing season from June to August, 2006. The seasonal variations of water quality factors (pH, electrical conductivity, turbidity, dissolved oxygen, total dissolved solid, and temperature) and different forms of nitrogen such as nitrite, nitrate, ammonium, total nitrogen, dissolved organic nitrogen and dissolved inorganic nitrogen concentrations were analyzed as important indicators of water quality for the surface water of the wetlands. The surveyed wetlands were classified into three types (non-disturbed wetlands, moderately-disturbed wetlands and highly-disturbed wetlands), based on the degree of human disturbance to their catchment areas. An analysis of variance indicated that there was a significant difference among the wetland groups in the annual mean values of electrical conductivity, total dissolved solids, total nitrogen, nitrite, dissolved inorganic nitrogen and dissolved organic nitrogen. Classification of the wetlands into three groups has revealed a pattern of changes in the composition of plant species in the wetlands and a pattern of changes in nitrogen concentrations. A majority of the non-disturbed wetlands were characterized by *Brasenia schrebi* and *Trapa bispinosa* as dominant; with *Potamogeton fryeri* and *Iris pesudacorus* as sub-dominant species. For most of the moderately-disturbed wetlands, *Brasenia schrebi* were shown to be a dominant species; *Elocheriss kuriguwai* and *Phragmites australis* were observed as sub-dominant species. For a majority of the highly-disturbed wetlands, *Typha latifolia* and *T. angustifolia* were observed as dominant species, and *Nymphea tetragona* as the sub-dominant species in the study area. An analysis of land use and water quality factors indicated that forest area played a considerable role in reducing the concentration of nutrients, and can act as a sink for surface/subsurface nutrient inputs flowing into wetland water, anchor the soil, and lower erosion rates into wetlands.

Key words: Dissolved nitrogen, Vegetation, Water quality, Wetland

INTRODUCTION

Wetlands continue to receive recognition for their importance as a functional unit (Lee et al. 2005) and an importance which is certainly not limited to their status as unique habitats for rare or endemic species of plants and animals (DeBusk 1999). Wetlands play an important role in reducing nutrient loads to surface waters (Jones et al. 2001) by trapping sediment; removing nutrients; storing and releasing inorganic nutrients and transforming them into organic forms (DeBusk 1999). The environmental quality of these valuable ecosystems has been undergoing extensive change and degradation because of anthropogenic interventions. Because of their significant role in improving the quality of the environment, there has been much attention paid to the conservation, restoration, and creation of wetlands (Lee et al. 2005). Although there has been little research which has examined the relationship between land use and wetland water in comparison with studies which have looked at land use and stream water quality (Houlahan and Findlay 2004), Detenbeck et al. (1996), Schwartz et al. (1996), Crosbie and Chow-Fraser (1999) and Brock (2003) have studied the relationship between the proportion of land use in the watershed of the wetlands and the quality of wetland water. Daley and McDowell (2002) studied the relationships between nitrate and dissolved organic nitrogen and their catchment attributes. They found that human population density and human activities are the main factors controlling dissolved organic nitrogen content in wetlands, and that riparian soils are the main source of dissolved organic nitrogen.

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Plants, as primary producers, have a great effect on ecosystem functions like hydrology and also on nutrient and carbon dynamics in wetlands (Gopal 1990, Vymazal et al. 1998, Davidsson et al. 2000). Therefore, the detection of the spatial distribution and the temporal change of plant communities can provide important information on the effects of environmental factors relevant to the wetland (Davidsson et al. 2000). With regard to a linkage between vegetation and environmental factors, the findings of Lee et al. (2005) indicated that water depth was the major factor affecting the distribution of the wetland plants, and that nutrients such as NH_4-N and NO_3-N were also important factors in determining the distribution of several plant groups during specific seasons.

Brock (2003) also investigated the natural dynamics of wetland plants and wetlands in the landscape and considered the resilience of wetland plants to be an indicator of the wetlands' response to changes in the environment. The findings of this study revealed that plant communities responded to changes induced by alterations in water quantity and water quality. Shimoda (1993) studied the effects of urbanization on vegetation in irrigation ponds in Saijo Basin in Higashi-Hiroshima City and found water plant communities (including sub-merged and floating-leaved communities), emerged shore communities (characterized by small annual plants, reed swamp and tall sedge communities), and *Moniniopsis* marsh communities in and around the irrigation ponds in the study area. She concluded that land development and its accompanying urbanization are changing the landscape of the Saijo Basin in Higashi-Hiroshima. The vegetation of many ponds has been completely altered or, in some cases, has disappeared due to the anthropogenic effects of water pollution, eutrification, and land development.

Shimoda (1997) studied 15 irrigation ponds spread over a wide range of environmental settings, from mountainous areas to plateaus, and concluded that plant distribution might be influenced, not only by water quality, but also by other factors such as accidental species, inter-specific competition, aquatic animals, and pond history. Shimoda and Hashimoto (1993) studied the relationship between water quality (total nitrogen) and the frequency of occurrence of aquatic plants within the wetlands, and reported a direct relationship between the concentration of total nitrogen and the populations of the plant species *Brasenia schreberi, Trapa bisponsa, Nymphea tetragona* var. *angusta, Nuphar oguranse, Utricularia tenaicaulis, Utricularia minor, Potamogeton fryeri, P. actandrus, Najas gramina.* The objectives of this study are 1) to investigate the relationship between aquatic plant composition and the environmental conditions of the wetlands, and 2) to study the relationship between the changing proportions of land use in contributing catchment areas and the concentration of different forms of nitrogen in the wetlands.

MATERAILS AND METHODS

Study Area

The study region (Higashi-Hiroshima) is located within 132° 36' 23"~132° 51' 19" E and 34° 15' 19"~34° 34' 58" N with a 635 km^2 area (Fig 1). Annual rainfall was on average 160 mm/month with a maximum monthly value of 304 mm/month in July, and a minimum monthly value of 19 mm/month in October. Mean annual temperature was 14.1℃, with a mean monthly air temperature ranging from 2.3℃ in January, to 26.8℃ in August, as minimum and maximum values, respectively, in the study area. Spatial analysis of the landscape setting (geological formations, soil types and land-use types) of the catchment of the wetlands indicated that granite and alluvial sand are the main geological formations in the catchment areas of the wetlands. Residual regosols and brown forest soil were observed as dominant and sub-dominant soil types.

The location of the 24 wetlands in various landscape settings is illustrated in Fig. 1. It should be noted that all the wetlands are of similar geographic features except their physical features of catchments. Shimoda (1993) suggested that there are about 1,100 water bodies (ponds) that were constructed for irrigation of rice fields in the study area. Twenty-four out of 1,100 wetlands were chosen as our study sites using a topographical map (1:50,000) (Japan Geographical Survey Institute). The contributing catchment areas of the wetlands were then checked by field observation in order to obtain a variety of landscape setting-related data for future analysis. The maximum water level of the water bodies was considered in order to meet the definition of a wetland based on the Ramsar Convention on Wetlands (http://www.ramsar.org/ris/key_ris_types.htm) (5/3/2006).

Materials and Methods

Water quality factors including pH, electrical conductivity, turbidity, dissolved oxygen, temperature, total dissolved solids, specific gravity, and chloride were measured by a portable water quality monitor (HORIBA, Model U-21 XD) in outflow of each wetland. This was done during each of the four seasons through 2006.

Surface water samples were collected from outflow of each wetland at the same time as above and immediately placed in a cooler for transport to the laboratory in order to analyze them for dissolved nitrogen content, including nitrate, nitrite, ammonium, dissolved inorganic nitrogen, dissolved organic nitrogen, and total nitrogen. After they were transported to the laboratory, samples were immediately analyzed using the Ion Chromatography Method for nitrate and nitrite, the Ultraviolet Spectrophotometeric Screening Method for ammonium and total nitrogen (APHA 1995), and 4500-N_{org} C. Semi-Micro Kjeldal Method for dissolved organic nitrogen. To characterize plant composition in each wetland, we used the line

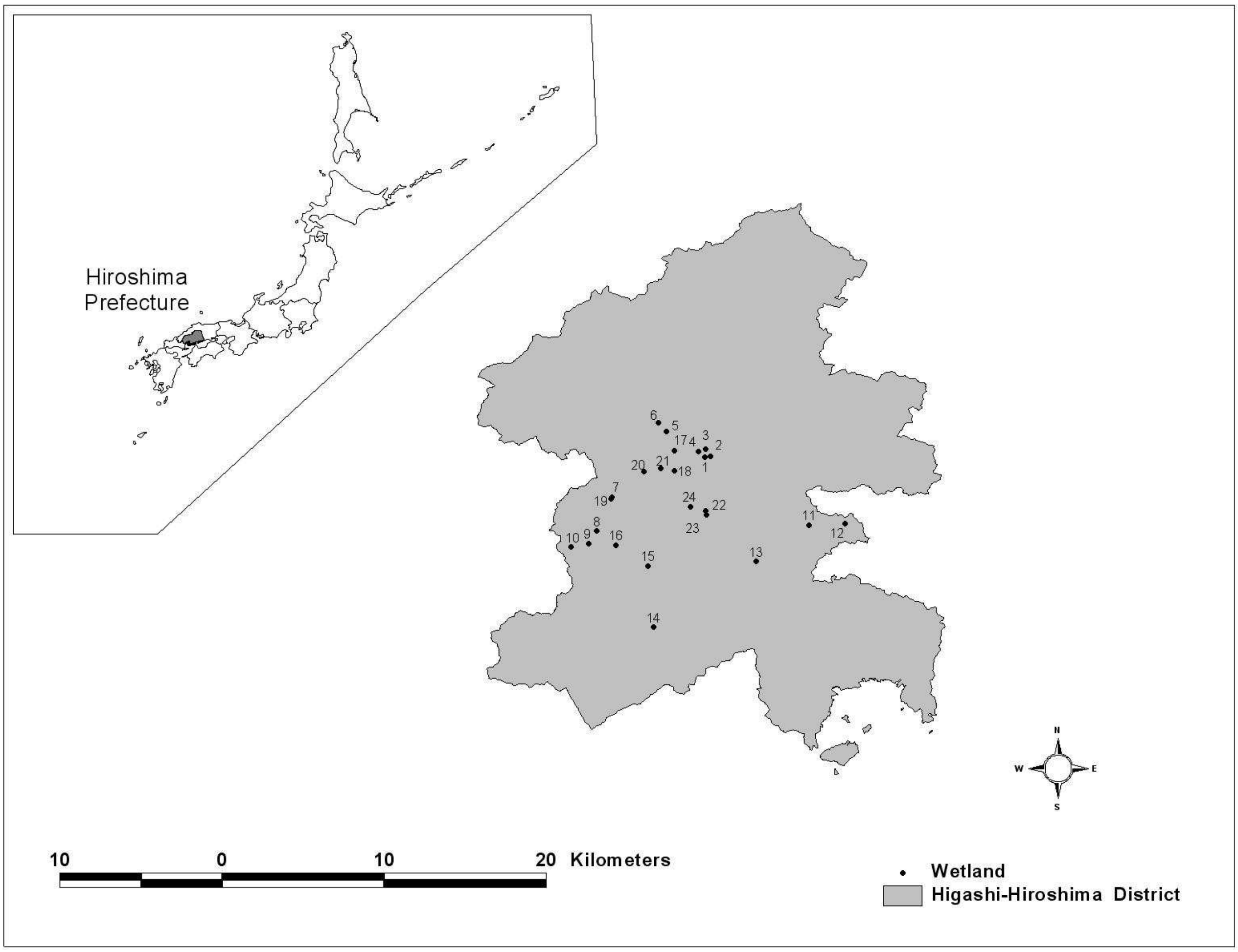

Fig. 1. Geographical position of the study area.

transect method, and took samples of the plants once during the middle of the growing season (June~August 2006). The dominant and sub-dominant species were recognized and the percentage of plant cover was estimated in each wetland. All field work-related to this study was conducted during 2006. A one-way analysis of variance (ANOVA) was applied to determine whether there was a significant difference between wetland groups in the annual mean value of water quality factors and the annual mean value of different forms of nitrogen. A correlation coefficient test ($p<0.05$) was used to specify the relationship between the annual mean concentrations of different forms of nitrogen, the annual mean concentrations of different water quality factors, and the proportion (%) of different land use patterns (urban, forest, agriculture, grassland) in the watershed of the wetlands.

The catchments boundaries were hand digitized, using 1:25,000 topographic quadrangle maps (Japan Geographical Survey Institute 2000). The land cover map (Amiri and Nakane 2006) was then superimposed on the watershed boundaries of the wetlands map in order to calculate the real extent of each land use type within the watershed; the result of this calculation was then subsequently divided by the area of the watershed in order to determine the percentage of the watershed covered by each type. All databases were transformed into a common digital format and projected onto a common coordinate system (UTM, zone 53).

The landscape attributes of the watershed of each wetland (the proportion of each land use type present in each area) were estimated using a Geographical Information System (ArcView 3.2, ESRI 1999).

RESULTS

Land Use Around Wetlands

The wetlands were classified into three groups based on the land use surrounding them (Table 1) in order to establish a basis for comparing the composition of aquatic plant life, water quality factors, and the concentration of different forms of nitrogen.

Table 1. Proportion (%) of land use in watershed of wetlands

Group	Wetland No.	Land use (%)			
		Urban	Forest	Agriculture	Grassland
Ⅰ	22	0.00	53.63	30.86	15.51
	12	0.00	72.30	18.69	9.01
	19	0.00	94.92	0.00	5.08
	20	0.00	74.75	8.93	16.32
	8	0.00	41.24	33.38	25.38
	10	0.00	100	0.00	0.00
	7	0.00	100	0.00	0.00
	9	0.00	99.33	0.67	0.00
	18	0.00	39.65	60.35	0.00
	2	0.00	100	0.00	0.00
	4	0.00	83.88	16.12	0.00
Mean		0.00	78.15	15.36	6.48
Ⅱ	6	9.19	85.97	1.98	2.86
	23	4.16	18.78	77.06	0.00
	13	3.22	92.95	3.83	0.00
	11	4.45	74.14	21.41	0.00
	15	10.50	45.38	22.06	22.06
	1	32.20	0.00	67.80	0.00
	21	23.44	53.31	13.95	9.30
Mean		7.92	61.11	27.27	3.70
Ⅲ	17	72.53	9.45	3.04	14.98
	14	32.91	24.04	34.91	8.14
	3	78.20	0.00	21.80	0.00
	5	42.40	6.44	45.17	5.99
	16	34.20	1.48	38.89	25.43
	24	40.73	0.00	59.27	0.00
Mean		27.42	27.05	37.38	8.15

The classification of the wetlands were carried out with consideration of the percentage of urbanized area in their catchment. Specifically, less than 1% of the catchment of wetlands group I were covered by urbanized area; about 1.1∼33 % of that of wetlands group Ⅱ was covered by urban area. For wetlands group Ⅲ, more than 33% of that of wetlands was covered by urbanized areas. Accordingly, Group Ⅰ was called non- disturbed; group Ⅱ, moderately-disturbed; and group Ⅲ, highly-disturbed.

Water Quality

Trends in the variation of the water quality were analyzed and a specific pattern was observed for each factor (Tables 2 and 3). In the majority of the wetlands, the range of pH values was between 5.30∼8.42, with the maximum value in the period from the winter through the spring, and the minimum value in autumn (Table 2). If the range values observed decreased accordingly from group Ⅰ to group Ⅲ, then this decrease would be expressed as G. Ⅰ > G.Ⅱ> G.Ⅲ. G stands for group in this instance.

For electrical conductivity, it was observed that the range varied between 3∼24 (mS/m) on average with the maximum value in winter and spring, and the minimum value observed in the summer (Table 2). Although electrical conductivity for wetland groups Ⅱ and Ⅲ was observed to be in the same range, wetland group Ⅰ was lower than the other two groups (G.Ⅰ< Two other groups, and G.Ⅱ = G.Ⅲ).

Results indicated that turbidity values ranged between 0∼190 (mg/L) with maximum and minimum values in the winter and summer, respectively (Table 2). This was expressed as a decreasing trend within the wetland groups under investigation, as G.Ⅱ> G. Ⅰ> G.Ⅲ.

DO values varied between 2 and 13.2 (mg/L) with the maximum values observed in the early spring and the minimum in autumn. A decreasing trend was observed within the groups as G.Ⅱ> G.Ⅲ> G.Ⅰ, respectively (Table 3).

For TDS values, the range of this water quality variable was indicated to be between 0.02 and 0.15 (g/L) (Table 3). It did not reveal a significant change during any of the four seasons for the majority of the wetlands. However, while the range of TDS values for wetlands group Ⅱ and Ⅲ were the same, wetland group Ⅰ had a lower range than two other groups (G.Ⅰ< Two other groups, and G.Ⅱ = G.Ⅲ).

Temperature values ranged between 5.83∼27.8, and a natural pattern (maximum and minimum values in summer and winter, respectively) emerged (Table 3). A decreasing trend was observed among the wetland groups under study and expressed as G.Ⅱ> G. Ⅰ> G.Ⅲ.

An analysis of variance (Table 6) revealed that there was a significant difference in the mean values of EC and TDS between the wetland groups with $p<0.05$. Other water quality factors (pH, turbidity and DO) did not indicate a significant difference in the mean value between wetland groups with $p<0.05$.

Nitrogen Concentration

Trend analysis of nitrogen concentration in the surface water of the wetlands revealed patterns within the three wetland groups. For total nitrogen (Table 4), the range of the values was between 0.265

TABLE 2

TABLE 3

~3.562 (mg/L) with the maximum (32%) in the summer, and the minimum (43%) in winter for the whole wetlands. Table 6 also suggests there was a significant difference in the annual mean value of TN among wetland groups with $p<0.05$. Nitrite concentration in these wetlands ranged between 0~0.148 (mg/L) (Table 5) with the maximum value (43%) occurring in autumn and the minimum value (43%) in spring. The result from an analysis of variance revealed a significant difference in the mean value of nitrite between wetland groups with $p<0.05$ (Table 6). For dissolved organic nitrogen, the range of concentration was between 0.225~1.393 (mg/L) with the maximum (45.5%) in the summer and the minimum (41%) in the winter (Table 4). Furthermore, a significant difference was observed in the mean value of DON between wetland groups with $p<0.05$ (Table 6). The concentration of ammonium varied between 0~2.538 (mg/L) (Table 5) with a maximum value of 34% in summer and a minimum value of 33% in autumn. For the concentration of nitrate (Table 4), the range in value was between 0~0.837 (mg/L) with the maximum in winter and the minimum in autumn for 41%, 38% of wetlands, respectively. In addition, the annual mean concentration of ammonium, and that of nitrate did not indicate a significant difference between wetland groups with $p<0.05$ (Table 6). Finally, the concentration of dissolved inorganic nitrogen varied from 0 to 3.454 (mg/L) (Table 5), with the maximum in spring and the minimum in summer for 41%, and 32% of the wetlands, respectively. ANOVA results suggest a significant difference in the annual mean value of DIN between wetland groups with $p<0.05$ (Table 6).

The concentration of all forms of nitrogen - dissolved organic nitrogen, dissolved inorganic nitrogen, nitrite, nitrate, ammonium and total nitrogen - was found to increase progressively from group Ⅰ to group Ⅲ.

Vegetation Composition

Based on the results of an aquatic vegetation inventory, 84 plant species were identified across 24 wetlands. These species were then classified according to whether or not they were present in each of the three wetland groups. The results of this classification indicated distinctive changes in plant species composition among the three wetland groups. The result of the vegetation composition analysis is summarized in Table 8. Accordingly, seven types of plant compositions were observed, which are described as follows:

Type A: 25 species exclusively observed in the wetlands of group Ⅰ that their watersheds were covered by forest (non-disturbed) areas.

Type B: 19 species exclusively observed in the wetlands of group Ⅱ that less than 33% of their watersheds were covered by urban (moderately-disturbed) areas.

Type C: 5 species exclusively observed in the wetlands of group Ⅲ that more than 33% of their watersheds were surrounded by urbanized (highly-disturbed) areas.

Type D: 16 species commonly observed in wetlands of groups Ⅰ and Ⅱ.

Type E: 4 species commonly observed in wetlands of groups Ⅰ and Ⅲ.

Type F: 6 species commonly observed in wetlands of groups Ⅱ and Ⅲ.

Type G: 9 species commonly observed in wetlands of group Ⅰ, Ⅱ, and Ⅲ.

DISCUSSION

Relationship between Land Use and Water Quality

The relationship between the water quality factors (annual mean concentration) of the wetland water and type of watershed (the proportion of land use) was examined using a correlation coefficient test ($p<0.05$) (Table 7). The results indicated significant positive relationships between the proportion (%) of urbanized area in the contributing watershed of the wetlands and the EC value (r = 0.65, $p<0.05$), and TDS (r = 0.64, $p<0.05$). As the percentage of urban area increases, the annual mean of the EC and the TDS value seems to increase in the wetland water. This would first of all be related to the transformation of surrounding vegetation from a forested area into an urban area, and secondarily to a loss in soil resources in the urban area due to improper storm water management, which can cause degradation of water quality due to soil erosion and sediment transportation (Kaste et al. 1997, Castillo et al. 2000).

The percentage of forested area in the contributing watersheds of these wetlands was seen to have had a significant negative relationship with EC (r = -0.63, $p<0.05$), and TDS (r = -0.64, $p<0.05$). These relationships indicated that forest area would be able to play a controlling role in regulating the water quality of wetlands. As the proportion of forest area increases in the watershed of wetlands, the annual mean values of EC and TDS would significantly be decreased in the wetland water. It has been well documented that there is a positive relationship between watershed land use practices and soil erosion. In particular, the loss of forest cover is associated with increased soil erosion (Bormann and Likens 1979, Currier 1980, Omernick et al. 1981) and diminished water quality (Houlahan and Findlay 2004).

Relationship between Land Use and Nitrogen Concentration

The results of a correlation coefficient test (Table 7) suggests that there was a significant relationship between the proportion (%) of urban area in the contributing watershed of these wetlands and

TABLE 4

TABLE 5

Table 6. Result of analysis of variance between and within groups of wetlands (ANOVA-one way)

		Sum of squares	df	Mean square	F	Sig.
EC	Between groups	161.322	2	80.661	10.733	0.000*
	Within groups	157.82	21	7.515		
	Total	319.142	23			
TDS	Between groups	9.58E-03	2	4.79E-03	10.855	0.000*
	Within groups	9.27E-03	21	4.41E-04		
	Total	1.89E-02	23			
NO_2	Between groups	2.56E-03	2	1.28E-03	5.820	0.020*
	Within groups	4.62E-03	21	2.20E-04		
	Total	7.18E-03	23			
NO_3	Between groups	9.08E-02	2	4.54E-02	2.938	0.070
	Within groups	0.325	21	1.54E-02		
	Total	0.415	23			
NH_4	Between groups	0.275	2	0.138	2.840	0.070
	Within Groups	1.018	21	4.85E-02		
	Total	1.293	23			
DIN	Between groups	0.817	2	0.409	3.413	0.050*
	Within groups	2.514	21	0.120		
	Total	3.331	23			
DON	Between groups	0.348	2	0.174	9.946	0.000*
	Within groups	0.368	21	1.75E-02		
	Total	0.716	23			
TN	Between groups	2.095	2	1.047	14.684	0.000*
	Within groups	1.498	21	7.13E-02		
	Total	3.592	23			

TN (r = 0.60, p<0.05), and DON (r = 0.72, p<0.05), and NO_2 (r = 0.42, p<0.05). The annual mean amounts of nutrients (TN, DON and NO_2) increased as the percentage of urbanized area increased in the watershed of these wetlands. Tong and Cheng (2002) reported a strong relationship between the concentration of TN and an area of either urban or agricultural use, and a negative relationship between the area of forest and the concentration of TN was also confirmed by Norton and Fisher (2000).

Significant negative relationships were revealed between the proportion of forest area and the annual mean of TN (r = - 0.63, p<0.05), DON(r = - 0.56, p<0.05), DIN (r = - 0.39, p<0.05), and

Table 7. Result of correlation coefficient between water quality, different forms of nitrogen and percentage of land use types in watershed of wetlands

	Urban	Forest	Agriculture	Grassland
pH	- 0.26	0.15	- 0.06	0.19
EC	**0.65**	**- 0.63**	0.33	0.09
Turbidity	0.14	- 0.31	0.35	0.01
DO	- 0.27	0.21	- 0.07	- 0.01
TDS	**0.64**	**- 0.64**	0.35	0.11
TN	**0.60**	**- 0.63**	**0.42**	- 0.01
NO_3	0.24	- 0.33	0.30	- 0.05
DON	**0.72**	**- 0.56**	0.15	0.12
NH_4	0.29	- 0.39	0.38	- 0.14
NO_2	**0.42**	**- 0.51**	**0.43**	- 0.07
DIN	0.30	**- 0.39**	0.37	- 0.11

Bold value is significant at p<0.05.

NO_2 (r = - 0.51, p<0.05). Forest area could act as a controlling factor in improving the quality of the aquatic ecosystem (wetland) by reducing the inflow of nutrients (TN, DON, DIN and NO_2,) to the water body of the wetland. In the case of TN, this finding was confirmed by those of Houlahan and Findley (2004).

The annual mean concentration of TN (r = 0.42, p<0.05) and NO_2 (r = 0.43, p<0.05) was positively associated with an increasing proportion of agricultural area in the watershed of the wetlands. It could originate from the application of chemical fertilizers and soil erosion from farmlands; the fertilizer and eroded soil is carried out by overland flows from the agricultural area into the wetland water (EPA 2002). The potential nitrogen loss rates (kg/ha/yr) for agricultural areas (0.98 kg/ha/yr) are 2.23 times that of natural vegetation (0.44 kg/ha/yr) (Omernik 1977, Marsh 1998).

A statistically significant relationship was not observed between the proportion (%) of grassland area in the contributing watershed of wetlands and changes in water quality factors and nitrogen concentrations.

Relationship between Land Use and Vegetation Composition

Results of the vegetation inventory indicated that plant species composition differed widely among three wetland groups (Table 8). While the number of individual species was decreased as one moved from non-disturbed wetlands to highly-disturbed wetlands, the plant cover percentage was increased considering this gradient in environment.

Table 8. Summary of the occurring, dominant and sub-dominant plant species in three wetland groups

	Plants	Wetlands group	GⅠ											GⅡ							GⅢ					
	type	Plandts Name/wetlands No	22	12	19	20	8	10	7	9	18	2	4	6	13	11	23	15	1	21	17	14	3	5	16	24
1		*Carex dickinsii*		+				+		+																
2		*Viola verecunda*	+	+	+																					
3		*Sparganium* sp.		◎		+		+																		
4		*Pleioblastus shibuyanus*		+							+															
5		*Juncus papillosus*			+			+																		
6		*Miscanthus sacchariflorus*						+			◎															
7		*Schoenoplectus tiquter*	+																							
8		*Sagittaria* sp.	+																							
9		*Eupatorium lindleyanum*	+																							
10		*Sarothra laxa*	+																							
11		*Sphagnum palustre*	+																							
12		*Juncus walichianus*	+																							
13	A	*Eleocharis wichurai*	+																							
14		*Haloragis micrantha*		+																						
15		*Cirsium sieboldi*		○																						
16		*Eleochairs attenuata*		+																						
17		*Dorsera routundifolia*		+																						
18		*Galium trifidum*		+																						
19		*Lonicera japonica*	+	+																						
20		*Potamogeton malaianus*				+																				
21		*Typha orientalis*				+																				
22		*Sium suave*						+																		
23		*Lycopus maackianus*						+																		
24		*Sparganium erectum*								+																
25		*Scirpus lacustris*									+															
26		*Potamogeton pusillus*													+											
27		*Lysimachia fortunei*													+											
28		*Alisma canaliculatum*														+										
29		*Blyxa japonica*																		+						
30		*Myriophyllum oguraense*																		+						
31		*Lobelia sessilifolia*																		+						
32		*Cyperus haspan*																		+						
33		*Polygonum nipponenes*																		+						
34		*Ischaemum aristatum*																		+						
35	B	*Hosta longissima*																		+						
36		*Cyperus* sp.																		+						
37		*Iris ensata*															+									
38		*Chara braunii*															+									
39		*Sagittaria trifloia*																+								
40		*Spiranthes sinensis*																	+							
41		*Dryopteris erythrosora*																	+							
42		*Artemisia princeps*																	+							
43		*Isodon inflexus*																	+							
44		*Nuphar oquraenes miki*																	○							

Table 8. Continued

	Plants type	Wetlands group	GⅠ											GⅡ							GⅢ					
		Plandts Name/wetlands No	22	12	19	20	8	10	7	9	18	2	4	6	13	11	23	15	1	21	17	14	3	5	16	24
45		*Phalaris arundinacea*																					+		+	+
46		*Scirpus juncoides*																				○				
47	C	*Lemna paucicostata*																			○					
48		*Equisetum arvense*																			+					
49		*Polygonum hydropiper*																								+
50		*Brasenia schrebri*			+	◎		◎		◎		+		+	◎	+	+	○		◎						
51		*Trapa bispinosa*			○	○	◎					◎			+	+		+	+							
52		*Potamogeton cristatus*	+		+	+					+				+	+	◎									
53		*Elocheris kuroguwai*	+					+							+		○	+		○						
54		*Scirpus mucronatus*			+			+							+	+		+								
55		*Leerisa japonica*					+			+	+				+	+		+								
56		*Potamogeton fryeri*						○		○					+	+										
57	D	*Utricularia tenuicaulis*					+	+		+						+										
58		*Utricularia aurea*				+					○				+											
59		*Potamogeton distinctus*	+		+											○										
60		*Utricularia vulgaris*	+		+													+								
61		*Najas* sp.	+														+									
62		*Nuphar japonicum*			+														+							
63		*Zizania latifolia*					+												+							
64		*Carex amplifolia*		+												+										
65		*Epilobium pyrricholophum*		+														+								
66		*Iris pseudacorus*					○						○									+	+		+	
67	E	*Paederia scandens*		+																	+					
68		*Acorus calamus*											+										+			
69		*Agropyron tsukushienes*											+										+			
70		*Typha latifolia*														◎		+			◎	+	○		+	◎
71		*Polygonum thunbergii*														+			+		+		+			+
72	F	*Oenanthe javanica*																	+		+				+	
73		*Spirodela polyrhiza*													+										+	
74		*Nelumbo nucifera*																+							◎	
75		*Polygonum lapathifolium*																+								+
76		*Nymphaea tetragona*	+	+	+	+		+		+	+		◎	◎	+					+		◎	◎	○		
77		*Phragmites australis*	+		◎		+					○		○			+		◎	+	+	+	+			
78		*Isachne globosa*	◎	+	+			+										+		+		+				
79		*Juncus effusus*	+		+									+	+	+					+	+				
80	G	*Typha angustifolia*			+		○								○			◎			◎			◎		○
81		*Bidenes frondosa*		+	+								+					+	+		+					
82		*Miscanthus sinensis*		+						+			+			+		+	+				+			
83		*Murdannia keisak*									+				+						+					
84		*Solidago altissima*											+						+		+		+			

\+ Occurance of species

◎ Dominant species

○ Sub-dominant species

It indicated that the number of exclusive species and the percentage of plant cover were decreased and increased according to anthropogenic changes in the wetland environment, respectively.

Another interesting piece of information was obtained about the average number of species (diversity of plant species) in these three wetland groups. High numbers of plant species were observed in moderately-disturbed wetlands (group Ⅱ), but medium and low numbers of species were found in non-disturbed and highly-disturbed wetlands, respectively (group I and group Ⅲ). Considering the aforementioned findings, we concluded that species are less varied in highly-disturbed wetlands than in moderately-disturbed and non-disturbed wetlands. This confirmed the findings of Lopez and Fennessy (2002) that highly-disturbed wetlands would not provide desirable habitats for plants. That there was less plant variety within non-disturbed wetlands when compared with the level of plant variety in moderately-disturbed wetlands implies that the non-disturbed wetlands were abandoned without any conserving action. Finally, we recognized that group Ⅰ wetlands were typically a habitat for type A plants; group Ⅱ for type B plants; and group Ⅲ for type C plants.

Based on dominant and sub-dominant species, the majority of the group Ⅰ wetlands were characterized by *Brasenia schrebi* and *Trapa bispinosa* as dominant and *Potamogeton fryeri* and *Iris pesudacorus* as sub-dominant. Most of the group Ⅱ wetlands were characterized by *B. schrebi* as dominant and *Elochairs kuriguwai* and *Phragmites australis* as sub-dominant. The majority of the group Ⅲ wetlands were dominated by *Typha latifolia* and *Typha angustifolia* with *Nymphaea tetragona* as the characteristic sub- dominant species. Type G indicates a relatively large number of species found over a larger, region-wide scale. For example, Hitchcock et al. (1964) noted that *N. tetragona* is found in ponds, swamps, lakes, and quiet streams in the lowland and mountain zones, at an elevation of 0 to 1,200 m.

A small number of species in each wetland were observed to be unique to their settings and were considered incidental species by this study.

Relationship between Vegetation and Water Quality

There were no significant relationships observed between the types of vegetation present and various water quality factors (pH, DO, temperature, TDS). Decreased turbidity values in summer (during the plant growing season) indicated the influence of plants on the decrease in the turbidity value, and an inverse relationship between them was noted. Decreased electrical conductivity values during summer would be related to the effect of plants on decreasing turbidity values and the decreasing turbidity would, in turn, decrease the electrical conductivity.

Relationship between Vegetation and Nitrogen Concentration

The minimum concentration of dissolved inorganic nitrogen reported in the summer indicates the influence of plants during the growing season and emphasizes the uptake by plants of dissolved inorganic nitrogen in the surface water (Santamaria 1999, Redden et al. 1995, Salisbury and Ross 1978). In contrast, the highest value of total nitrogen indicates increased dissolved organic nitrogen concentration during the summer plant growing season. Finally, an analysis of all forms of nitrogen concentration, fluctuations in plant appearance time (summer), and disappearance time (winter), indicated, on average, a decrease in the dissolved inorganic nitrogen concentration, and an increase of the dissolved organic nitrogen concentration during the plant growing season, and *vice versa*. Seasonality in nitrogen concentration was confirmed by the findings of Jackson and Allen-Diaz (2002) and McHale et al. (2004). The results revealed that species diversity (average number of plant species) and number of individual species were decreased but percentage of plant cover was decreased as one moved from group 1 wetlands to group 3 wetlands.

CONCLUSION

Classification of the wetlands into three groups, based on the extent of anthropogenic degradation in their contributing catchments, revealed a pattern of changes in the composition of plant species in the wetlands and nitrogen concentrations. Based on the results of this study, plant species like *B. schrebri* and *Trapa bisionsa* were recognized as plant species sensitive to water quality fluctuations in the wetlands. *N. tetragona* and *P. australis* were the main plant species showing resistance to environmental changes in the contributing catchments of the wetlands. The observation of the extensive occurrence of *Typha* spp. could lead one to the conclusion that this plant species also tolerates a broad spectrum of environmental changes in aquatic ecosystems.

The result of an analysis of variance indicated that the annual mean concentration of only two water quality factors, (EC and TDS), out of the five water quality factors (which included pH, turbidity and DO) showed a significant difference among wetland groups. The findings of the analysis of variance for different forms of nitrogen suggested that the annual mean concentration of all forms of nitrogen -- namely nitrite, dissolved inorganic nitrogen, dissolved organic nitrogen, and total nitrogen -- with exception of nitrate and ammonium, showed a significant difference among wetland groups.

Investigating the relationship between the proportion of land use types and the annual mean concentration of water quality in wetland water revealed that forest area played a considerable role in reducing the concentration of TDS, TN, DIN, DON, NO_2 and EC values, since forest cover can act as a sink for surface/subsurface nutrient inputs flowing into wetland water, and anchor the soil and lower erosion rates into wetlands. The findings of this study indicated that there were direct relationship between the percentage of urban area in watershed and annual mean of nutrients such as TN, DON, NO_2, TDS and EC value in wetland waters so that increasing the urban area would be able to impair the water quality of the wetland water. Moreover, increasing the proportion of agricultural area would increase the annual mean of NO_2 and TN in wetland waters. Therefore, implementation of the policy that control the extending the agricultural and urban areas in the contributing watershed of wetland would result in halting degradation of environmental quality of the wetlands.

The results suggested that there is an association with changes in the composition of plant species, plant cover percentage and concentration of soluble nitrogen in wetlands groups Ⅰ, Ⅱ and Ⅲ, respectively. They indicated that the average number of species (diversity of plant species) decreased in correspondence with an increase in the extent of anthropogenic degradation. Moreover, a direct relationship was observed between plant cover percentage and the extent of anthropogenic degradation among the wetlands. Investigating the relationship between plant cover percentage and the concentration of nitrogen indicated a direct association between them in the study area.

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