Available online at www.sciencedirect.com
ScienceDirect
Procedia Environmental Sciences 2 (2010) 768–880
Procedia Environmental Sciences

International Society for Environmental Information Sciences 2010 Annual Conference (ISEIS)

Analysis of Trophic Status and its Influence Factors of Different Water Body Types in Xixi National Wetland Park, China

Yufeng Li, Hongyu Liu*, Nan Zheng, Xiao Cao

Jiangsu Key Laboratory of Environmental Change and Ecological Construction, College of Geographical Science, Nanjing Normal University, Nanjing 210046, China

Abstract

An ecological survey was carried out to determine the water body concentrations of nutrients and its factors in Xixi National Wetland Park, China. According to the intensities of human activities, water body was classified into natural ponds, ornamental ponds, natural creeks and sight-seeing creeks. Based on calculated Trophic State Index (TSI), we can get conclusion that the trophic status of different water body types all exceeded the eutrophic level in the Xixi National Wetland Park. The natural creeks showed the highest TSI, followed by ornamental ponds, sight-seeing creeks and natural ponds, suggesting that natural creeks should be considered as priority sites for the implementation of water quality improvement. The main factors for trophic status in Xixi Wetland Park were discussed using canonical correspondence analysis (CCA) and multiple linear regression analysis (MLR). As a result, the trophic states in ponds were mainly controlled by hydrophyte cover. The trophic states in creeks made great relation to creek width and water quality of inflows. So we can find that human management can improve water quality by planting macrophytes of wetlands and controlling sewage water inflows from surrounding areas.

Keywords: urban wetland; wetland utilization; water body types; trophic status; CCA; Xixi National Wetland Park

1. Introduction

The world's population is projected to continue expanding [1], particularly in urban areas, dramatically impacting natural landscapes and environmental resources at global, regional, and local scales [2-6]. Combined with vegetation removal and land degrading, the increases in impervious surface cover (ISC) have the potential to affect regional hydrology and water quality [7-9]. Urban environments are potential source of nutrient (i.e., nitrogen and phosphorus) and sediment. Nutrient and sediment transport to aquatic ecosystems increase in urbanizing watersheds due to associated increases in impervious surface cover (ISC) [10-12]. Wetland degradation and loss is common in a rapidly urbanizing area [13], increasingly compromising many important wetland ecosystem services such as water quality improvement (nutrient and sediment removal and retention), flood mitigation, biodiversity support and

* Corresponding author.
E-mail address: pandalee_0826@163.com.

doi:10.1016/j.proenv.2010.10.088

recreation [14]. In an effort to promote wetland restoration in urban area, Chinese government is developing the policy to establish urban wetland parks to protect wetlands and coordinate economic development and environment protection simultaneously. In addition to wetland's roles in city tourism, the wetland parks are intended to mimic some of the ecosystem services provided by natural wetlands [15, 16].The number of urban wetland parks was dramatically increased especially in developed regions of China. For example, during the period 2005-2009, more than 100 urban wetland parks were approved and established by the government of China. At present, wetland functions in urban area, which incorporated with ecological protection, tourism, education and scientific researches, are generally accepted [17, 18].

Assessing the trophic state of water in Xixi wetalnd park can provide a useful tool for management and restoration. Various classification methods have been applied for evaluations of the trophic state in lentic systems [19, 20]. Researchers of reservoirs, however, have reported that the trophic state often varies depending on parameters and classification methods used, and on the locations within the system [21]. Carlson provided a two dimensional graphical approach for assessing the trophic state of a lake, based on previous calculations of the Trophic State Index [22]. He found that trophic state deviations among conventional trophic state indices depend on the particular trophic parameter. This approach is an effective method for tracking long-term changes in pelagic structures and functions [23] and represents a powerful tool for lake management. It has been widely applied in evaluating various regional water bodies in North America [24, 25] and revised into Chinese own eutrophication assessment standards to evaluate the eutrophication in lentic systems [26, 27].

Wetlands in urban areas which provided ecological services are especially different from those in areas with low impact of human [28]. Urban wetlands provides a range of valuable ecosystem services such as drinking water, recreation, and aesthetic benefit, all of which can be negatively impacted by excess nutrients in water bodies. Therefore, the objectives of this paper are to analyze the spatial and temporal characteristics of water quality during spring and summer 2009 and to evaluate the trophic status and its factors in wetland. This analysis is also intend to explore the different nutrients among water body types, which can offer the baseline or reference condition information for further research and wetland park management.

Nomenclature

T	temperature
SD	secchi depth
TN	total nitrogen
TP	total phosphorus
COD_{Mn}	permanganate index
Chla	chlorophyll a
TSI_c	the comprehensive index of trophic state
superscripts ^{a}, ^{b}, ^{c}	the significantly different ($P<0.05$) of the means
Sign *	the significantly different ($P<0.05$) between two means
NS	not significant

2. Study site

Xixi National Wetland Park is located in the East China coastal zone, close to the center of Hangzhou city, a location that is well-known in China for its fast development of tourism. The study area has experienced high

population growth over the past 60 years, with wetland and remnant area increasingly substituted by fish ponds and resident area. The park, established in 2003 and opened to the public in 2005, was known as the first National Wetland Park in China, and designated as an outstanding demonstration example for urban wetland protection. It is bounded by four roads, Tianmushan road to the south, Wener road to the North, and high road of city round to the West and Zijingang road to the east. Characterized by rich precipitation, clay-enriched subsoil and flat surface topography, wetland in the study area can be divided into many types such as river, pond, creek and other manual wetlands. Water temperature varies seasonally and ranges from 7℃ to 33℃. Totaling 11.5km^2 area has been divided into more than 2000 ponds (Fig. 1). Approximately 46% of the total area is covered with rivers and ponds.

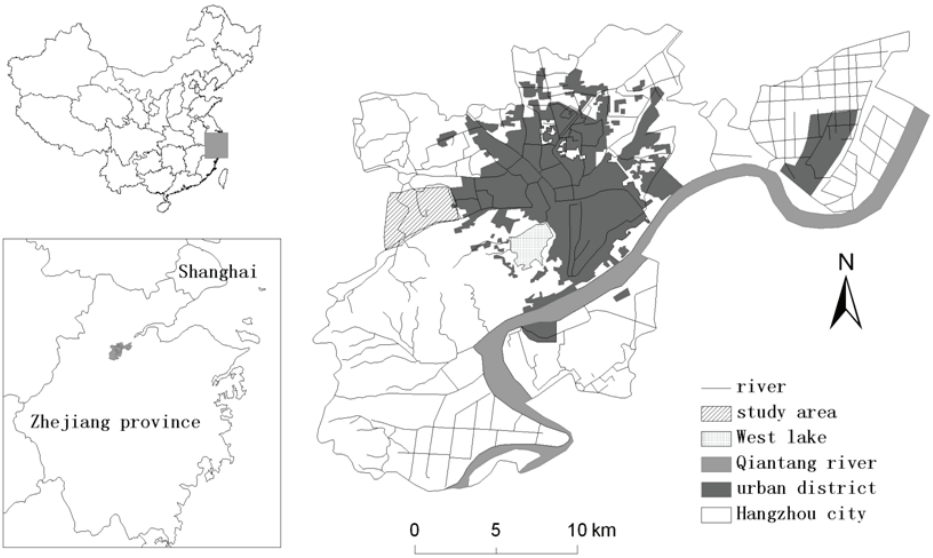

Fig. 1. The location of Xixi National Wetland Park. The park is located in Zhejiang province in China and is a typical urban wetland

3. Methods

3.1. Classification of water bodies

The rules to classification of water bodies in study area should be different from non-urban areas, as they mainly provide opportunities for local leisure activities. Because wetlands in urban regions may take on human-related values, water body types were determined by various types and intensities of human activities. In this study, water bodies were divided into the following categories: natural ponds, ornamental ponds, natural creeks, sight-seeing creeks. The “natural ponds” were water bodies with no human activities. The plants in natural ponds were local to the habitat such as *Phragmites australis*, *Miscanthus sacchariflour* and *Alternanthera philoxeroides*; the “ornamental ponds” with higher ornamental values were managed by human and planted with some macrophytes such as *Iris tectorum, Pontederia cordata, Thalia dealbata, Nelumbo nucifera* and so on; the “natural creeks” are nature's way of channeling runoff. *Colocasia antiquorum* and *Salvinia natans* were easy to be seen in natural creeks; and the “sight-seeing creeks” were used for boating by tourists to enjoy the wetland landscape. The types of plants in sight-seeing creeks were fewer than in other wetlands except for *Zizania latifolia* which was found frequently.

3.2. Water Sampling and Analysis

From March to August 2009, six sampling expeditions were carried out in the natural ponds, ornamental ponds, natural creeks and sight-seeing creeks on March 26, April 28, May 27, June 25, July 22, and August 26. Totally 79 sampling stations were selected with 28 sites in "natural creeks" and 21 sites in "sight-seeing creeks" and 30 pond sites composed of 13 sites in "natural ponds" and 17 sites in "ornamental ponds" (Fig. 2). Water samples were collected in 500ml LDPE (low density polyethylene) sample containers, stored on ice and transported to the laboratory for filtration and preservation within 4h of collection. Each sampling sites was geo-referenced using a GPS guided system and collected 3 times to control error. All the samples were analyzed for temperature (T), secchi depth (SD), total nitrogen (TN), total phosphorus (TP), permanganate index (COD_{Mn}), chlorophyll a (Chla).

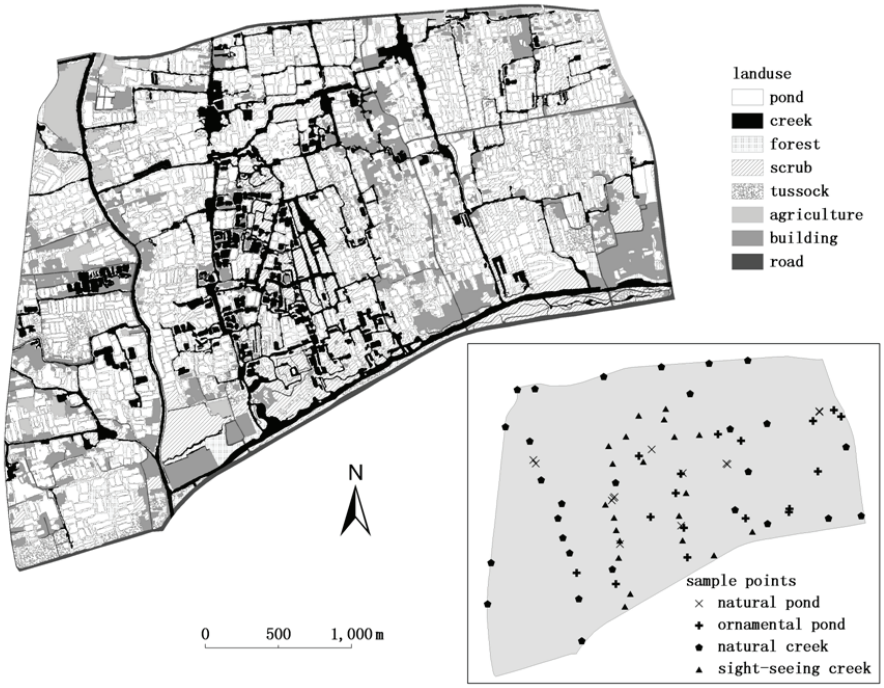

Fig. 2. Sampling stations and land use in Xixi Natural Wetland Park. Sampling points and land use are delineated

Creek Samples were collected on bridges and ponds samples were collected by a long rod with a line linking the sample container so as not to disturb the soil surfaces, and thus not introduce sediment or plant-associated particles into the sample container. Temperature and secchi depth were measured at the time of sample collection using portable instruments (YSI556; 20 cm disk). In order to avoid disturbance of soil surfaces of ponds, we stood on shore and used 4m telescopic link linking SD disk to measure SD and then calculated the actual SD indoors because of slantwise read of SD. TN, TP, COD_{Mn} and Chla were determined for 3 times in laboratory according to Monitoring and Analysis Methods for Water and Wastewater [29].

Distance to entrances of inflows, hydrophyte cover, creek width and pond area were measured by Arcgis9.2 software using remote sensing data. By the way, remote sensing data were obtained by Quickbird images in 2006 and Spot images in 2009. Creek depths were measured on bridges and the average of pond depth was calculated using 4m telescopic link on pond shore for 3 times. In addition, we got data about boats numbers per hour from administrative center of Xixi wetland. Gaps in data for any parameter were treated as missing data and no estimates were made to fill in gaps.

3.3. Trophic state index

TSI was implemented using five variables, namely, Chla, SD, TP, TN and COD_{Mn} in China [29]. The equations are as follows [26, 27]:

$$TSI(chla, mg/m^3)=10\times(2.46+\ln(chla)/\ln 2.5) \quad (1)$$

$$TSI(SD, m)=10\times(2.46+(3.69-1.53\times\ln(SD))/\ln 2.5) \quad (2)$$

$$TSI(TP, mg/L) = 10\times(2.46+(6.71+1.15\times\ln(TP))/\ln 2.5) \quad (3)$$

$$TSI(TN, mg/L)=10\times(2.46+(3.93+1.35\times\ln(TN))/\ln 2.5) \quad (4)$$

$$TSI(COD_{Mn}, mg/L)=10\times(2.46+(1.50+1.36\times\ln(COD_{Mn}))/\ln 2.5) \quad (5)$$

Each quality value is then multiplied by a weighting factor, to take into account the relative contribution of each variable to the overall water quality. Weighing factors were calculated based on the standard parameter of Chla. The equations for weighting factors expressed in the formulae [27]. Finally, the index value (TSI_c, the comprehensive index of trophic state) is calculated as the sum of the weighted quality values, ranging from 0 (poorest state) to 100 (best condition). The TSI_c ranged from 0-30, 30-50, 50-60, 60-70, 70-100 are used to represent oligotrophic, mesotrophic, eutrophic, hypertropic and dystrophic state, respectively.

4. Results and discussion

4.1. Water quality in different water body types

Table 1 presents a summary of the statistics of water quality data in the wetland. It also shows that the water quality concentration of different water body types varied significantly. The ANOVA shows significant differences obtained from measured values of variables. SD is an important indicator to identify bedload, microorganism and organic matter of water. The values of SD in natural ponds were significant differences (ANOVA, $p<0.05$) from the other water body types. COD_{Mn} can express the contaminations of organic matters and reducible inorganic materials. COD_{Mn} in ornamental ponds and in sight-seeing creeks shows significant differences (ANOVA, $p<0.05$) in mean values of sites (the concentration of COD_{Mn} in ornamental ponds was the highest and that in sight-seeing creeks was the lowest), while there was no significant differences for COD_{Mn} contents in natural ponds and natural creeks. TN

shows significance differences (ANOVA, $p<0.05$) in natural ponds and natural creeks, with 0.78mg/l and 2.91mg/l of TN respectively. Concentrations of TP in natural ponds and sight-seeing creeks were significantly lower than those in ornamental ponds and natural creeks. For the mean concentrations of Chla, there were significant differences in all sampling sites except ornamental ponds and sight-seeing creeks (ANOVA, $p>0.05$). The mean concentrations of Chla were highest in natural creeks and lowest in natural ponds.

Table 1. Means (minimums-maximums) of trophic variables in Xixi Natural Wetland Park

Water body types	n	SD/m	COD_{Mn}/mg/L	TN/mg/L	TP/mg/L	Chla/mg/m^3
natural ponds	13	0.43^{b} (0.36-0.46)	8.15^{b} (5.48-12.53)	0.78^{c} (0.63-0.98)	0.07^{c} (0.04-0.10)	11.38^{c} (6.68-16.34)
ornamental ponds	17	0.45^{a} (0.35-0.58)	12.34^{a} (8.75-19.21)	1.37^{b} (1.05-1.87)	0.17^{a} (0.05-0.26)	26.88^{b} (22.81-32.67)
natural creeks	28	0.41^{a} (0.32-0.50)	8.37^{b} (6.76-11.29)	2.91^{a} (1.78-4.51)	0.18^{a} (0.09-0.24)	45.67^{a} (36.82-56.21)
sight-seeing creeks	21	0.47^{a} (0.35-0.51)	7.46^{c} (5.58-10.38)	1.91^{b} (1.46-2.70)	0.09^{b} (0.05-0.15)	19.17^{b} (15.84-22.69)

Mean values with different superscript letters (a, b and c) in the same column for different water body types are significantly different ($P<0.05$).

4.2. TSI application

TSI_c values in the wetland are shown in table 2. The variations of eutrophication in Xixi wetland were demonstrated by TSI_c and illustrated in Fig. 3. There were certain differences of TSI_c among the types of water body from March to August, 2009. Among the four classifications of water body, natural creeks were the most eutrophication area, followed by ornamental ponds, sight-seeing creeks and natural ponds (Table 2). The ANOVA shows significant differences in TSI_c (ANOVA, $p<0.05$) between natural ponds and natural creeks, while there is no significant difference between ornamental ponds and sight-seeing creeks. TSI_c value showed highest in June and July, while March lowest. It can be seen from Fig. 3 that the trophic state in natural ponds stayed in eutrophic condition in first three months (from March to May) and was up to hypertropic state from June to August. TSI_c value in ornamental ponds showed increasing from 62.0 in March to 70.2 in May and reduced in June and then raised again in July and dropped in August. All monthly TSI_c values in natural creeks exceeded the hypertrophic standard 70 and had a fluctuant trend. TSI_c values in sight-seeing creeks showed an ascending trend and expressed the highest in June.

Table 2. The result of the comprehensive index of trophic state (TSI_c) in Xixi Natural Wetland Park

	natural ponds	ornamental ponds	natural creeks	sight-seeing creeks
TSIc	59.76^{c}±9.32	68.1^{b}±7.26	72.71^{a}±8.67	65.66^{b}±9.03

Mean values plus or minus one standard deviation are included. Mean values with different superscript letters (a, b and c) for different water body types are significantly different (P<0.05).

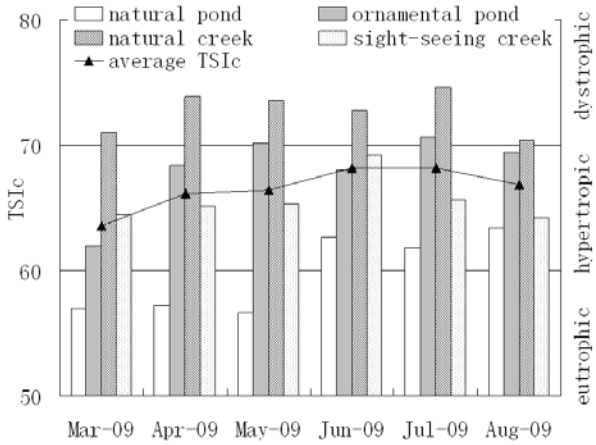

Fig. 3. The comprehensive index of trophic state (TSI_c) monthly in Xixi Natural Wetland Park

4.3. Main factors for ponds eutrophication

Comparing with creek, an ecosystem of pond is a closed system. The eutrophication variation in ponds was closely related to the hydrophyte cover, depth and area of ponds. In our study, we did not consider atmospheric (wet) deposition. The hydrophyte cover and depth in natural ponds were significant differences (t-test, $p<0.05$) from those in ornamental ponds, while there were no significant differences in areas between natural ponds and ornamental ponds. Table 3 showed that hydrophyte cover in ornamental ponds was 89% and more than two times higher than the average hydrophyte cover of natural ponds. The average depth in natural ponds was 0.996m which was higher than 0.528m of the depth in ornamental ponds.

Table 3. Summary of means for basic characteristics of ponds in Xixi Natural Wetland Park

	hydrophyte cover /%	Depth/m	area/m^2
natural ponds	35.38±27. 97	0.996±0. 422	3190.23±2721. 26
ornamental ponds	89.12±18. 49	0.528±0. 342	6027.94±5406. 62
Sign.	*	*	NS

Mean values plus or minus one standard deviation are included. The significance of differences between basic characteristics of ponds by t-test is shown as: NS, not significant; *p<0.05.

Canonical correspondence analysis (CCA) showed that hydrophyte cover and the nutrient indicators of TP, Chla, TN and COD_{Mn} were positively related, with SD negatively related to hydrophyte cover. Pond area was positively correlated with Chla, TP and TN, while depth was just positively correlated with SD (Fig. 4). The first two axes together accounted for 100% of the cumulative percentage variance of entrophication and its factors within 85.6% accounted for by the first axes.

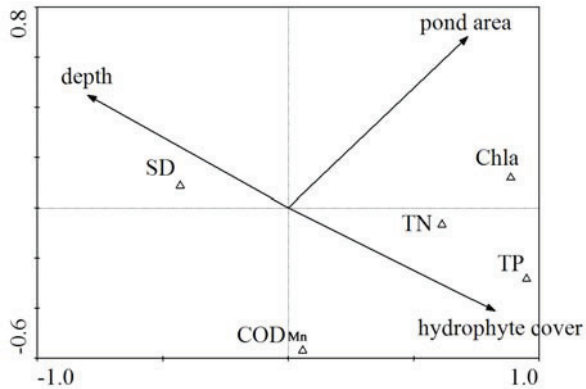

Fig. 4. Ordination diagram for the CCA of the relationships between entrophication and the characteristics of ponds. Arrows show the loading of each variable on the two canonical axes

Multiple Linear Regression analysis (MLR) was developed for ponds. The method of MLR was also used to identify the water quality and its factors [30, 31]. All the input variables (dependent variable, TSI_c, (Y) and independent variables, (the factors of TSI_c), X_i, i = 1, 2, 3, …) were modeled by stepwise method. In ponds, Best-fit, simple linear regression equation containing the first important model parameters is TSI_{c_pond}=56.562+0.073*hydrophyte cover. The factor of hydrophyte cover alone was found to be sufficient to the TSI_c of ponds with high precision (the model was at the 0.05% level with an F statistic of 7.125). The other factors considered (the depth and area of pond) could not predict the TSI_c with significant precision, so they ruled out. The significant linear regressions between TSI_c and the factors of TSI_c indicate that hydrophyte cover drive the TSI_c among the ponds. However, the depth and area of pond revealed the less effects of TSI_c.

4.4. Main factors for creeks eutrophication

The reasons for the eutrophication of creeks are very complicated. The spatial variation of eutrophication in the creeks could be explained by factors such as pollution sources from park outside and the chemical attributes of creeks in the studied area. The factors of pollution sources included SD, COD_{Mn}, TN, TP and Chla of inflows, with the attributes of creeks including the distance to inflow entrances, hydrophyte cover, creek depth, creek width, boat numbers and velocity of flow. The velocity of flow was eliminated due to the flatness of topography and disordered direction of flows. The concentrations of SD, TP and Chla of inflows, distance to entrances and the boat numbers in natural creeks were significant differences (t-test, $p<0.05$) from those in sight-seeing creeks whereas the concentrations of COD_{Mn} and TN, the hydrophyte cover, the depth and width of creeks in all creeks were not significant differences (Table 4).

CCA was also used to identify the relationships between eutrophication of creeks and its factors. CCA determined that the first axis explained 72.1% of trophic indicators and 93.7% of the relation of trophic indicators and those factors. The trophic indicators most strongly loaded with first axis were SD, Chla, TP and TN. The factors of trophic status most strongly loaded (negatively) with the first axis included Chla of inflows, creeks width and TN, TP, SD of inflows. The angle between the arrows of the factors can be used to approximate the correlations among those variables and the approximated correlation between two variables is equal to the cosine of the angle between the corresponding arrows. So, TP, TN and COD_{Mn} of inflows, hydrophyte cover and creek depth had higher correlation than others among the factors of trophic indicators. In creeks, TN and TP concentrations were correlated positively, and SD negatively correlated, with TN, TP and COD_{Mn} of inflows; concentrations of Chla correlated positively, and SD correlated negatively, with Chla of inflows and creeks width; positive correlations occurred between concentrations of COD_{Mn} and hydrophyte cover, with the negative correlations between concentrations of COD_{Mn} and creek width (Fig.5).

Table 4. Summary of means for variables which may have influence on the trophic status of creeks in Xixi Natural Wetland Park (Ⅰ: SD of inflows, Ⅱ: COD_{Mn} of inflows, Ⅲ:TN of inflows, Ⅳ:TP of inflows, Ⅴ: Chla of inflows, Ⅵ: distance to entrances of creeks, Ⅶ: hydrophyte cover of creeks, Ⅷ: creek depth, Ⅸ: creek width, Ⅹ: boat numbers per hour)

	Ⅰ/m	Ⅱ/mg/L	Ⅲ/mg/L	Ⅳ/mg/L	Ⅴ/mg/m^3	Ⅵ/m	Ⅶ/%	Ⅷ/m	Ⅸ/m
natural creek	0.39± 0.04	8.40± 2.13	4.47± 2.02	0.24± 0.14	56.46± 12.47	664.93± 550.96	26.07± 18.08	1.45± 0.89	15.79± 9.20
sight-seeing creek	0.32± 0.02	7.81± 0.33	3.74± 0.51	0.13± 0.02	34.76± 10.71	1406.52± 551.02	2.86±1.94	1.56± 0.44	13.81± 9.96
Sign.	*	NS	NS	*	*	*	NS	NS	NS

Mean values plus or minus one standard deviation are included. The significance of differences between variables by t-test is shown as: NS, not significant; *p<0.05.

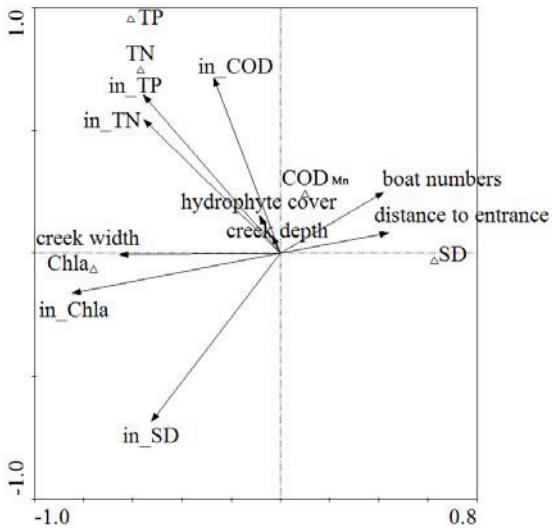

Fig. 5. Ordination diagram for the CCA of the relationships between entrophication and the characteristics of creeks. Arrows show the loading of each variable on the two canonical axes. (SD, COD_{Mn}, TN, TP and Chla of inflows were abbreviated to in_SD, in_COD, in_TN, in_TP and in_Chla respectively)

In creeks, the stepwise approach was also applied for determining a final model representing the linkage between TSI_c and the characteristics of creeks. Best-fit, simple linear regression model was produced by SPSS. The regression coefficients of the model obtained through MLR is presented in Table 5. Determination coefficients of this model were found to be 75.0% and the following model was used to predict TSI_{c_creek}:

$$TSI_{c\_creek}=27.684+1.898*in\_TN+0.223*creek\ width+0.541*in\_SD+0.952*\ in\_COD \quad (6)$$

For the model given in equation (F=36.942, p<0.005), significant explanatory variables were creek width and TN, SD, COD_{Mn} of inflows.

Table 5. Results of the simple linear regression model in creeks

Included independent variables	regression coefficients (b_k)	standard error of b_k	T	P	R^2 (%)
Constant	27.684	4.572	6.055	0.000**	75.0
TN of inflows	1.898	0.290	6.545	0.000**	
creek width	0.223	.0.48	4.671	0.000**	
SD of inflows	0.541	.0.99	5.486	0.000**	
COD_{Mn} of inflows	0.952	0.281	3.383	0.002**	

** $P < 0.01$.

5. Conclusion and suggestion

- This study illustrated the different trophic levels of different types of wetlands and provided a clear view about water quality in Xixi National Wetland Park. There are many studies conducted to analyze factors which controlled trophic state in recent years [26, 32]. The analysis of trophic state in urban wetland is a popular tool to assess sustainability of park which can be used for protection decision-making and the assessment of management and policy scenarios.
- There was a direct relationship between trophic status and water quality in Xixi National Wetland Park. The results of the MLR modeling in ponds showed that hydrophyte cover is the main factor for controlling eutrophication. The results of the MLR modeling in creeks suggest that the simple linear regression model was found to be sufficient to the TSI_c with higher precision. Mathematically, equation suggests positively direct relationships between TN, SD, COD_{Mn} of inflows, creek width and TSI_c. The concentration of inflow's TN might be considered as the most important predictor for the value of TSI_c according to the regression coefficient. Comparing with the MLR of ponds and creeks, the result of MLR using the attributes of ponds revealed that only the hydrophyte cover was chosen to explain the trophic status of water body. While the trophic state in creeks could be explained by TN, SD, COD_{Mn} of inflows and creek width. As the findings of the present study have indicated, changes in hydrophyte cover of ponds and the concentration of TN, SD, COD_{Mn} of inflows would be the cause to lighten eutrophication in ponds and water quality in creeks respectively. In order to achieve an explicit tool based on application of findings for explaining the variations of water quality in Xixi National Wetland Park, it is necessary to increase hydrophyte cover in ponds and establish buffer area in the entrances of inflows to purify the water in creeks. Finally, these insights would provide us with a planning procedure for water quality management in Xixi National Wetland Park.
- All in all, some measures should be made to improve water quality in Xixi National Wetland Park because the trophic status exceeded the eutrophic level in the park. We suggest that natural creeks should be considered as priority sites for the implementation of water quality improvement. Efforts should be focused on the improvement of water quality of entrance water entering natural creeks. Historically, natural creeks were well suited for water quality improvement. However, urbanization results in increased pollutant loads in runoff, and alters the physical landscape, with a result of redirecting surface water flows away from natural creeks. Because of this, natural creeks may no longer function effectively to improve water quality or mitigate downstream flooding. It is necessary to modify current systems to reduce urban impervious surface cover runoff. Combined with use of individual property management protocols such as rain gardens and rain barrels, Broadening creeks buffer area could promote sustainable urban development and be an appropriate mitigation action, and thus allow cleaner water to enter local creeks and down creeks.

Acknowledgements

This work was supported by the National Natural Science Foundation of China (No.40871084, 40701174) and the Program for Postgraduates Research Innovation in University of Jiangsu Province and Nanjing

Normal University. The authors would like to thank Prof. Biao Xie for his help and valuable advice in preparation of this article.

References

[1] Smail JK. Confronting a surfeit of people: Reducing global human numbers to sustainable levels: An essay on population two centuries after Malthus. *Environ Dev Sustain* 2002; **4**:21–50.

[2] Vitousek PM. Beyond global warming: Ecology and global change. *Ecology* 1994; **75**:1861–1876.

[3] Bolund P, Hunhammar S. Ecosystem services in urban areas. *Ecol Ecos* 1999; **29**:293–301.

[4] Walsh CJ. Urban impacts on the ecology of receiving waters: A framework for assessment, conservation, and restoration. *Hydrobiologia* 2000; **431**:107–114.

[5] McKee JK, Sciulli PW, Fooce CD. Forecasting global biodiversity threats associated with human population growth. *Biol Conserv* 2003; **115**:161–164.

[6] Faulkner S. Urbanization impacts on the structure and function of forested wetlands. *Urban Ecosyst* 2004; **7**:89–106.

[7] Watson VJ, Loucks OL, Wojner W. The impact of urbanization on seasonal hydrologic and nutrient budgets of a small North American watershed. *Hydrobiologia* 1981; **77**:87–96.

[8] Rhodes AL, Newton RM, Pufall A. Influences of land use on water quality of a diverse New England watershed. *Environ Sci Technol* 2001; **35**:3640–3645.

[9] Groffman PM, Bain DJ, Band LE. Down by the riverside: Urban riparian ecology. *Front Ecol Environ* 2003; **1**:315–321.

[10] Hopkinson CS Jr, Day JW Jr. Modeling the relationship between development and stormwater and nutrient runoff. *Environ Manage* 1980; **4**:315–324.

[11] Carpenter SR, Caraco NF, Correll DL. Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecol Appl* 1998;**8**:559–568.

[12] Reinelt L, Horner R, Azous A. Impacts of urbanization on palustrine (depressional freshwater) wetlands–Research and management in the Puget Sound region. *Urban Ecosyst* 1998; **2**:219–236.

[13] Holland CC, Honea J, Gwin SE. Wetland degradation and loss in the rapidly urbanizing area of Portland, Oregon. *Wetlands* 1995;**15**:336–345.

[14] Walbridge MR, Struthers JP. Phosphorus retention in non-tidal Palustrine forested wetlands of the mid-Atlantic region. *Wetlands* 1993; **13**:84–94.

[15] Johnston CA. Sediment and nutrient retention by freshwater wetlands: effects on surface water quality. *Crit Rev Environ Control* 1991; **21**:491–565.

[16] Zedler JB. Wetlands at your service: reducing impacts of agriculture at the watershed scale. *Front Ecol Environ* 2003; **2**:65–72.

[17] Chen JH, Xu CD. Study on the Tourism Environmental Capacity of Wetland on the Edge of the City. *B Sci Technol* 2006; **22**:714–718.

[18] Wu J, Zhou NX, Huang JW. The study of harmonious relationship between wetland park construction and wetland tourism resources conservation. *Human Geog* 2007; **22**:124–127.

[19] Havens KE. Seasonal and spatial variation in nutrient limitation in a shallow sub-tropical lake (lake Okeechobee, Florida) as evidenced by trophic state index deviations. *Arch Hydrobiol* 1994; **131**:39–53.

[20] Nurnberg GK. Trophic state of clear and colored, soft- and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish. *Lake Reserv Manage* 1996; **12**:432–447.

[21] Jones JR, Knowlton MF. Limnology of Missouri reservoirs: An analysis of regional patterns. *Lake Reserv Manage* 1993; **8**:17–30.

[22] Carlson RE. Atrophic state index for lakes. *Limnol Oceanogr* 1977; **22**:361–369.

[23] Havens KE. Using Trophic State Index (TSI) values to draw inferences regarding phytoplankton limiting factors and seston composition from routine water quality monitoring data. *Korean J Limnol* 2000; **33**:187–196.

[24] Kratzer CR, Brezonik, PL. A Carlson-type trophic state index for Nitrogen in Florida lakes. *Water Resour bull* 1981; **17**:713–715.

[25] Carpenter SR, Ludwig D, Brock WA. Management of eutrophication for lakes subject to potentially irreversible change. *Ecol Appl* 1999; **9**,751–771.

[26] Cai Q, Liu J, Lorenz K. A comprehensive model for assessing lake eutrophication. *Chinese J Appl Ecol* 2002; **13**:1674–1678.

[27] Jin XC. *Eutrophication of lakes in China*. Beijing: China Environmental Science Press; 1990.

[28] Dodds W, Bouska W, Eitzmann J. Eutrophication of U.S. Freshwaters: Analysis of Potential Economic Damages. *Environ Sci Technol* 2009; **43**:12–19.

[29] State Environment Protection Administration of China (SEPA). *Methods for Water and Wastewater monitoring and analysis in China (the fourth edition)*. Beijing: China Environmental Science Press; 2002.

[30] Jayalakshmy KV, Saraswathy M, Nair M. Effect of water quality parameters on the distribution of *Pleuromamma* (Copepoda–Calanoida) species in the Indian Ocean: a statistical approach. *Environ Monit Assess* 2009; **155**:373–392.

[31] Rothenberger MB, Burkholder JM, Brownie C. Long-Term Effects of Changing Land Use Practices on Surface Water Quality in a Coastal River and Lagoonal Estuary. *Environ Manage* 2009; **44**:505–523.

[32] Gao YX, Zhu GW, He RR. Variation of Water Quality and Trophic State of Lake Tianmu, China. *Environ Sci* 2009; **30**(3):673–679.