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Original Article

Temporal and Spatial Analysis of Fish Diversity and Community Structure in Lihu Lake, China

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ABSTRACT

From May 2010 to April 2011, 10 sampling sites were set to analyze fish diversity, community structure and dominant species. The results showed that 3720 fish of 710.860 kg were collected by using cage net and gill net, total of 45 fish species belonged to 7 orders and 12 families, which is less than 18 fish species than that of 63 fish species in 1960s, a decrease of 28.57%. The IRI index of Erythrocu1ter *dabryi dabryi* and *Coilia ectenes taihuensis* were more than 2000, and the above 2 fish were dominant species. Shannon-Wiener diversity index ranged between 1.759 with 3.011, and Pielou's evenness index ranged between 0.609 with 0.939, which showed the current state of fish diversity and community was good. The temporal and spatial variation of fish diversity and community structure in Lihu Lake were analyzed, and ecological effect of endogenous treatment was studied, which could provide references to the further treatment of exogenous pollution in Lihu Lake.

Keywords: Lihu Lake, fish diversity, fish community, temporal analysis, spatial analysis.

INTRODUCTION

Since the 1960s, disorderly production and development such as sewage directly into the lake, large area of reclamation from lake and enclosure culture and others, which caused the destruction of the ecological and fishery environment of Lihu Lake (Yin *et al*.,1994). The comprehensive evaluation of water quality standard in Lihu Lake was inferior class V, and Lihu Lake was the hyper-eutrophication lake, which gradually led to the decline of fishery'sresources (Fan *et al*., 2012). From 2002, the integrated measures of ecological restoration and water environment treatment were taken to reconstruct the healthy aquatic ecosystem of Lihu Lake, including the sewage interception, ecological dredging, restoration from paddy fields to fishing, dynamic water exchange, lakeshore remediation and construction shelter belt around the lake, etc., and to achieve the goals of water self-purification capacity enhancement, water quality improvement, landscape optimization and biodiversity restoration, etc (Courrat *et al*., 2009; Zhang and Tang, 2003).

Fish researches of Lihu Lake have been reported a lot. Wu Xianwen analyzed the composition of fish fauna, and reported there were 63 fish species that belonged to 18 families, among them 48 species belonged to 37 genera of Cyprinidae (Wu, 1962). Li Wenchao analyzed the fish evolution of Lihu Lake during the eutrophication process, and reported that fisheries resources of Lihu Lake were relatively abundant, ferocious carnivore fish were dominant in 63 fish species and had more benthic fish (Li, 1996). Duan Jinrong *et al*. used diversity index to analyze fish community structure of Lihu Lake, and preliminary evaluation the effect of fisheries resources releasing and enhancement and fishery management taken to the Lihu Lake (Duan *et al*., 2009).

To evaluate the implementation of endogenous treatment impact on fisheries resources, 10 sampling sites were chosen to investigate the fish during 12:00 AM on the 15th day of each month to 12:00 AM on the next day, from May 2010 to April 2011. Based on the data of sampling fish, the temporal and spatial variation of fish diversity and community structure in Lihu Lake were analyzed, and ecological effect of endogenous treatment was studied, which could provide references to the further treatment of exogenous pollution in Lihu Lake.

MATERIAL AND METHODS

Study area

Lihu Lake, is also named Wulihu Lake, the tributary lake of Taihu Lake and the inner lake of Wuxi, Jiangsu province, and locates in the southwest of Wuxi, and is a shallow lake with an average depth of about 3m and between 119°13′12″-119°17′11″E and 31°29′54″-31°32′50″N (Duan *et al*., 2009). Lihu Lake looks like gourd-shape, and is about 6000m from the east to the west, between 300 to 1800m from the north to the south and an area of about 9.5 km2 (Fan *et al*., 2012). 10 sampling sites were set in the Lihu Lake based on the coverage situation of the lake, and the book named Chinese inland water fisheries resources (Figure 1) (Zhang and He, 1991).

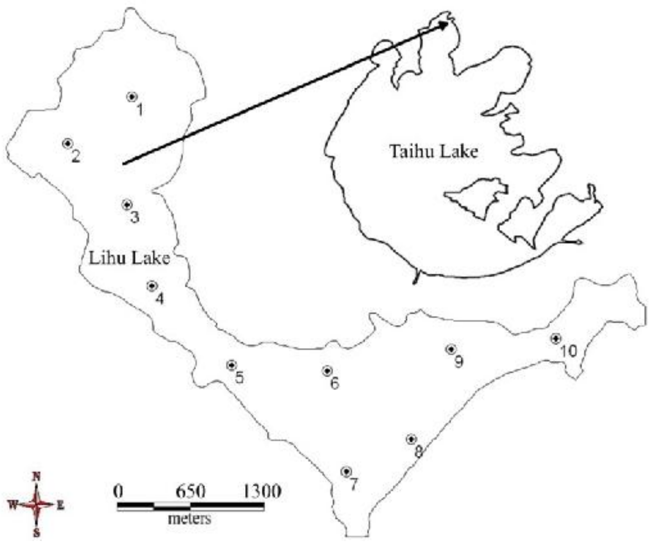

Fig-1 Map of the study area with sites indicated

Sampling procedure

Cage net (cross section 500mm×500mm, length 5m) and gill net (2a=50mm, height 1.5m, length 16m) were set at each sampling site. The operation period was 24 hours from 12:00 AM on the 15th day of each month to 12:00 AM on the next day. Fish from each sampling site were identified, counted and weighed, and biological parameters such as body length and body weight were measured at the same time, and all the above data were stored to the constructed database and used for the temporal and spatial analysis of fish diversity and community structure.

Data analysis

The species diversity was expressed by using Shannon diversity index (H′) and Pielou's evenness index (J):

$$H' = -\sum_{i=1}^{s}(Pi)(\log_2 Pi) \text{ and } J = \frac{H'}{\log_2 s}$$

Where Pi is the proportion of individuals in a community, which are members of the ith species, s is the total number of fish species (Pielou, 1975; Shannon and Weaver, 1949).

The dominant species and important species were classified by the calculation result of the index of relative importance (IRI):

IRI=（P_i+W_i）F_i

Where P_i is the ratio of the ith fish species individuals and total number of fish species, W_i is the ratio of the ith fish species weight and total weight of fish species, and F_i is the ratio of the frequency of the ith fish species and total sampling times (Micheli and Halpern, 2005; Przybylski *et al*., 1991) .

Similarity between sampling sites and species was calculated by using the Marczewski and Steinhaus(1958) equation:

q=c/(a+b-c)

where q is the similarity of 2 sampling sites, c is the total of the lower number of specimens of each pair of species common for 2 given analyzed sampling sites, a is the total number of specimens of a species at the sampling site A, and b is the total number of specimens of a species at the sampling site B. When q is between 0 and 0.25 and means no similarity, q is between 0.25 and 0.5 and means medium no similarity, q is between 0.5 and 0.75 and means medium similarity, q is between 0.75 to 1 and means very similarity (Marczewski and Steinhaus, 1958).

One-way ANOVA was conducted to examine the variations in Shannon'sShannondiversity index and Pielou's evenness index of two surveys, when a significant difference was found, Tukey's test was performed ($P<0.05$). All the statistical analysis was run in SPSS 16 and isoline of diversity index was expressed by surfer 8.0 (Shan *et al*., 2011).

RESULTS

Composition of fish community

During study period, 3720 fish of 710.860kg were collected by using cage net and gill net, total of 45 fish species belonged to 7 orders and 12 families (Figure 2), which is 18 fish species less than that of 63 fish species in 1960s, a decrease of 28.57%, among them 31 fish species belonged to 24 genera of Cyprinidae and accounted for 68.89% of total fish species, which is less than 17 fish species than 48 fish species belonged to 37 genera of Cyprinidae in 1960s, a decrease of 7.30% (Wu,1962).

In addition, there were 3 fish species belonged to Gobiidae, 2 fish species belonged to

Salangidae and 1 fish species belonged to the other'sfamilies.

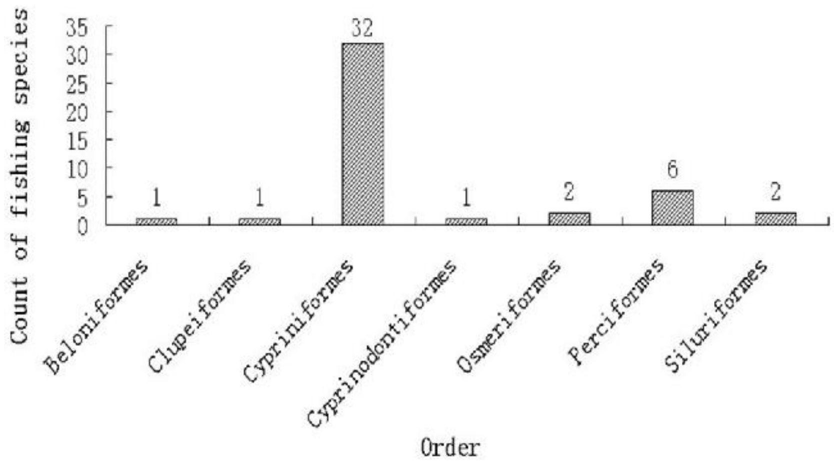

Fig2- The general classification of fishing species of Lihu Lake

Dominant species and its biologic characteristics

The index of relative importance (IRI) is used to express the community ecological dominance and is calculated by fishing volume, biomass and frequency of various species of the fish community. In general, the IRI index of fish is more than 1000 as an important species. Once, the IRI index of fish is greater than 2000 as a dominant species (Pianka, 1971). The IRI index of *Hypophthalmichthys molitrix* and *Carassius auratus* were more than 1000, and that of *Erythrocu1ter dabryi dabryi* and *Coilia ectenes taihuensis* were more than 2000 (Table 1).

Table 1- Important relative index of major species of fish community in Lihu Lake

Species	Body length/mm	Body weight/g	Quantity percentage (%)	Weight percentage (%)	Frequency rate/%	IRI
Erythrocu1ter dabryi dabryi	127.30±31.90	28.20±5.60	28.83	3.88	100.00	3271.00
Coilia ectenes taihuensi	178.70±44.30	23.40±14.50	22.77	2.36	91.65	2303.16
Hypophthalmichthys molitrix	342.30±64.90	878.90±233.60	2.28	16.89	83.45	1599.73
Carassius auratus	182.90±22.80	189.20±23.80	3.47	13.46	83.54	1414.33

Body length and body weight were used to fit the power function, and that of *Erythrocu1ter dabryi dabryi*, *Coilia ectenes taihuensis*, *Hypophthalmichthys molitrix* and *Carassius auratus* were:

$W = 0.0016 \times L^{2.9205}$ (R^2 = 0.9252, P = 0.018 <0.05)
$W = 0.0011 \times L^{2.7704}$ (R^2 = 0.9462, P = 0.014 <0.05)
$W = 0.0021 \times L^{2.9783}$ (R^2 = 0.0.8779, p = 0.022 <0.05 and
$W = 0.0004 \times L^{2.4761}$ (R^2 = .8111, P = 0.027 <0.05) respectively.

Similarity of fish community

The similarity degrees of different sampling sites were determined by the common amount of species, and the common amount of fish from 10 sampling sites in Lihu Lake was from 19 to 31. According to the similarity coefficient formula, the statistical results ranged from 0.5000 to 0.7692 and showed in Table 2.

Table-2 Similarity coefficient of all sampling sites

Sampling site	1	2	3	4	5	6	7	8	9	10
1	1									
2	0.6785	1								
3	0.6400	0.6428	1							
4	0.7307	0.6666	0.6923	1						
5	0.7307	0.6666	0.6923	0.6000	1					
6	0.7600	0.6896	0.7200	0.6206	0.6785	1				
7	0.6551	0.6562	0.6206	0.6451	0.5454	0.6666	1			
8	0.6923	0.5312	0.7200	0.6206	0.6206	0.7692	0.5625	1		
9	0.6363	0.5769	0.5909	0.5600	0.5600	0.6521	0.6666	0.5833	1	
10	0.7500	0.5666	0.6400	0.6071	0.5517	0.6296	0.6000	0.6923	0.5652	1

Based on the assessment criteria of the similarity, the fish community of each sampling site in Lihu Lake was in medium similar, namely the spatial distribution of fish in Lihu Lake was relatively even (Przybylski and Zalewski, 1991; Zalewski *et al*., 1990).

Variety of diversity index

According to the formula of Shannon's diversity index and Pielou's evenness index, the calculation results of each sapling site were listed in Tab1. Shannon-Wiener diversity index ranged between 1.759 with 3.011, and Pielou's evenness index ranged between 0.609 with 0.939, which showed the current state of fish diversity and community was good (Table 3).

Table 3- Shannon diversity index and Pielou's evenness index of all sampling sites

Sampling sites	Item	Season			
		Summer May-Jul	Autumn Aug-Oct	Winter Nov-Jan	Spring Feb-Apr
1	H′	2.649	2.493	2.542	2.099
	J	0.833	0.774	0.848	0.911
2	H′	2.393	2.817	2.679	2.779
	J	0.786	0.828	0.867	0.899
3	H′	2.520	2.701	2.578	2.493
	J	0.815	0.839	0.860	0.899
4	H′	2.835	3.011	2.423	2.642
	J	0.851	0.924	0.823	0.897
5	H′	2.669	2.822	2.602	2.562
	J	0.851	0.877	0.918	0.855
6	H′	2.599	2.955	2.563	2.486
	J	0.818	0.896	0.887	0.897
7	H′	2.224	2.405	2.502	1.759
	J	0.867	0.707	0.835	0.609
8	H′	2.362	2.735	2.466	2.672
	J	0.817	0.850	0.837	0.907
9	H′	1.793	2.479	2.814	2.462
	J	0.721	0.894	0.939	0.909
10	H′	2.228	2.710	2.493	2.418
	J	0.803	0.832	0.806	0.916

According to a logarithmic relationship between Shannon-Wiener diversity index and Pielou’s evenness index based the scatter distribution diagram to fit equation of

H′= 2.8653 +1.9547 Ln (J) (R^2 = 0.8814, P = 0.037 <0.05).

The analysis result of ANOVA showed that Shannon's diversity index differences of No.1 site and No.2 sites as well as that of No.1 site and No.4 site were significant (P<0.05), Shannon diversity index differences of others sites were not significant (P> 0.05). Pielou’s evenness index differences of 10 sites were not significant (P> 0.05). Shannon diversity index differences of summer and autumn as well as that of spring and autumn were significant (P<0.05). Pielou’s evenness index differences of 4 seasons were not significant (P> 0.05). To calculate the average Shannon's diversity index and Pielou’s evenness index of each sampling site of 4 seasons, and use surfer8.0 to complete the spatial distribution of isoline about the average Shannon diversity index and Pielou’s evenness index (Figure 3 and Figure 4) (Belliard *et al*., 1997; Galacatos *et al*., 2004).

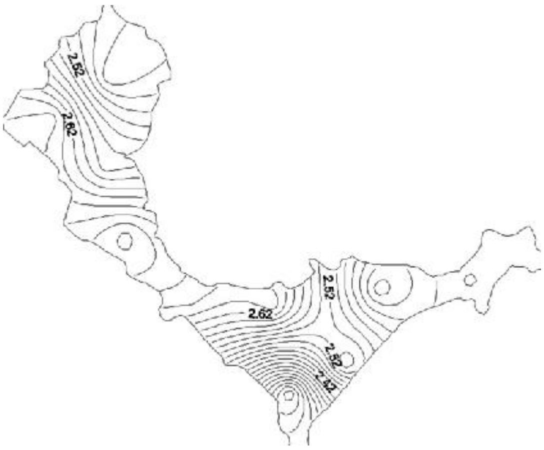

Fig 3- Isoline of Shannon diversity index

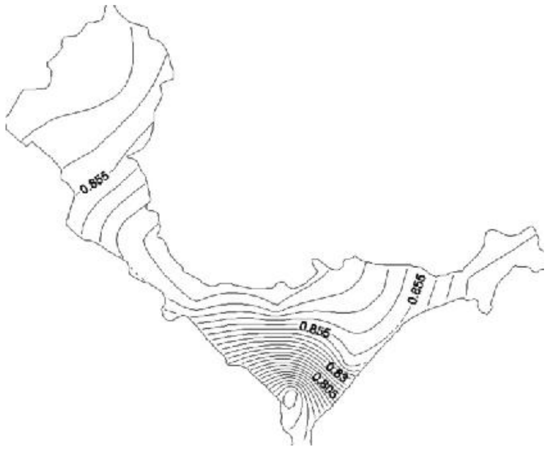

Fig 4- Isoline of Pielou’s evenness index

DISCUSSION

Before 2002, Lihu Lake belonged to cultured lake and the releasing fingerling in spring, and fishing adult fish in winter were taken as general management method. The implementation of endogenous treatment for Lihu Lake began in 2002, and the function of Lihu Lake transferred cultured lake to natural Lake, and the dominant position of four major Chinese carps such as black carp, grass carp, silver carp and bighead carp gradually weakened (Lowe-McConnell, 1987). This result showed that small carnivorous fish of *Erythrocu1ter dabryi dabryi(Bleeker)* and *Coilia ectenes taihuensis* in every sampling site were the dominant species and belonged to top three in fishing volume, which may lead to the change of a food chain, thus increase the ratio of filter-feeding fish such as silver carp and bighead carp of fishery releasing and enhancement in order to maintain the relatively stable status of fish diversity in Lihu Lake (Duan *et al*., 2009).

The Shannon diversity index and Pielou’s evenness index of the whole Lihu Lake could be calculated based the summary data of the whole study period and those were 2.689 and 0.886 respectively, which showed that the status of fish diversity in Lihu Lake was stable. After the implementation of endogenous treatment of Lihu Lake, the fishing volume of each sampling site increased over 50% than that of 1990s, but the species number decreased 18 than that of 1990s by preliminary statistic analysis (Li, 1996). The method of fishery releasing and enhancement increased the fishing volume of four major Chinese carps, and indigenous fish significant increased by their own reproduction owing the improvement environment, and the virtuous cumulative effect had achieved, but there was a long way to reach the level of fish diversity and community structure in 1960s.

According to the report of local media, 2 kinds of exotic fish were found in Lihu Lake. The origin of *Lophiuslitulon* is South America. *Lophiuslitulon* is also known as scavenger, and it feeds mainly on detritus, and it harms the indigenous fish by eating their eggs (Chen *et al*., 2010). The origin of *lepisosteus oculatus* is North America, and it is a ferocious fish with sharp teeth and attacks all fish that it meets (Chen *et al*., 2010). The above 2 exotic fish were not collected during the study period, but in order to prevent the invasion of exotic species, fishery management departments should strengthen the propaganda of fishery law and rule, and enhance the environment protection awareness of nearby residents, and spread the knowledge of the ecological hazard of any release of exotic species to Lihu Lake. On the other hand, the fry and fingerling from Taihu Lake basin should be taken as the first choice to release to Lihu Lake and to avoid mixing of exotic species, to maintain the purification of germplasm resources.

To maintain and promote the status of fish diversity in Lihu Lake, the following recommendations and management measures were proposed.

1) To continue to fishery releasing and enhancement, and deepen the study of reasonable ratio of releasing variety and number.

2) To enhance the propaganda of knowledge of ecological balance of natural water body and to prevent any releasing of exotic fish to Lihu Lake.

3) To implement the policy on transferring fishermen's jobs and to prevent the fishermen to re-enter Lihu Lake for fishing operations and destruct the fish community.

4) To set up breeding ground for indigenous fish and provide good ecological environment for the fisherie'sresources restoration.

CONCLUSIONS

During study period, 3720 fish of 710.860 kg were collected by using cage net and gill net, total of 45 fish species belonged to 7 orders and 12 families. Among them, 31 fish species that belonged to 24 genera of Cyprinidae and accounted for 68.89% of total fish species. The IRI index of *Hypophthalmichthys molitrix* and *Carassius auratus* were more than 1000 and the above 2 fish were important species, and that of *Erythrocu1ter dabryi dabryi* and *Coilia ectenes taihuensis* were more than 2000 and the above 2 fish were dominant species. The spatial distribution of fish in Lihu Lake was relatively even.

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