Study on Fishery Ecological Environment and Fish Species Diversity in Yantan Water Area

Yaoquan HAN[1]*, Anyou HE[1], Li HUANG[2], Jun SHI[1], Dapeng WANG[1], Weijun WU[1]

1. Guangxi Key Laboratory of Aquatic Genetic Breeding and Healthy Aquaculture, Guangxi Academy of Fishery Sciences, Nanning 530021, China; 2. Guangxi International Business Vocational College, Nanning 530007, China

Abstract Through analysis on water quality, planktonic organism, fish resources, and fish species diversity in Yantan water area, this paper evaluated current situation of quality of fishery ecological environment in Yantan water area. The survey recorded all 52365 fishes and 1410.2 kg catches obtained by fishermen in half a year, and more than 98% catches are small fishes. The Shannon-Weiner diversity index of Yantan water area is 0.162, Wilhm improvement index is 1.814, D_{G-F} index is 0.083, and the index of fish species diversity is far lower than other water areas. The average quantity per unit of phytoplankton is 1.0134 million ind./L, and the average quantity per unit of organisms is 1.1151 mg/L. The average quantity per unit of zooplankton is 459.6 ind./L, and the average quantity per unit of organisms is 0.6422 mg/L. Evaluation results indicate that water quality and planktonic organism in Yantan water area are basically normal, but fish resources are increasingly exhausted, fish resource composition is not reasonable, and fish species diversity is extremely low. From the perspective of biomanipulation, it is required to restore fishery ecological environment of reservoir area through restoring normal composition of aquatic organisms.

Key words Yantan water area, Fishery ecological environment, Fishes species, Species diversity

1 Introduction

The fishery ecological environment is foundation for survival, growth and breeding of fish resources, the quality and change of fishery ecological environment will exert a series of short-term or long-term direct or indirect influence on fish resources. High quality fishery ecological environment needs mutual support of excellent aquatic ecological and natural environment and reasonable composition of aquatic organism community[1]. Hongshui River where the Yantan water area is situated is the most important fishery water area in upstream of Xijiang River, is the key enhancement and release area specified in *Overall Plan for Enhancement and Release of National Aquatic Organisms*[2], and there is the most complex aquatic ecological environment and the largest fish spawning ground of Xijiang River basin[3]. Yantan Reservoir is the second largest reservoir in main stream of Hongshui River. It consists of 166 km original river section and 107.5 km^2 surface water area, it controls water area of 107000 km^2. Because water conservancy dam construction and fishery development are not scientific, there has been huge change in ecological environment of Hongshui River basin, such as occurrence of serious deterioration of fishery ecological environment, death of numerous fishes, and excessive mussels. Evaluating current situation of fishery ecological environment in the reservoir area and scientifically restoring ecological environment in water area are major projects of production and ecological safety. In recent 30 years, many scholars have made extensive researches on cross sections of Hongshui River basin and Yantan water area and have obtained mass data, but there is no research about evaluation of fish species diversity in reservoir area, especially after the artificial enhancement and release. In 2003, freshwater mussel problem appeared in Yantan water area. After 2006, freshwater mussel started propagating rapidly, fishery production in the reservoir area suffered a huge loss and hidden danger of ecological safety appeared. From 2009, reservoir area started restoration of fishery ecological environment including enhancing and releasing black carps. This study is the first survey of fishery ecological environment in reservoir area in recent years. It is expected to provide reference for fishery organizations formulating development plan of enhancement and release of fishes.

2 Materials and methods

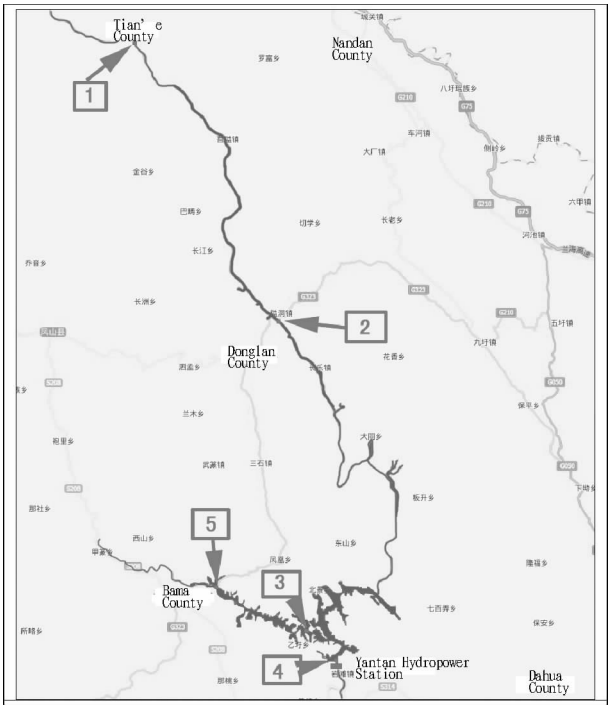
2.1 Distribution of sampling points and frequency of sampling We carried out a survey in 4 cross sections (as shown in Fig. 1), collected water sample, specimens and data of aquatic organism including phytoplankton, zooplankter, zoobenthos, and fishes. Besides, we collected samples of planktonic organisms in Cifu Bridge cross section in Bama County of Guangxi. We sampled one time separately in March, June, September and December in 2013.

2.2 Sampling and analysis of water quality Water samples were collected simultaneously in 5 cross sections in accordance with HJ 495 - 2009 *Water quality-Technical Regulation on the Design of Sampling Programs* and HJ 493 - 2009 *Water Quality-Technical Regulation of the Preservation and Handling of Samples*. Water quality was tested using methods specified in GB 3838 - 2002

Received: April 10, 2015 Accepted: June 2, 2015

Supported by Special Fund for Scientific Research of Public Welfare Industry (Agriculture) (201303048); Key Project for Natural Science Foundation of Guangxi (2013GXNSFEA053003); Systematic Research Project of Guangxi Key Laboratory of Aquatic Genetic Breeding and Healthy Aquaculture (13-A-02-01).

* Corresponding author. E-mail: hyqao@sohu.com



Location of cross section: 1. Tian'e County, 2. below Anlou Bridge in Donglan County, 3. Panyang River Reservoir of Dahua County, 4. Yantan Dam in Dahua County, 5. below Cifu Bridge in Bama County

Fig. 1 Schematic map of cross sections surveyed

Environmental Quality Standards for Surface Water and GB 11607 – 1989 *Water Quality Standard for Fisheries*. We measured total phosphorus, total nitrogen, volatile phenols, non-ionic ammonia, oils, mercury, copper, zinc, lead, cadmium, pH value of the index, and measured air temperature, water temperature, clarity, turbidity and dissolved oxygen and other indicators.

2.3 Survey and analysis of planktonic organisms Survey and analysis of planktonic organisms were carried out with reference to CAF2005 0001 *Regulations on Survey of Fishery Natural Resources in Inland Water Area* (*for Trial Implementation*). Trophic level and water quality were evaluated in accordance with SL218 – 98 *Standard for the Fishery Trophic Classification of Reservoirs* with average quantity per unit of planktonic organisms as basis.

2.4 Survey and analysis of the catches We selected specialized fishermen normally operating in fixed areas of upstream, midstream and downstream, and made a record of their daily catches and biological data of major fishes. The operation areas are mainly near Tian'e County, Anlou Bridge of Donglan County, and front area of Yantan Reservoir dam in Dahua County. Fishermen conduct normal production in accordance with usual fishing gear and methods, such as fishing nets, fishhooks, and fishing cages. Most fishermen place fishing nets at 18:30 to 3:00 in the next day, and haul up fishing nets at 7:00. Net is 400 – 500 m long, and the mesh is 4 – 10 cm. There are 4 – 6 fishing cages and 300 – 400 fishhooks.

Analysis methods of the catches include statistical method, Shannon-Weiner diversity index[4], Wilhm improvement index[5], and D_{G-F} species diversity index[6] analysis method[7].

Calculation methods of Shannon-Weiner index (H) and Wilhm improvement index (H'').

$$H = -\sum_{i=1}^{S}(P_i \ln P_i);$$

$$H'' = --\sum_{i=1}^{S}(W_i \ln W_i)。$$

where P_i denotes the proportion of the i-th organism individual to total organisms, S refers to total organism types, N is total organisms, and W_i signifies the proportion of the i-th organism quality to total organism quality.

The calculation method of D_{G-F} species diversity index is as follows:

$$D_{G-F} = 1 - \frac{D_G}{D_F}$$

$$D_F = \sum_{k=1}^{m} D_{FK} = -\sum_{k=1}^{m}\sum_{i=1}^{n}(p_i \ln p_i)$$

$$p_i = S_{ki}/S_k$$

$$D_G = -\sum_{j=1}^{p} D_{Gi} = -\sum_{j=1}^{p}(q_j \ln q_j)$$

$$q_i = S_{sj}/S$$

where S_{ki} denotes total organisms of genus i of family k, S_k signifies total organism individuals of family k, n is the number of genus in family k, m refers to total of the whole organism families, S_j signifies total organisms of genus j, S is total organisms, and p is total organism genus.

3 Results and analyses

3.1 Water quality Water quality test results indicate that total phosphorus, volatile phenols, non-ionic ammonia, oil, mercury, copper, zinc, lead, cadmium, pH value of water in Yantan Reservoir conform to category III standard specified in *Standard for Environmental Quality of Surface Water* (GB 3838 – 2002) and *Water Quality Standard for Fisheries* (GB 11607 – 1989). Total nitrogen of water in Yantan Reservoir is up to 1.25 – 2.70 mg/L, the average value is 1.75 mg/L. According to category III standard specified in *Standard for Environmental Quality of Surface Water* (GB 3838 – 2002), the total nitrogen exceeds 0.25 – 1.7 times, and the average value exceeds 74.6% of the standard of Category III water, as listed in Table 1.

3.2 Planktonic organisms We collected 6 phyla and 57 genera planktonic organisms, including 9 genera of Cyanophyta, 23 genera of Chlorophyta, 17 genera of Bacillariophyta, 2 genera of Euglenophyta, 4 genera of Pyrrophyta, and 2 genera of Chrysophyta. Bacillariophyta, Pyrrophyta, Chlorophyta, and Cyanophyta are dominant species, and the Bacillariophyta has the largest biomass, as listed in Table 2. The average quantity per unit of phytoplankton is 1.0134 million ind./L, and the average quantity per unit of organisms is 1.1151 mg/L. According to SL218 – 98 *Standard for the Fishery Trophic Classification of Reservoirs*, taking average quantity per unit of planktonic organisms as basis, Tantan Reservoir belongs to trophic water and the water quality is general.

Table 1 Test results of water quality

Indicators	Indicators of water quality									
	Total P mg/L	Total N mg/L	Volatile phenols mg/L	Non – ionic ammonia mg/L	Oils mg/L	Hg mg/L	Cu mg/L	Zn mg/L	Pb mg/L	Cd mg/L
Average value	0.035	1.75	<0.001	<0.02	<0.01	0.00006	<0.005	0.02	<0.01	<0.001
Provision in Water Quality Standard for Fisheries			≤0.005	≤0.02	≤0.05	≤0.0005	≤0.01	≤0.1	≤0.05	≤0.005
Provision of Category III water in Standard for Environmental Quality of Surface Water	≤0.2	≤1.0	≤0.005		≤0.05	≤0.0001	≤1.0	≤1.0	≤0.05	≤0.005

Table 2 List of phytoplankton collected

Types		Frequency of occurrence
Cyanophyta	*Microcystis*	+ + + +
	Merismopedia	+ + +
	Aphanizomenon	+ +
	Oloeothece	+
	Oscillatoria	+ + + +
	Dactylococcopsis	+
	Chroococcus	+
	Coelosphaerium	+ +
	Aphanocapsa	+
Chlorophyta	*Chamydomonas*	+ + + +
	Eudorina	+ + + +
	Pandorina	+ + +
	Pleodorina	+
	Chlore lla	+ + + +
	Ankistordesmus	+ + + +
	Pediastum	+ + + +
	Coelastrum	+ + + +
	Crucigenia	+
	Scenedesmus	+ + + +
	Astrococcus	+
	Micractinium	+
	Mougeotia	+ + +
	Spirogyra	+ + +
	Oedogonium	+
	Closterium	+ + +
	Staurastrum	+ + +
	Oocystis	+ +
	Tetraspora	+
	Tetraëdron	+ + + +
	Pleodorina	+
	Dictyosphaerium	+
	Franceia	+ +
Bacillariophyta	*Triceratium*	+
	Melosira	+ + + +
	Cyclotella	+ + + +
	Rhizosolenia	+ +
	Attheya	+ + +
	Fragilaria	+ + + +
	Synedra	+ + + +
	Achnanthes	+ + +
	Navicula	+ + + +
	Pinnularia	+
	Cymbella	+ + + +
	Gyrosigma	+ +
	Cynatopleura	+
	Gomphonema	+ + + +
	Cocconeis	+ + +
	Nitzschia	+ +
	Surirellia	+ +
Euglenophyta	*Euglena*	+ + +
	Trachelomonas	+ + +
Pyrrophyta	*Cryptomonas*	+ + + +
	Glenodinium	+ + +

to be continued

continued

Types		*Frequency of occurrence*
	Peridinium	+ + +
	Ceratium	+ + + +
Chrysophyta	*Dinobryon*	+ + +
	Mallomonas	+ + + +

Note: " +", " + +", " + + + +" and " + + + + +" denote samples collected in cross section 1, 2, 3, and 4 separately.

Table 3 List of zooplankton collected

Types		Frequency of occurrence
Protozoan	*Cucurbitella sp.*	+ + + +
	Centropyxis aculeata	+
	Difflugia glogbulosa	+ +
	Difflugia urceolata	+ +
	Difflugia acuminata	+
	Difflugia lobostoma	+ + +
	Difflugia lebes	+
	Pseudodifflugia gracilis	+ +
	Askenasia olvox Clap	+ + +
	Askenasia faurei Kahl	+
	Strombidium sp.	+ +
	Genus Strobilidium gyrans	+
	Tintinnopsis sp.	+ +
Rotifera	*Brachionus falcatus*	+ +
	Keratella valga	+ + + +
	Keratella cochlearis	+ + + +
	Euchlanis dilatata	+
	Lecana luna	+ +
	Asplanchna priodonta	+
	Diurella stylata	+ +
	Trichocerca cylindrica	+
	Trichocerca rattus	+
	Polyarthra trigla	+ + + +
	Synchaeta pectinata	+
	Ploesoma hudsoni	+ + +
Cladoceia	*Diaphanosoma brachyurum*	+ + + +
	Daphnia cucullata	+ + +
	Ceriodaphnia quadrangular	+ + + +
	Alona intermedia Sars	+
	Moina macrocopa	+
	Pleuroxus laevis	+
	Bosmina Iongirostris	+ + + +
	Bosminopsis deitersi	+ + + +
Copepoda	*Sinocalanus dorrii*	+ + +
	Onychocamptus mohammed	+
	Allodiaptomus specillodactylus	+
	Mongolodiapomus birulai	+ + + +
	Heliodiaptomus serratus	+ + + +
	Macrocyclops labidus	+ +
	Eucyclops serrulatus	+ + +
	Tropocyclops prasinus	+ + +
	Mesocyclops leuckarti	+ +
	Thermocyclops hyalinus	+ + +
	Nauplius	+ + + +

We collected 4 types, 19 families, 35 genera and 43 species of zooplankton, including 4 families, 8 genera and 13 species of protozoon, 5 families, 10 genera and 12 species of rotifera, 6 families, 7 genera and 8 species of cladoceia, and 4 families, 10 genera and 10 species of copepoda, as listed in Table 3. There is a great difference in quantity of types of zooplankton: the sequence is Rotifera, protozoon, cladoceia and copepoda. The average quantity per unit of zooplankton is 459.6 ind./L, and the average quantity per unit of organisms is 0.6422 mg/L. According to SL218 – 98 *Standard for the Fishery Trophic Classification of Reservoirs*, taking average quantity per unit of zooplankton as basis, Tantan Reservoir belongs to oligotrophic water and the water quality is excellent.

3.3 The catches The catches were surveyed in June-November 2013. Daily catches were recorded for single ship operation of upstream, midstream and downstream. In total, 1410.2 kg and 52365 pieces of catches were recorded. Through search, the whole fishes belong to 3 orders and 6 families (cyprinidae includes 6 subfamilies), 17 genera and 17 species, as shown in Table 4. For upstream fishermen, we made a record of 181 operating days (178 days had catches), 178 pieces of catch data, the total 51351 pieces of catches weighed 905.9 kg; for midstream fishermen, we made a record of 174 operating days (64 days had catches), 64 pieces of catch data, the total 430 pieces of catches weighed 268.2 kg; for downstream fishermen, we made a record of 150 operating days (86 days had catches), 86 pieces of catch data, the total 584 pieces of catches weighed 236.1 kg. Daily catches per ship for all three areas of fishermen were 2.7 kg.

According to types, quantity, and quality distribution of catches obtained, the Shannon-Weiner diversity index is 0.162, Wilhm improvement index is 1.814, and D_{G-F} species diversity index is 0.083.

Table 4 Data of the catches

Types	Upstream		Midstream		Downstream	
	Quantity	Weight//kg	Quantity	Weight//kg	Quantity	Weight//kg
Discogobio tetrabarbatus	51060	688.0	0	0.0	0	0.0
Cyprinus carpio	16	21.9	12	23.7	132	153.2
Tilapia niloticus	41	9.2	206	106.0	83	29.5
Hypophthalmichthys molitrix	45	70.1	10	16.3	0	0.0
Mylopharyngodon piceus	4	45.1	2	9.5	1	0.9
Pelteobagrus vachelli	130	17.9	61	16.7	151	17.6
Aristichthys nobilis	2	14.5	8	35.5	0	0.0
Cranoglanis bouderius bouderius	0	0.0	23	23.6	3	2.9
Mystus guttatus	4	7.8	6	11.1	0	0.0
Siniperca kneri	22	15.3	0	0.0	0	0.0
Ctenopharyngodon idellus	0	0.0	3	9.7	3	5.2
Silurus asotus	0	0.0	3	6.6	3	5.3
Elopichthys bambusa	6	11.0	0	0.0	0	0.0
Semilabeo notabilis	18	3.0	0	0.0	0	0.0
Parabramis pekinensis	2	1.1	0	0.0	0	0.0
Cirrhinus molitorella	1	1.0	0	0.0	0	0.0
Hemiculter leucisculus	0	0.0	96	9.5	208	21.5
Total	51351	905.9	430	268.2	584	236.1

4 Conclusions and discussions

4.1 Discussions

4.1.1 Natural environment for water quality of Yantan water area is basically normal. Testing results of water quality of Yantan water area in 1981 – 1982, 1996 – 1997, 2003 – 2004, 2005 – 2006, and 2013 indicate that there are changes of physical and chemical indicators of water quality. However, except total nitrogen exceeding the standard, all other indicators conform to category III standard specified in *Standard for Environmental Quality of Surface Water* (*GB* 3838 – 2002) *and Water Quality Standard for Fisheries* (GB 11607 – 1989).

From Table 5, it can be known that the quantity of types of phytoplankton in Yantan Reservoir area is lower than historical data, the unit average quantity and biomass are slightly higher than the period before construction of the reservoir, but there is obvious decline compared with the quantity of 5 and 10 years after water storage of the reservoir; the quantity of types of zooplankton is slightly lower than the historical data, and there is obvious decline in unit average quantity and biomass compared with the quantity of 5 and 10 years after water storage of the reservoir[8]. According to unit biomass indicator surveyed, water quality of Yantan area is oligotrophic and mesotrophic, and natural environment in reservoir water area is basically normal.

Table 5 Planktonic organisms in Yantan Reservoir area in different periods

Period	Types	Quantity of types	Unit quantity ind./L	Biomass in unit//mg/L
1981 – 1984	Phytoplankton	8 phyla, 73 genera	660000	0.7063
1996 – 1998	Phytoplankton	7 phyla, 69 genera	2550000	2.5743
2003 – 2005	Phytoplankton	7 phyla, 71 genera	1600000	3.0935
This survey	Phytoplankton	6 phyla, 57 genera	1010000	1.1151
1981 – 1984	Zooplankton	20 families, 47 species	388	0.0490
1996 – 1998	Zooplankton	26 families, 108 species	3197	2.8630
2003 – 2005	Zooplankton	51 families, 93 species	338	0.7865
This survey	Zooplankton	19 families, 43 species	460	0.6422

4.1.2 Fish resources in Yantan water area are exhausted. According to survey results in recent 30 years for fishery ecology in Hongshui River and Yantan Reservoir area, fish types were 15 families and 70 species in 1981 – 1984[3], 15 families and 43 species in 1997 – 1998, and 14 families and 42 species in 2003 – 2005[10], and there are 30 types of commercial fishes. Due to influence of fishing tools and methods, survey results are not fully reflecting current situations of fish resources in the reservoir area. Our survey lasts half year, but the catches we recorded only 3 orders, 6 families, 17 genera and 17 species, and the daily catches per ship is only 2.7 kg, showing gradually exhausting fish resources in the reservoir area.

4.1.3 Diversity of fish species in Yantan water area is low. Shannon-Weiner diversity index reflects abundance of community species from quantity distribution of different species; Wilhm improvement index combines influence of species abundance and evenness and reflects complexness of community structure from quality distribution of different species[11]; D_{G-F} species diversity index reflects species diversity level from distribution of community organisms in families and genera[6]. In the second half of 2013, Shannon-Weiner diversity index of the catches in Yantan water area was 0.162, Wilhm improvement index is 1.814, and D_{G-F} species diversity index is 0.083. Zhou Jie et al[7], Han Yao[8], Li Jie et al[12], Ling Qufei et al[13], Zhang Jiabo et al[14], and Zhang Minying et al[15-16] made survey and diversity analysis of fish resources respectively in inland water area of Guangxi, Lijiang River and Qian River water area, Xijiang River in Zhaoqing City of Guangdong Province, Swan Island Ancient Course of Yangtze River, Laojianghe River, and Yangtze River. Compared with Pearl River, Yangtze River valley, the fish species diversity of Yantan water area is lower, Shannon-Weiner diversity index is only 4.14% of average value of other water areas, Wilhm improvement index is 59.05% of the average value of other water areas, and D_{G-F} index is only 15.82% of the average value of other water areas, as listed in Table 6.

4.1.4 Fish resource structure of Yantan water area is abnormal. According to the quantity of the catches, more than 98% are small fishes (*Discogobio tetrabarbatus* accounts for 97.51%). More than 50% catches are small fishes and commercial fishes account for a small portion. Except small fishes, only carps and tilapias exceed 10%, other fishes not artificially enhanced and released only account for about 6%. These differ greatly with historical data that 13 major commercial fishes in rivers of Guangxi account for more than 54%[2]. Thus, it can be known that fish resources of Yantan Reservoir are exhausted, and structure of fish resources are extremely abnormal.

Table 6 Comparison in diversity of fish species in water areas

Water area	Shannon-Weiner index	Wilhm improvement index	D_{G-F} index
Qingpitang section of Xijiang River	3.89	3.37	
Swan Island Ancient Course of Yangtze River	3.7	4.19	
Laojianghe River	4.14	3.16	
Changshu section of Yangtze River		2.50	
Anqing section of Yangtze River		2.14	
Fresh water fishes in Guangdong Province			0.638
Fresh water fishes in Guangxi Province			0.668
Qian River			0.428
Li River			0.443
Water area of Yantan	0.162	1.814	0.083

4.2 Conclusions This study indicates that water quality of Yantan water area is basically normal, but fish resources are exhausted, and fish species diversity is extremely low. Compared with natural rivers before construction of the reservoir, the structure of fish resources in the reservoir area is extremely abnormal. Due to barrier of water conservancy dam of Hongshui River, ecological environment of Yantan water area is deteriorated. Especially, major commercial fishes such as *Mylopharyngodon piceus*, *Ctenopharyngodon idellus*, *Hypophthalmichthys molitrix*, and *Aristichthys nobilis* lose their natural environment for reproduction and accordingly fish resources are gradually exhausted. In addition to superposition influence of other factors such as disorderly development of fishery and increase of environmental pressure, aquatic organisms of reservoir area in recent years lose balance in structure, especially the structure of fish resources. Unreasonable fish structure will deteriorate unreasonable structure of aquatic organisms in reservoir area and increase hidden dangers of ecological safety accidents in reservoir area. According to survey results of *Survey Report of Hazards of Freshwater Mussel in Yantan Reservoir Area in Dahua County*, breakout of freshwater mussel in Yantan reservoir is partly resulted from sharp decrease of Mylopharyngodon piceus which is the natural enemy of freshwater mussel.

Table 7 Distribution of the catches in Yantan water area

Types	Quantity	Quantity proportion %	Weight kg	Quality proportion %
Discogobio tetrabarbatus	51060	97.51	688.0	48.81
Cyprinus carpio	160	0.31	198.7	14.09
Tilapia niloticus	330	0.63	144.7	10.26
Hypophthalmichthys molitrix	55	0.11	86.3	6.12
Mylopharyngodon piceus	7	0.01	55.5	3.93
Pelteobagrus vachelli	342	0.65	52.1	3.70
Aristichthys nobilis	10	0.02	50.0	3.55
Cranoglanis bouderius bouderius	26	0.05	26.5	1.88
Mystus guttatus	10	0.02	18.9	1.34
Siniperca kneri	22	0.04	15.3	1.09
Ctenopharyngodon idellus	6	0.01	14.9	1.05
Silurus asotus	6	0.01	11.8	0.84
Elopichthys bambusa	6	0.01	11.0	0.78
Semilabeo notabilis	18	0.03	3.0	0.21
Parabramis pekinensis	2	0.00	1.1	0.07
Cirrhinus molitorella	1	0.00	1.0	0.07
Hemiculter leucisculus	304	0.58	31.0	2.20
Total	52365	100.00	1409.8	100.00

In the context of ecological safety of water area in the reservoir, it is urgent to restore ecology of Yantan water area. From the perspective of biomanipulation, fish enhancement and release carried out by fishery department should be based on thorough survey. It is recommended to increase indigenous fishes of Hongshui River and gradually restore fish structure and the diversity. For example, it is recommended to release some bottom fishes to improve bottom feeder of the reservoir area, release *Mylopharyngodon piceus* to eat benthic animals, and release certain quantity of carnivorous fishes to eliminate excessive small fishes and improve aquatic ecological environment and biological structure of the water area. Through correct estimation of primary productivity and fishing ground capacity, it is recommended to release *Ctenopharyngodon idellus*, *Hypophthalmichthys molitrix*, and *Aristichthys nobilis* to slow down and adjust eutrophication of reservoir area, reduce nitrogen and phosphorus content in water, and improve water quality.

References

[1] JIA XP, LI CH, GAN JL, *et al*. Diagnosis and assessment on the health status and quality of the fishery ecoenvironment of the northern South China Sea[J]. Journal of Fishery Sciences of China, 2005, 12(6): 757 – 765. (in Chinese).

[2] Fisheries Bureau, Ministry of Agriculture. Total planning of enhancement and releasing of national aquatic organism (2011—2015), Nong Yu Fa【2010】44[R]. Beijing: Fisheries Bureau, Ministry of Agriculture, 2010: 1 – 83. (in Chinese).

[3] Institute of Fisheries Research of Guangxi Zhuang Autonomous Region. Investigation and study on inland waters of fisheries natural resources in Guangxi Zhuang Autonomous Region[M]. Nanning: Youth Printing, 1984: 1 – 645. (in Chinese).

[4] SHANNON CE, WEINER W. The mathematical theory of communication [M]. Urbana: The University of Illinois Press, 1949: 117.

[5] WILHM JL. Use of biomass units in Shannon's formula[J]. Ecology, 1968, 49(1): 153 – 156.

[6] JIANG ZG, JI LQ. Avian mammalian species diversity in nine representative sites in China[J]. Biodiversity Science, 1999, 7(3): 220 – 225. (in Chinese).

[7] ZHOU X, ZHANG CG. Guangxi Freshwater Fish[M]. Nanning: Guangxi People's Publishing House, 2006: 1 – 535. (in Chinese).

[8] HAN YQ. Studies on fish species diversity and evolution trend in Lijiang River[J]. Journal of Hydroecology, 2010, 3(1): 22 – 28. (in Chinese).

[9] Institute of Fisheries Research of Guangxi Zhuang Autonomous Region. On investigation report of aquatic organism natural resources of Yantan Reservoir [R]. Nanning: Institute of Fisheries Research of Guangxi Zhuang Autonomous Region, 1998. (in Chinese).

[10] Institute of Fisheries Research of Guangxi Zhuang Autonomous Region. Investigation on aquatic biological resources of Yantan hydroelectric station reservoir and reviewing assessment[R]. Nanning: Institute of Fisheries Research of Guangxi Zhuang Autonomous Region, 2005. (in Chinese).

[11] DUAN XB, LIU SP, XIONG F, *et al*. Analysis of fishing structure and biodiversity in the Upper Mainstream of the Yangtze River before and after Three Years' spring fishing off[J]. Resources and Environment in the Yangtza Basin, 2008, 17(6): 878 – 885. (in Chinese).

[12] LI J, LI XH, TAN XC, *et al*. Species diversity of fish community of Provincial Xijiang River Rare Fishes Natural Reserve in Zhaoqing City, Guangdong Province[J]. Journal of Lake Science, 2009, 21(4): 556 – 562. (in Chinese).

[13] LING QF, LI SF. On diversity of fish community in Tian – e – zhou Oxbow of the Yangtze River and[J]. Journal of Fishery Sciences of China, 1998, 5(2): 1 – 5. (in Chinese).

[14] ZHANG JB, FAN QX, WANG WM. Species diversity and their dominant for Fishes in Laojianghe Lake (old course of Changjiang River)[J]. Freshwater Fisheries, 1998, 28(6): 14 – 17. (in Chinese).

[15] ZHANG MY, XU DP, LIU K, *et al*. Ichthyologic survey and primary studies on diversity of fishery species in Anqing section of the Yangtze River [J]. Journal of Lake Science, 2006, 18(6): 670 – 676. (in Chinese).

[16] ZHANGMY, XUDP, DUAN JR, *et al*. Primary studies on structure of fishery community and species diversity in Changshu section of the Yangtze River[J]. Ecologic Science, 2007, 26(6): 525 – 530. (in Chinese).

[17] WEI CY, LIU XL, DU YL, et al. Study of Breeding Sea and Breeding Technical Analysis[J]. Journal of Anhui Agricultural Sciences, 2015, 28(02): 132 – 133, 147. (in Chinese)