Journal of Oceanology and Limnology
Vol. 39 No. 2, P. 623-636, 2021
https://doi.org/10.1007/s00343-020-9288-1

A comparison of zooplankton assemblages in Nansi Lake and Hongze Lake, potential influences of the East Route of the South-to-North Water Transfer Project, China*

Kandathil Radhakrishnan DIVYA[1], Shasha ZHAO[1], Yushun CHEN[1], Fei CHENG[1, **], Lei ZHANG[2], Jiao QIN[1], Thundiparambil Sathrajith ARUNJITH[1], V. Bjorn SCHMIDT[1], Songguang XIE[1, 2]

[1] *Key Laboratory of Aquatic Biodiversity and Conservation of Chinese Academy of Sciences, Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan 430072, China*

[2] *Key Laboratory of Sustainable Fisheries and Environmental Protection for Lakes of Northern Jiangsu, Huai'an Research Center, Institute of Hydrobiology, Chinese Academy of Sciences, Huai'an 223002, China*

Received Nov. 16, 2019; accepted in principle Jan. 7, 2020; accepted for publication Feb. 29, 2020

Abstract Nansi Lake and Hongze Lake are both water storage lakes along the East Route of the South-to-North Water Transfer project (ESNT). Frequent changes in hydrologic properties are responsible factors for controlling the zooplankton community assemblages in both lakes, so we studied the possible influence of water transfer and environmental factors on zooplankton community structure and abundance. Zooplankton assemblages were investigated seasonally for one year in both lakes; a total of 133 and 122 zooplankton taxa were identified in Nansi Lake and Hongze Lake, respectively. The most dominant rotifer species were littoral, e.g., *Keratella tecta*, *Keratella valga* and *Lecane lunaris* in Nansi Lake and *Brachionus angularis*, *Brachionus forficula* and *Polyarthra vulgaris* in Hongze Lake. Comparatively, Nansi Lake had a higher Shannon-Wiener diversity index value (5.13), while Hongze Lake had a higher species richness index (4.21). The average number of zooplankton across seasons in Nansi Lake (protozoa: 774±63 ind./L, rotifers: 4 817±212 ind./L, cladocerans: 896±14 ind./L, copepod: 435±42 ind./L) was comparatively lower than Hongze Lake (protozoa: 1 238±63 ind./L, rotifers: 6 576±112 ind./L, cladocerans: 1 013±20 ind./L, copepod: 534±25 ind./L). Canonical correspondence analysis identified differing environmental gradients that were most responsible for influencing zooplankton communities in the two lakes (Hongze Lake: NH_4-N, total nitrogen, transparency and pH; Nansi: pH, temperature and total phosphorus). Frequent changes related to water transfer in lakes favoured the diversity of rotifers and protozoa communities. Zooplankton habitat preference, changes in community structure and opportunistic peaks and extinction of certain taxa were also observed in the study lakes.

Keyword: zooplankton assemblage; water transfer; Hongze Lake; Nansi Lake

1 INTRODUCTION

Inter-basin water transfer has been applied around the world to alleviate water shortages in water-deficient areas. The difference in hydrologic properties between donor and recipient systems influences both abiotic (physical and chemical) and biotic (species interactions, habitat, species composition of plants and animals) features of the connected ecosystems (Gruberts et al., 2007; Kufel and Leśniczuk, 2014; Winemiller et al., 2015). Several studies have shown positive effects of water transfers, through decreasing phytoplankton concentrations and improvement of water quality in downstream reservoirs (Padisák et al., 2000; Hu et al., 2010; Zhai et al., 2010). Other

* Supported by the Service Project of Special Institute of Chinese Academy of Sciences (No. Y55Z06), the Key Project in Frontier Science of Chinese Academy of Sciences (No. QYZDB-SSW-SMC041), the National Science Foundation of Jiangsu Province, China (No. BK20141268), and the National Natural Science Foundation of China (No. 31400486a)

** Corresponding author: chengfei@ihb.ac.cn

studies have reported negative implications of water transfer such as fluctuations of the nutrient influx in recipient systems, including a significant increase in silica, total iron and chlorophyll *a* content (Matsumura-Tundisi and Tundisi, 2005; Fornarelli and Antenucci, 2011). Water transfer can also negatively affect fish and invertebrate communities through increasing the likelihood of species invasions, possibly through the transfer of alien species and toxic cyanophytes into recipient systems (Matthews et al., 1996; Snaddon and Davies, 1998).

Zooplankton communities provide an ideal indicator of human disturbances in lake monitoring programs (Stemberger et al., 2001; Dodson et al., 2005). In lacustrine habitats, zooplankton community structure and seasonal dynamics are determined by a variety of factors such as geographic location, the lake area, water depth, water current velocity, and presence of macrophytes. Lake morphological characteristics such as surface area and shape influence species composition and richness of zooplankton, mainly based on the available limnetic and littoral habitats in the lake (Fryer, 1985; Gasith and Gafny, 1990; Dodson, 1991, 1992; Karatayev et al., 2005; Padial et al., 2009). Additionally, fluctuations in hydrological properties can either directly or indirectly affect biological communities such as zooplankton (Wolcox and Meeker, 1992; Betsill and Van Den Avyle, 1994; Poff et al., 1997; Gruberts et al., 2007; Leira and Cantonati, 2008). Biotic factors (both bottom-up and top-down factors) (Carpenter et al., 1985; McQueen et al., 1986; Northcote, 1988; Vanni, 1988) and abiotic factors like water chemistry can also act as driving forces for structuring zooplankton communities (Johannsson et al., 1991; Pourriot et al., 1994).

In recent centuries, many aquatic sources have been strongly transformed as a result of intensive engineering and water diversion, and these kinds of activities caused deterioration of biodiversity. The zooplankton assemblages, as well as the other biotic communities that inhabit the aquatic ecosystems, constitute an important element of the food chain, and are effective indicators of the trophic conditions. Moreover, zooplankton communities are sensitive to anthropogenic impacts and their study may be useful in the prediction of long-term changes in lake ecosystems. To understand the ecological function in lakes, sufficient knowledge is required for all biotic elements, including zooplankton. The present study aims to identify the trends of zooplankton diversity and distribution in Nansi Lake and Hongze Lake and their relationships with environmental factors (physical and chemical features of the water). Two questions were answered: How did the water transfer affect the zooplankton community structure and distribution in water storage lakes (Nansi anid Hongze) along the East Route of the South-to-North Water Transfer Project (ESNT)? Which environmental factors were responsible for temporal changes of zooplankton community in both lakes?

2 MATERIAL AND METHOD

2.1 Study area

Nansi Lake and Hongze Lake are water storage lakes along the ESNT. The ESNT diverts water from the lower reaches of the Changjiang (Yangtze) River at Jiangdu near Yangzhou, Jiangsu Province, to the North China Plain, using the Grand Canal as the main conveyance channel. The ESNT also intersects and passes through Nansi and Hongze Lake during the transfer process. The ESNT was expected to increase the water levels of Nansi and Hongze Lake by 0.5 m, and the annual water exchange rate was expected to be 1.2 times after it became fully operational (Zhang, 2009). The first full East Route transfer was done in 2013; during normal operation water passes through Hongze Lake and is conveyed to Nansi Lake. Nansi Lake has a dividing dam between the upper and lower lakes, and the water collects first in lower Nansi Lake (Weishan) and then is lifted and moved to upper Nansi Lake. Comparatively, water depth is higher in Hongze Lake than in Nansi Lake. Additionally, water flow may cause there to be less macrophytes in Hongze Lake due to stronger water currents during transfer, while in Nansi Lake water is first collected at the dam leading to comparatively weaker currents and more extensive macrophyte coverage.

Nansi Lake (34°36′N, 117°12′E) (Fig.1a) is located in the north of the Huaihe River basin in Shandong Province, China. It is a relatively large, shallow lake, with a total surface area (combined upper and lower lakes) of 1 266 km^2 and an average depth of 1.5 m. According to lake morphology, most of the area of Nansi Lake is covered by vegetation, providing more habitat heterogeneity for species colonization.

Hongze Lake (33°18′27″N 118°42′36″E) (Fig.1b) is the fourth largest freshwater lake in China, in the middle reach of the Huaihe River in Jiangsu Province with a total surface area of 1 960 km^2. The mean water depth of the lake is 1.77 m, with the deepest sections

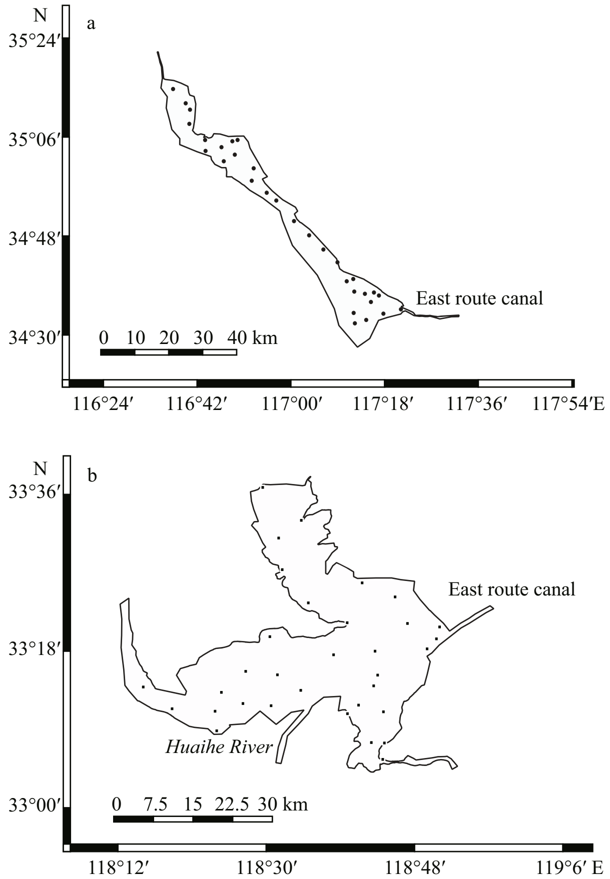

Fig.1 Map of the Nansi Lake (a) and Hongze Lake (b) showing the distribution of sampling stations

being around 4.37 m (Chu, 2001). The water volume is about 27.9×10^8 m^3. The average elevation of the lake basin is around 4–8 m higher than the eastern plain of China. Approximately 73% of the lake water is contributed by the inflowing Huaihe River (Yang, 1993). Hongze Lake is a transitional lake where water levels often undergo large fluctuations both annually and seasonally (Wang and Chen, 1999). Overall, the macrophyte coverage in Hongze Lake is very low, although there remains some coverage in the northeast and southwest sections. Therefore, comparatively, the open water area of Hongze Lake is higher than Nansi Lake (Liu et al., 2009; Lin et al., 2017).

2.2 Physico-chemical environmental analysis

Physico-chemical environmental variables were measured for each sample site during zooplankton sampling. Water temperature (°C), pH, and dissolved oxygen (DO) (mg/L) were measured in-situ using a Yellow Springs Instrument (YSI proplus probe). Transparency (m) and water depth (m) were measured with a Secchi disk. Water samples (from 0.5 m below the surface) were also obtained during zooplankton sampling. Water samples were analyzed to determine total phosphorus (TP, stannous chloride method, mg/L), nitrate nitrogen (NO_3-N, nitrate selective method, mg/L), chemical oxygen demand (COD, open reflux method, mg/L) (APHA, 1992), and total nitrogen (TN, potassium persulfate digestion and ultraviolet spectrophotometry method, mg/L), ammonia nitrogen (NH_4-N, Nessler's reagent spectrophotometry method, mg/L) (Huang et al., 1999).

2.3 Zooplankton sampling and analysis

Zooplankton was sampled at 31 sampling stations in Nansi Lake and 33 sampling stations in Hongze Lake covering the whole area for both lakes (Fig.1). Sampling was carried out seasonally (spring, summer, autumn and winter) in April, July, and October of 2015, and January 2016. Sampling was carried out both qualitatively and quantitatively. Qualitative samples were collected using conical nets of 23-μm mesh for protozoa and rotifers (fixed at 1% Lugol's solution) and of 64-μm mesh for crustaceans (fixed at 4% formalin) by horizontally towing at the surface at approximately 0.5 m depth, at a speed of 1–1.5 m/s, for approximately 5 min. Zooplankton were identified in the lab to the lowest possible taxonomic level, usually to species or genus (Chiang and Du, 1979; Shen and Song, 1979; Tai and Chen, 1979; Tai and Song, 1979; Shen, 1983; Shiel, 1995) at 10×, 40×, and 100× magnifications using an Olympus compound microscope.

Quantitative sampling was performed using a 5-L modified Patalas water sampler. For quantitative samples of smaller organisms (e.g., protozoa and rotifers, nets of 23 μm mesh), 5 L of water was filtered and fixed in 1% Lugol's solution. For crustaceans (nets of 23-μm mesh), 20 L of water was filtered and preserved with 4% formalin. Zooplankton (rotifers, protozoans, cladocerans and copepods) samples were counted using Sedgewick-Rafter counting chambers. The enumeration of specimens in the samples was done using subsamples of 0.1 mL for protozoans and rotifers and 1 mL for crustaceans. Dominant species were calculated as those species occurring with more than 10% of the total individuals of a sample according to (Patalas, 1971). Habitat preference of zooplankton species was classified as limnetic, littoral, or limnetic/littoral (Tai and Chen, 1979; Shen, 1983; Smirnov and Timms, 1983; Koste and Tobias, 1987; Koste and Shiel, 1991).

2.4 Statistical analysis

The datasets were checked with the Shapiro-Wilk test, and then, if necessary, square root (physico-chemical environmental variables) or log (x+1) (zooplankton density) transformed to achieve normality. To analyze differences between the lakes, a two-way analysis of variance (ANOVA) was performed for zooplankton density and a Friedman test was performed for physico-chemical parameters. All the above statistical analyses were conducted using SPSS, Version 20 (IBM Chicago, IL). Analyses were also conducted to calculate species richness, evenness and Shannon-Wiener diversity indices of zooplankton (rotifers, protozoans, cladocerans, and copepods) of the two lakes using software package Primer 5 (Clarke and Warwick, 2001).

Finally, to elucidate the relationship between the zooplankton composition and environmental conditions, a canonical correspondence analysis (CCA) was conducted for each lake (Ter Braak and Verdonschot, 1995). Species abundances were square root-transformed and down-weighted for rare species, following the method of (Lepš and Šmilauer, 2003). The forward selection of CCA, which is analogous to stepwise multiple regression, was used to determine the significance (P<0.05) of environmental variables that could explain the variation in the species data. The significance of these variables was assessed using Monte Carlo permutation tests (with 999 unrestricted permutations). All the ordinations were performed using CANOCO version 4.5 (Ter Braak and Smilauer, 2002).

3 RESULT

3.1 Zooplankton community structure and density

Total of 133 zooplankton species were identified in Nansi Lake, and 122 were identified in Hongze Lake. Zooplankton species (either limnetic or littoral) appeared in the category of sporadic (<10%) in both lakes (Table 1). Rotifers contributed as the major grouping for the total zooplankton diversity with a

Table 1 Zooplankton taxa recorded in Nansi Lake and Hongze Lake with frequency of occurrence (FO) (%) of species

Taxon	Species	Hongze Lake	Nansi Lake	Taxon	Species	Hongze Lake	Nansi Lake
		FO (%)	FO (%)			FO (%)	FO (%)
Rotifera				*Keratella cochlearis* (Gosse)	Kcoc	67.46	61.26
Rotaria sp. (Scopoli)	Rot sp	8.11	8.11	*Keratella valga* (Ehenberg)	Kval	26.98	41.44
Colurella obtusa (Gosse)	Cobt	2.7	3.6	*Keratella tecta* (Gosse)	Ktec	34.92	54.05
Colurella colurus (Ehenberg)	Ccol	2.38	19.82	*Keratella tropica* (Apstein)	Ktro	8.73	3.6
Lepadella patella (Müller)	Lpat	1.59	21.62	*Trichotria pocillum* (Müller)	Tpoc	3.17	4.5
Lepadella ovalis (Müller)	Lova	–	1.8	*Trichotria tetractis* (Ehenberg)	Ttec	–	3.6
Brachionus angularis (Gosse)	Bang	48.41	57.66	*Notholca labis* (Marukawa)	Nlab	8.73	18.02
Brachionus calyciflorus (Pallas)	Bcal	63.49	80.18	*Notholca squamula* (Müller)	Nsqa	3.17	2,3
Brachionus urceolaris (Hempel)	Burc	0.79	6.31	*Mytilina acanthophora* (Hauer)	Maca	1.3	3.6
Brachionus diversicornis (Daday)	Bdiv	29.37	33.33	*Macrochaetus subquadratus* (Perty)	Msub	1.4	1.8
Brachionus havanaensis (Koste)	Bhav	2.7	2.5	*Mytilina ventralis* (Gosse)	Mven	–	8.11
Brachionus forficula (Wierzejski)	Bfor	24.32	24.32	*Euchlanis triquetra* (Gosse)	Etri	4.76	25.23
Brachionus budapestinensis (Hempel)	Bbud	21.43	7.21	*Euchlanis dilatata* (Ehenberg)	Edil	27.03	9.52
Brachionus caudatus (Stemberger)	Bcau	7.14	2.7	*Euchlanis piriformis* (Gosse)	Epir	–	3.6
Brachionus quadridentatus (Hermann)	Bqua	30.63	30.63	*Anuraeopsis fissa* (Gosse)	Afiss	9.01	–
Brachionus rotundiformis (Tschugunoff)	Brot	0.79	–	*Epiphanes* sp. (Ehenberg)	Epi sp	7.21	–
Brachionus capsuliflorus (Pallas)	Bcap	0.79	–	*Lecane spenceri* (Shepard)	Lspe	0.79	0.9
Brachionus bennini (Leißling)	Bben	7.14	–	*Lecane closterocerca* (Schmarda)	Lclo	7.14	24.32
Brachionus falcatus (Zacharias)	Bfal	4.76	–	*Lecane luna* (Müller)	Llun	5.56	15.32
Brachionus rubens (Ehenberg)	Brub	11.9	17.12	*Lecane lunaris* (Ehenberg)	Lluns	7.14	28.83
Keratella quadrata (Carlin)	Kqua	47.62	32.43	*Lecane curvicornis* (Harring)	Lsti	–	0.79

FO: frequency of occurrence, >70%: much frequent; 70%–40%: frequent; 40%–10%: less frequent; <10%: infrequent/sporadic. –: no occurrence.

To be continued

Table 1 Continued

Taxon	Species	Hongze Lake	Nansi Lake
		FO (%)	FO (%)
Lecane ludwigii (Eckstein)	Llud	–	0.9
Asplanchna brightwelli (Daday)	Abri	0.9	–
Cephalodella tantilloides (Hauer)	Ctan	–	0.9
Cephalodella gibba (Ehenberg)	Cgib	–	1.8
Monommata longiseta (Müller)	Mlon	–	0.79
Notommata sp. (Ehenberg)	Notsp	1.59	4.5
Scaridium longicaudum (Müller)	Slon	0.79	1.8
Gastropus hyptopus (Lindner)	Ghyp	7.14	4.5
Ascomorphs sp. (Perty)	Ascsp	–	0.9
Trichocerca rattus (Müller)	Trat	–	6.31
Trichocerca weberi (Edmondson)	Tweb	–	9.01
Trichocerca gracilis (Carlin)	Tgra	15.08	20.72
Trichocerca bicristata (Harring)	Tbic	7.14	16.22
Trichocerca tenuior (Gosse)	Tten	–	6.31
Trichocerca elongata (Gosse)	Telo	–	5.01
Trichocerca rattus (Muller)	Trat	–	6.87
Trichocerca similis (Wierzejski)	Tsim	36.94	–
Platyias quadricornis (Ehrenberg)	Pqua	–	5.67
Polyarthra sp. (Ehrenberg)	Ptri	13.51	–
Polyarthra major (Burckhardt)	Pmaj	0.79	–
Polyarthra remata (Skorikov)	Prem	7.14	48.65
Polyarthra vulgaris (Carlin)	Pvul	53.97	–
Polyarthra dolichoptera (Idelson)	Pdol	42.06	37.84
Synchaeta longipes (Gosse)	Slon	12.7	8.11
Synchaeta grandis (Zacharias)	Sgran	8.11	8.11
Testudinella mucronata (Gosse)	Tmuc	–	5.41
Testudinella patina (Hermann)	Tpat	11.71	–
Hexarthra fennica (Levander)	Hfen	3.97	6.31
Hexarthra mira (Hudson)	Hmir	7.94	13.51
Filinia cf terminalis (Plate)	Fter	10.32	15.32
Filinia longiseta (Ehrenberg)	Flon	48.41	46.85
Macrotrachela plicata (Bryce)	Mpli	–	9.91
Cladocera			
Diaphanosoma leuchtenbergianum (Fischer)	Dleu	16.45	20.72
Diaphanosoma sarsi (Richard)	Dsar	2.15	2.7
Diaphanosoma brachyurum (Lievin)	Dbra	9.91	–
Diaphanosoma excisum (Sars)	Dex	6.31	–
Diaphanosoma chankensis (Ueno)	Dcha	0.72	0.9
Bosmina coregoni (Baird)	Bcor	19.31	24.32
Bosmina longirostris (Müller)	Blon	31.46	39.64
Daphnia hyalina (Leydig)	Dhya	17.46	–
Daphnia cucullata (Sars)	Dcuc	1.58	–

Taxon	Species	Hongze Lake	Nansi Lake
		FO (%)	FO (%)
Daphnia cristata (Sars)	Dcri	4.76	–
Simocephalus vetulus (Müller)	Svet	–	6.67
Ceriodaphnia laticaudata (Müller)	Clat	–	0.79
Ceriodaphnia hamata (Sars)	Cham	–	0.79
Ceriodaphnia cornuta (Sars)	Ccor	7.15	9.01
Moina micrura (Kurz)	Mmic	8.58	10.81
Moina chankensis (Ueno)	Mcha	6.34	–
Moina macrocopa (Straus)	Mmac	–	0.79
Moina rectirostris (Leydig)	Mrec	5.01	6.31
Moina weismanni (Ishikawa)	Mwei	0.72	0.9
Alona guttata (Sars)	Agut	5.72	7.21
Alona diaphana (King)	Adia	–	0.9
Alona costata (Sars)	Acos	1.78	24.32
Alona affinis (Leydig)	Aafi	–	3.6
Alona rectangularis (Sars)	Arec	–	5.41
Graptoleberis testudinaria (Fischer)	Gtes	–	10.81
Pleuroxus hamulatus (Birge)	Pham	1.43	1.8
Chydorus barroisi (Richard)	Cbar	24.31	30.63
Chydorus sphaericus (Müller)	Csp	13.78	–
Leydigia acanthocercoides (Fischer)	Laca	–	1.8
Ceriodahnia pulchella (Sars)	Cpul	–	1.76
Copepoda			
Acanthocyclops viridis (Jurine)	Avir	–	13.51
Diacyclops thomasi (Forbes)	Dtho	1.43	11.71
Mesocyclops leukartii (Claus)	Mleu	14.3	18.02
Thermocyclops taihokuensis (Harada)	Ttai	2.15	2.7
Cyclops vicinus (Ulyanin)	Cvic	9.3	1.8
Microcyclops varicans (Sars)	Mvar	12.97	14.28
Eucyclops serrulatus (Fischer)	Eser	9.01	9.87
Paracyclops fimbriatus (Fischer)	Pfim	–	0.79
Schmackeria poplesia (Shen)	Spop	3.96	–
Schmackeria forbesi (Poppe&Richard)	Sfor	2.86	3.6
Sinocalanus doerri (Brehm)	Sdor	6.44	8.11
Sinocalanus sinensis (Poppe)	Ssin	1.58	5.4
Neodiaptomus schmackeri (Poppe&Richard)	Nsch	8.73	–
Schmackeria inopinus (Burckhardt)	Sino	–	0.9
Nitocrella sp.(Chappuis)	Nit sp	2.12	3.6
Sinocalanus sp. (Burckhardt)	Sin sp	2.38	–
Limnoithona sp. (Burckhardt)	Lim sp	2.38	–
Nitokra lacustris (Schmankevitsch)	Nlac	–	1.78
Canthocamptus sp. (Westwood)	Cam sp	3.17	3.96

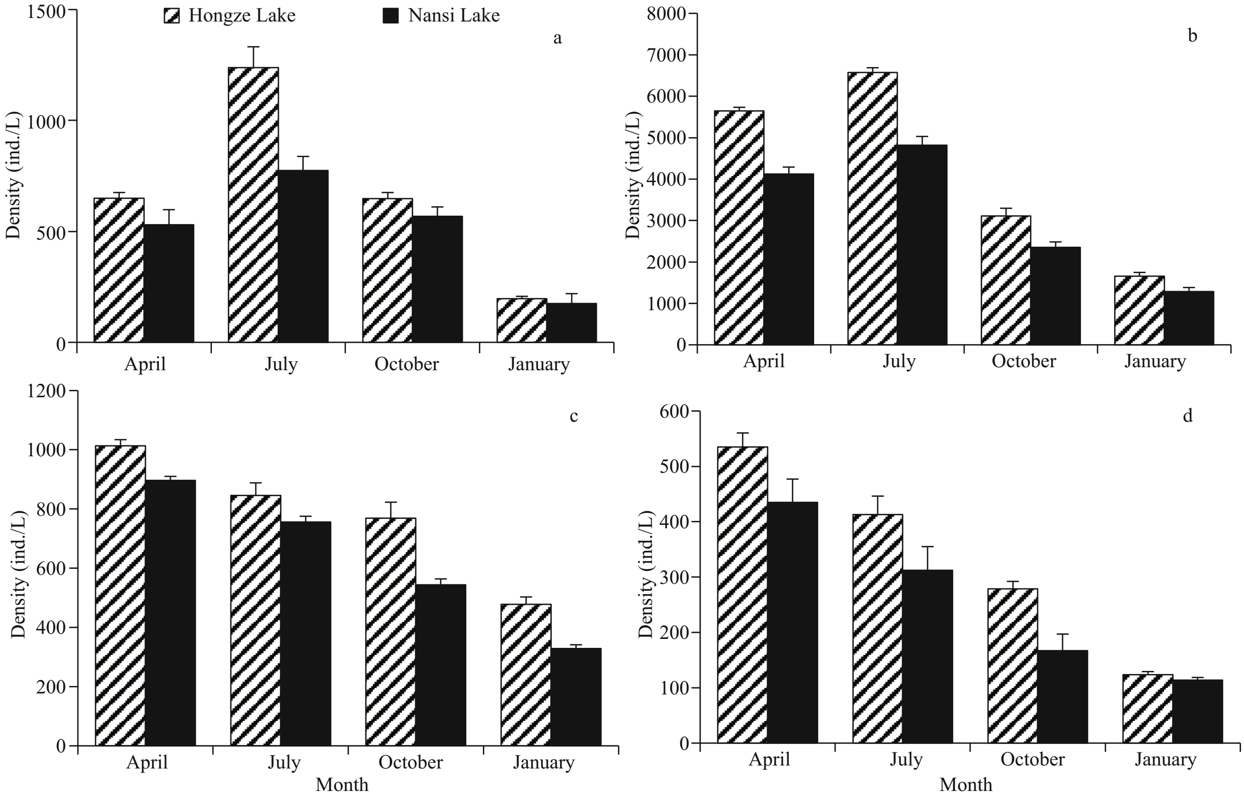

Fig.2 Comparison of temporal changes of zooplankton density in Nansi Lake and Hongze Lake

a. protozoa; b. rotifer; c. cladocera; d. copepoda. Data are represented with mean±standard deviation (SD; *n*=2).

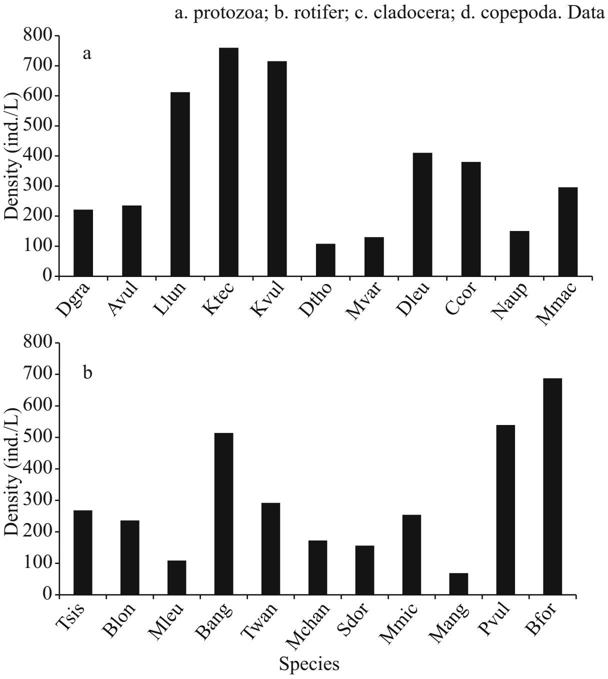

Fig.3 Average density of dominant zooplankton species in Nansi Lake (a) and Hongze Lake (b)

Refer Table 1 for species code.

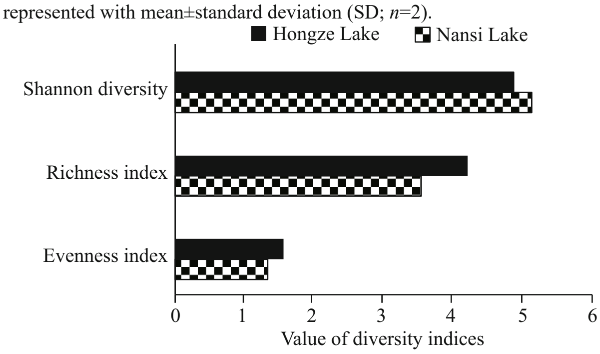

Fig.4 Zooplankton diversity indices (the richness index, evenness index, and Shannon index) in Nansi Lake and Hongze Lake

frequency of occurrence of more than 50%. In contrast with diversity patterns of protozoa and Rotifera, crustacean zooplankton in the two lakes had low species diversity. In Nansi Lake and Hongze Lake, rotifers and protozoans contributed more to the total zooplankton density (P<0.05), (Fig.2).

3.2 Dominant species and diversity indices

In Nansi Lake, the most dominant species were *Keratella tecta*, *Keratella valga*, and *Lecane luna* for rotifera (Fig.3a). In Hongze lake, the most dominant species were limnetic, e.g., *Brachionus angularis*, *Brachionus forficula*, and *Polyarthra vulgaris* for rotifer (Fig.3b). Shannon-Wiener diversity index (5.13) was higher in Nansi Lake than in Hongze Lake (4.87), while the species richness index was higher (4.21) in Hongze Lake than in Nansi Lake (3.54) (Fig.4).

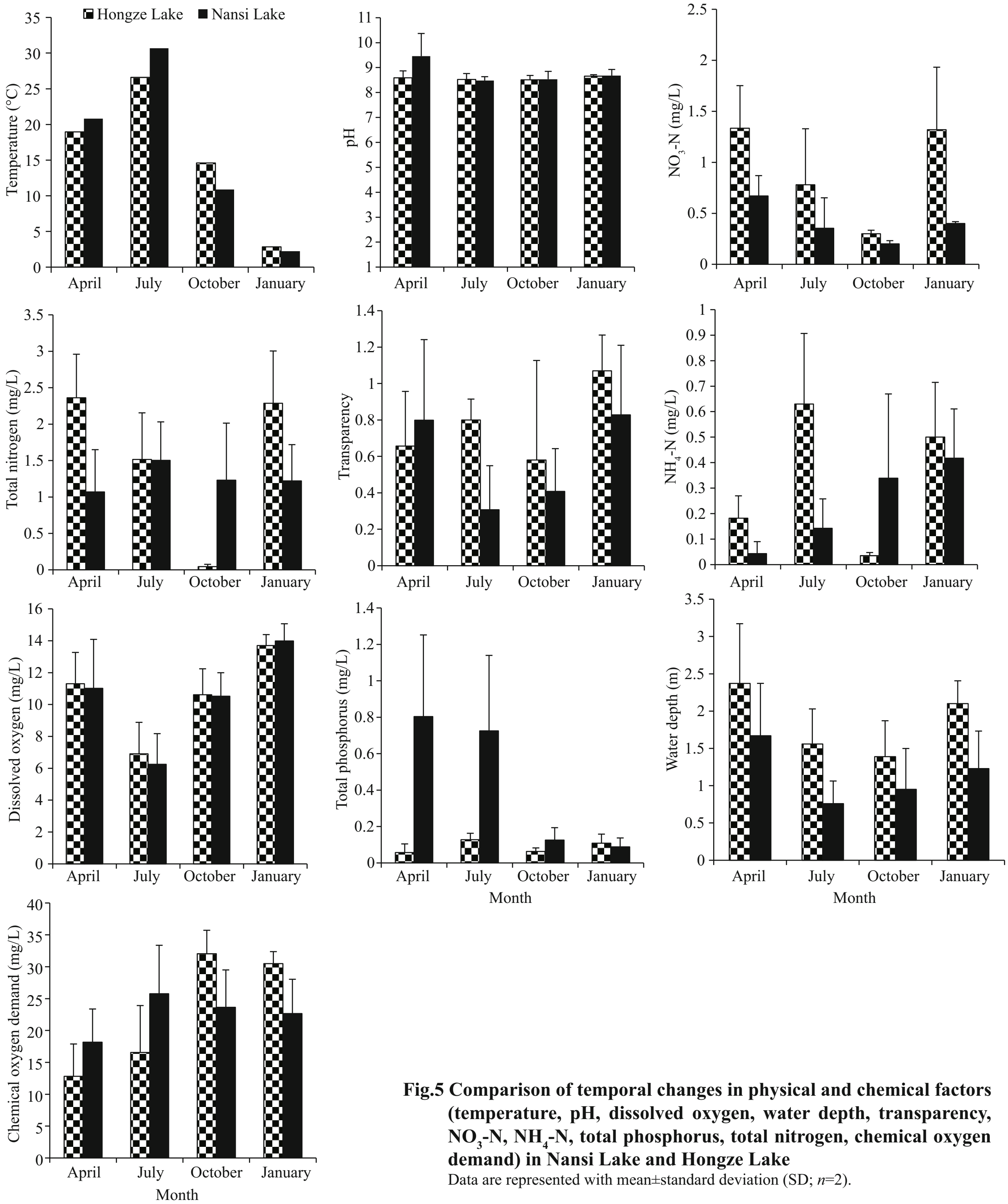

Fig.5 Comparison of temporal changes in physical and chemical factors (temperature, pH, dissolved oxygen, water depth, transparency, NO_3-N, NH_4-N, total phosphorus, total nitrogen, chemical oxygen demand) in Nansi Lake and Hongze Lake

Data are represented with mean±standard deviation (SD; *n*=2).

3.3 Factors related to seasonal dynamics of zooplankton assemblages

Figure 5 shows seasonal variation of physico-chemical factors between Nansi Lake and Hongze Lake. In Nansi Lake, CCA identified that the environmental variables pH, total phosphorus and temperature contributed significantly to zooplankton assemblages ($P<0.05$) (Fig.6a, Table 2). CCA axis 1 (λ: 0.08) and CCA axis 2 (λ: 0.05) explained 63.3% and 36.7% of the total variance of the species environmental relationship respectively. The correlation efficiencies of the first two axes were 0.72 and 0.57, respectively. The first axis was highly

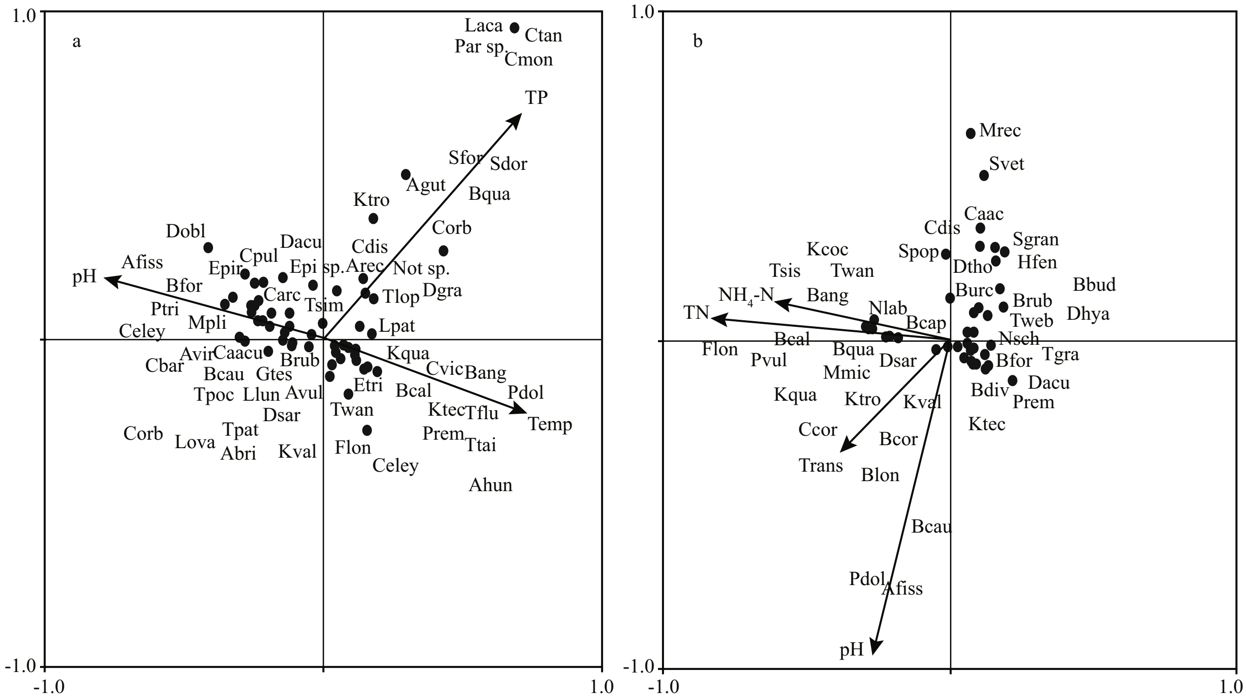

Fig.6 Canonical correspondence analysis biplots showing the relationships between zooplankton species and environmental variables in Nansi Lake (a) and Hongze Lake (b)

Species included on the diagram was set at 5% species fit range for both lakes.

correlated with temperature and pH; the second axis was highly correlated to total phosphorus. The dominant species such as *Ceriodaphnia cornuta*, and *K. tecta* were associated with higher temperature values, species such as *B. forficula* were associated with high pH, and species such as *Arcella vulgaris*, *L. luna*, and *K. valga* were associated with low pH. In addition, the dominant species *Moina macrocopa* and *Diaphanosoma leuchtenbergianum* were correlated with total phosphorus.

For Hongze Lake, CCA identified the environmental variables NH_4-N, total nitrogen, transparency and pH as contributing significantly to zooplankton assemblages (P<0.05). CCA axis 1 (λ: 0.08) and CCA axis 2 (λ: 0.06) explained 58.2% and 41.8% of the total variance of the species environmental relationship respectively. The correlation efficiencies of the first two axes were 0.79 and 0.68, respectively. The first axis was highly correlated with NH_4-N, total nitrogen and transparency; the second axis was highly correlated with pH. The dominant species such as *B. angularis*, *P. vulgaris*, *Tintinnopsis sinensis*, *Tintinnopsis wangi*, and *Moina micrura* were associated with higher levels of NH_4-N and total nitrogen, whereas species such *K. tropica*, *C. cornuta*, *Bosmina coregoni*, and *B. longirostris* were associated with high transparency. In addition, the species *Anuraeopsis fissa* and *Polyarthra dolichoptera* were more strongly correlated with pH. However, in the ordination plot of environmental variables and community structure, few species were scattered near the origin, which represents average values for environmental variables for these species (Fig.6b; Table 2).

Table 2 Summary statistics for the first two axes of CCA performed between environmental variables and zooplankton species for the Nansi Lake and Hongze Lake

Lake	Axes	λ	A	B	C	D
Nansi	1	0.08	0.72	7.4	63.3	
	2	0.05	0.57	11.6	36.7	0.18
Hongze	1	0.08	0.79	5.3	58.2	
	2	0.06	0.68	9.1	41.8	0.19

λ: eigenvalues; A: species-environment correlations; B: cumulative percentage variance of species data; C: cumulative percentage variance of species environment relation; D: sum of all canonical eigenvalues.

4 DISCUSSION

Water levels in Nansi and Hongze Lakes were strongly influenced by the operation of the East Route of the South-to-North Water Transfer project. The ESNT likely led to lower transparency, increased nutrients and more fluctuations in water level, which could have significantly altered abiotic and biotic factors in the lakes. More than 50% of zooplankton species (either limnetic or littoral) appeared within the category of sporadic in lakes. Water level fluctuations due to water exchange affected the zooplankton assemblage by the appearance or disappearance of certain taxa. Opportunistic peaks and declines of certain zooplankton taxa were likely correlated with the changing lake habitats and food resources affected by water transfer. Therefore, water level fluctuations may influence extreme habitat alterations in these ecosystems (Balkić et al., 2018).

The comparative analysis of zooplankton community assemblages showed that a large degree of variation occurred concerning species composition, habitat preference, and density of zooplankton in Nansi Lake and Hongze Lake. Protozoans and Rotifera species diversity and abundance were a characteristic feature of the two lakes. The current study found 133 zooplankton species in Nansi Lake and 122 in Hongze Lake. When compared to previous studies, there were 249 species reported in the early 1980's in Nansi Lake, and then species richness drastically declined to 28 species in 2002 and 48 species in 2008 (Gong et al., 2010). The zooplankton richness was gradually recovered with 163 species in 2012 (Chen et al., 2016). Zooplankton species richness was again reported to have decreased during surveys from 2011–2015. A total of 58 species of zooplankton were observed in 2011, 62 in 2012, 67 in 2013–2014 and 65 in 2015 (Meng et al., 2017). The data of the present study have shown a substantial decrease in the abundance of zooplankton communities in Nansi Lake. The contribution of pelagic species decreased, and the proportion of littoral species of zooplanktons increased. The decreased diversity of pelagic species is probably a consequence of the leaching action of flowing water (Havel et al., 2000). A key factor influencing the occurrence of particular species in the littoral zone and, in consequence, the diversity of communities colonizing this zone, is the availability of diverse habitats (Balayla and Moss, 2003). Yang (2003) reported 91 species of zooplankton and an average abundance of 1 458 ind./L in Hongze Lake. Du et al. (2014) reported 34 rotifer species comprised with the dominant species *Keratella cochlearis*, *Asplanchna priodonta*, *Polyarthra dolichoptera*, *Brachionus calyciflorus*, and *Keratella valga* were collected in 2011. Among the total zooplankton species, most of the species were limnetic, and remaining taxa were either littoral or common in both habitats. Therefore, the qualitative structure of zooplankton of Hongze Lake was significantly comprised of limnetic species. However, an increase in the percentage of pelagic rotifers in the total density of zooplankton was also observed in Hongze Lake. The greatest increase was noted in the limnetic species, *B. angularis*, *B. forficula*, *P. vulgaris*, and *K. cochlearis*, although these taxa are ubiquitous in many waters and are most common in flowing ecosystem (Ejsmont-Karabin and Kruk, 1998; Kobayashi et al., 1998; Czerniawski and Domagała, 2010; Czerniawski and Pilecka-Rapacz, 2011). This phenomenon is connected with the short generation cycle of this group and the possibility to satisfy the threshold food concentration in scanty river waters (Baranyi et al., 2002). However, the largest changes in habitat preference of the species, especially limnetic ones clearly indicate the effect of the water transfer on the lakes. Based on the morphology and habitat types of Hongze Lake, it may be subjected to more ecological effects of water transfer. Following ESNT, the downstream regions of Hongze Lake could be experiencing hydrological instability from high variability of water current in the lotic water transfer system. A second factor may be affecting the Rotifera richness in the pelagic zone, as a result of washout of aquatic macrophytes by the currents. Another factor could be that the ESNT connection between Hongze Lake and Changjiang River and nearby lakes through canals will allow recruitment of pelagic species to the lakes. Such plankton exchange could especially influence patterns of flowing water species such as *K. cochlearis*.

Protozoans and rotifers were the most abundant zooplankton group in both lakes. More abundant populations of rotifer genera (*Lecane*, *Keratella* in Nansi Lake, *Brachionus* and *Polyarthra* in Hongze Lake) and protozoans (*Difflugia* and *Arcella* in Nansi Lake and *Tintinnopsis* in Hongze Lake) were found during summer coinciding with lower water levels. Succession of the planktonic species, especially rotifers and protozoans, are determined by the environment with plentiful food resources of algae and detritus (Auer et al., 2004; Wallace et al., 2006; Sodré-Neto and Araújo, 2008). The dominant planktonic groups had opportunistic life history traits, with short life cycles and resilience to variation in the hydrologic regime. When compared to protozoans and rotifers, copepods and cladocerans tended to have low diversity and density in the studied lakes. The more abundant cladoceran genera (*Diaphanosoma*, *Moina*, and *Ceriodaphnia* in Nansi Lake; *Moina* in Hongze Lake) were developed during the summer-autumn seasons at lower water levels. The large-bodied cladoceran *Daphnia* was also found absent in Nansi Lake. In lower water levels, nutrient concentrations may be high, and a strong prevalence of few species preferring higher biogen concentrations, combined with a decrease in chemical components, may have caused an eradication of more sensitive taxa (Sampaio and López, 2000). In lakes, fish predation on large crustaceans may lead to a shift towards smaller crustaceans and rotifers (Brooks and Dodson, 1965; Korponai et al., 1997). The dominant copepod genera (*Diacyclops* and *Microcyclops* in Nansi Lake; *Mesocyclops* and *Sinocalanus* in Hongze Lake) occurred during spring and summer seasons, respectively. Higher temperatures during warmer months accelerate the growth of phytoplankton productivity that exceeded the growth of certain species. Dominance of cyclops and sinocalanus might be influenced by the availability of food resources in particular seasons (Simões et al., 2013).

Zooplankton community structure and their seasonal dynamics in the lacustrine environment are driven by a variety of factors such as lake morphology, hydrological properties, climate conditions, and anthropogenic activities (Fryer, 1985). CCA analysis identified differing significant environment variables that explained maximum variability in zooplankton community structure in the two lakes. These results confirm numerous former studies and show that abiotic factors such as pH, nutrients (N and P), temperature, and turbidity concentrations are major driving forces that influence directly or indirectly the zooplankton assemblage (Bērzinš and Pejler, 1989; Pinel-Alloul et al., 1990; Dodson, 1992; Jeppesen et al., 1994; Derry et al., 2003). Temperature significantly explained zooplankton variation in Nansi Lake, with *P. dolichoptera*, *Filinia terminalis*, and *K. tecta* being associated with increasing temperature. Rotifers generally have an extensive tolerance to temperature, but in separate lakes, they are restricted with temperature differences (Bērzinš and Pejler 1989). In the present study, *F. terminalis* and *P. dolichoptera* were associated with high temperature, but these species usually are considered to be "winter species", preferring temperatures below 10 °C (Carlin, 1943; Galkovskaya et al., 2006). However, other former studies also observed the occurrence of these species at higher temperatures in small lakes and ponds (Bērzinš and Pejler, 1989). Higher temperatures can theoretically promote comparable benefits for small zooplankton species exhibiting strategy life history traits and growth patterns (May, 1983; Hessen et al., 1995; Bunioto and Arcifa, 2007). *B. calyciflorus* was found to favor low temperatures in this study, but not in other studies (Bērzinš and Pejler, 1989; Xiang et al., 2010; Ji et al., 2013), *K. quadrata* preferred low temperatures in our study as well as in other studies (May, 1983; Galkovskaya et al., 2006; Wen et al., 2011). These differing results could be explained in that temperature alone does not generally determine when and where a species occurs, as there is a combination of other biotic and abiotic factors that contribute along with temperature (Bērzinš and Pejler, 1989). In addition, *Daphnia hyalina*, and *Cyclops vicinus* peaked at low temperatures, while other species such as *Thermocyclops taihokuensis* and *Ceriodaphnia cornuta* peaked at relatively high temperatures. Early spring species *Cyclops vicinus* and *Daphnia hyalina* normally prefer temperatures below 25 °C, attaining a higher growth rate and development at this temperature (Chiang and Du, 1979; Maier, 1989). Seasonal changes in temperature likely attributed to the changes in species composition and density of species (Tackx et al., 2004). Hongze Lake dominant species *C. cornuta*, *Bosmina coregoni* and *Bosmina longirostris* and *Keratella tropica* were associated with lower transparency, which may provide better shelter for this zooplankton than in clear water (Dodson, 1990; Wissel and Ramacharan, 2003). In Hongze Lake, dominant species *T. wangi*, *T. sinensis*, *K. cochlearis*, *B. angularis*, and *P. vulgaris* were correlated to NH_4-N and total nitrogen, while in Nansi Lake *Difflugia gramen*, *Centropyxis orbicularis*, *B. calyciflorus*, and *Keratella tropica* were correlated to total phosphorus. Nutrients including NH_4-N, NO_3-N, total nitrogen, and total phosphorus can indirectly affect protozoans and rotifers via trophic cascades. Rotifers are unselective micro filtrates, feeding on particles in the range of 0.5 to 20 μm with a differential ability to feed on bacteria, protozoans, heterotrophic flagellates, and numerous algae, including pico- and nano-phytoplankton (Arndt, 1993). In Nansi Lake, dominant species such as *Moina macrocopa*, *Diaphanosoma leuchtenbergianum*, and the copepods *Sinocalanus doerri* and *Schmackeria forbesi* were associated with total phosphorus concentration. Total phosphorus influences the growth of crustaceans by reflecting edible food materials for them. Cladocerans share available food with rotifers, and the majority of cladocerans are filter feeders (Gilbert, 1966; Yan, 1986; Pinto-Coelho et al., 2005).

5 CONCLUSION

Our study demonstrated that the differences in the zooplankton assemblages are likely due to water level fluctuations caused by water transfer, and some environmental conditions are likely responsible for biotic changes and ecosystem functioning in the studied freshwater lakes. Water exchange significantly affected the lake morphology due to water level fluctuations being responsible for the habitat preference of the zooplankton community structure in studied lakes. The stated decrease in taxonomic diversity of crustacean plankton fauna and the prevalence of specific zooplankton taxa, likely correlated with the change of lake habitats and food resources in the studied lakes. Further studies are needed to predict the influence of the ESNT on the hydrological and biotic community (phytoplankton, zooplankton, and fishes) in Nansi and Hongze Lakes.

6 DATA AVAILABILITY STATEMENT

All data generated or analyses during this study are included in this published article.

7 ACKNOWLEDGMENT

We thank the Institute of Hydrobiology for hosting this research work. We would also like to thank SONG Yiqing for supporting statistical analysis on the manuscript.

8 DISCLOSURE STATEMENT

There are no conflicts of interest arisen by authors.

References

APHA. 1992. Standard Methods for Examination of Water and Sewage and Wastewater. 18th edn. American Public Health Association, Washington, DC.

Arndt H. 1993. Rotifers as predators on components of the microbial web (bacteria, heterotrophic flagellates, ciliates)—a review. *Hydrobiologia*, **255**(1): 231-246.

Auer B, Elzer U, Arndt H. 2004. Comparison of pelagic food webs in lakes along a trophic gradient and with seasonal aspects: influence of resource and predation. *Journal of Plankton Research*, **26**(6): 697-709, https://doi.org/10.1093/plankt/fbh058.

Balayla D J, Moss B. 2003. Spatial patterns and population dynamics of plant-associated Microcrustacea (Cladocera) in an English shallow lake (Little Mere, Cheshire). *Aquatic Ecology*, **37**(4): 417-435, https://doi.org/10.1023/B:AECO.0000007045.85315.dc.

Balkić A G, Ternjej I, Špoljar M. 2018. Hydrology driven changes in the rotifer trophic structure and implications for food web interactions. *Ecohydrology*, **11**(1): e1917, https://doi.org/10.1002/eco.1917.

Baranyi C, Hein T, Holarek C, Keckeis S, Schiemer F. 2002. Zooplankton biomass and community structure in a Danube River floodplain system: effects of hydrology. *Freshwater Biology*, **47**(3): 473-482, https://doi.org/10.1046/j.1365-2427.2002.00822.x.

Bērzinš B, Pejler B. 1989. Rotifer occurrence in relation to temperature. *Hydrobiologia*, **175**(3): 223-231, https://doi.org/10.1007/bf00006092.

Betsill R K, Van Den Avyle M J. 1994. Spatial heterogeneity of reservoir zooplankton: a matter of timing? *Hydrobiologia*, **277**(1): 63-70, https://doi.org/10.1007/bf00023986.

Brooks J L, Dodson S I. 1965. Predation, body size, and composition of plankton. *Science*, **150**(3692): 28-35, https://doi.org/10.1126/science.150.3692.28.

Bunioto T C, Arcifa M S. 2007. Effects of food limitation and temperature on cladocerans from a tropical Brazilian lake. *Aquatic Ecology*, **41**(4): 569-578, https://doi.org/10.1007/s10452-007-9114-2.

Carlin B. 1943. Die planktonrotatorien des motalaström-zur taxonomie und Ökologie der planktonrotatorien. *Lunds Universitets Limnologiska Institution*, *und kologie der planktonrotatorien*, **5**: 256.

Carpenter S R, Kitchell J F, Hodgson J R. 1985. Cascading trophic interactions and lake productivity: fish predation and herbivory can regulate lake ecosystems. *BioScience*, **35**(10): 634-639, https://doi.org/10.2307/1309989.

Chen L, Gao D Q, Shu F Y, Zhang H H. 2016. Zooplankton community structure and its relationship with environmental factors in Nasi Lake. *Chinese Journal of Zoology*, **51**(1): 113-120. (in Chinese with English abstract)

Chiang S C, Du N S. 1979. Fauna Sinica, Crustacea, Freshwater Cladocera. Science Press, Beijing. p.274-289. (in Chinese)

Chu E G. 2001. Analysis on hydrological characteristic for Hongze Lake. *Hydrology*, **21**: 56-59.

Clarke K R, Warwick R M. 2001. Change in Marine Communities: an Approach to Statistical Analysis and Interpretation. 2nd edn. PRIMER-E, Plymouth. 172p.

Czerniawski R, Domagała J. 2010. Similarities in zooplankton community between River Drawa and its two tributaries (Polish part of River Odra). *Hydrobiologia*, **638**(1): 137-149, https://doi.org/10.1007/s10750-009-0036-y.

Czerniawski R, Pilecka-Rapacz M. 2011. Summer zooplankton in small rivers in relation to selected conditions. *Central European Journal of Biology*, **6**(4): 659-674.

Derry A M, Prepas E E, Hebert P D N. 2003. A comparison of zooplankton communities in saline lakewater with variable anion composition. *Hydrobiologia*, **505**(1): 199-215,https://doi.org/10.1023/b:hydr.0000007414.12566.19.

Dodson S I, Lillie R A, Will-Wolf S. 2005. Land use, water chemistry, aquatic vegetation, and zooplankton community structure of shallow lakes. *Ecological Applications*, **15**(4):

1 191-1 198, https://doi.org/10.1890/04-1494.

Dodson S. 1990. Predicting diel vertical migration of zooplankton. *Limnology and Oceanography*, **35**(5): 1 195-1 200, https://doi.org/10.4319/lo.1990.35.5.1195.

Dodson S. 1991. Species richness of crustacean zooplankton in European lakes of different sizes. *SIL Proceedings*, *1922-2010*, **24**(2): 1 223-1 229.

Dodson S. 1992. Predicting crustacean zooplankton species richness. *Limnology and Oceanography*, **37**(4): 848-856, https://doi.org/10.4319/lo.1992.37.4.0848.

Du X, Wang Q D, Zhang C W, Li W, Feng W S, Zhang T L, Liu J S, Li Z J. 2014. Community structure of rotifers in relation to environmental factors in Lake Hongze. *Journal of Lake Sciences*, **26**(2): 269-276. (in Chinese with English abstract)

Ejsmont-Karabin J, Kruk M. 1998. Effects of contrasting land use on free-swimming rotifer communities of streams in Masurian Lake District, Poland. *Hydrobiologia*, **387**: 241-249, https://doi.org/10.1023/a:1017081407452.

Fornarelli R, Antenucci J P. 2011. The impact of transfers on water quality and the disturbance regime in a reservoir. *Water Research*, **45**(18): 5 873-5 885.

Fryer G. 1985. Crustacean diversity in relation to the size of water bodies: some facts and problems. *Freshwater Biology*, **15**(3): 347-361, https://doi.org/10.1111/j.1365-2427.1985.tb00206.x.

Galkovskaya G A, Molotkov D V, Mityanina I F. 2006. Species diversity and spatial structure of pelagic zooplankton in a lake of glacial origin during summer stratification. *Hydrobiologia*, **568**(1): 31-40, https://doi.org/10.1007/s10750-006-0337-3.

Gasith A, Gafny S. 1990. Effects of water level fluctuation on the structure and function of the littoral zone. *In*: Tilzer M M, Serruya C eds. Large Lakes: Ecological Structure and Function. Springer, Berlin. p.156-173.

Gilbert J J. 1966. Rotifer ecology and embryological induction. *Science*, **151**(3715): 1 234-1 237.

Gong J X, Duan D X, Wang Z Z, Du X H, Zhang J L, Liu H C, Chen J P, Sun D. 2010. Research and analysis on the plankton of Nansi Lake. *Journal of Yangtze University* (*Natural Science Edition*), **7**(1): 39-42, 52. (in Chinese with English abstract)

Gruberts D, Druvietis I, Parele E, Paidere J, Poppels A, Prieditis J, Skute A. 2007. Impact of hydrology on aquatic communities of floodplain lakes along the Daugava River (Latvia). *Hydrobiologia*, **584**: 223-237.

Havel J E, Eisenbacher E M, Black A A. 2000. Diversity of crustacean zooplankton in riparian wetlands: colonization and egg banks. *Aquatic Ecology*, **34**(1): 63-76, https://doi.org/10.1023/a:1009918703131.

Hessen D O, Andersen T, Faafeng B A. 1995. Replacement of herbivore zooplankton species along gradients of ecosystem productivity and fish predation pressure. *Canadian Journal of Fisheries and Aquatic Sciences*, **52**(4): 733-742, https://doi.org/10.1139/f95-073.

Hu L M, Hu W P, Zhai S H, Wu H Y. 2010. Effects on water quality following water transfer in Lake Taihu, China. *Ecological Engineering*, **36**(4): 471-481, https://doi.org/10.1016/j.ecoleng.2009.11.016.

Huang X F, Chen W M, Cai Q M. 1999. Survey, Observation and Analysis of Lake Ecology. Standards Press of China, Beijing. 247p. (in Chinese)

Jeppesen E, Søndergaard M, Kanstrup E, Petersen B, Eriksen R B, Hammershøj M, Mortensen E, Jensen J P, Have A. 1994. Does the impact of nutrients on the biological structure and function of brackish and freshwater lakes differ? *Hydrobiologia*, **275**(1): 15-30, https://doi.org/10.1007/bf00026696.

Ji G H, Wang X Y, Wang L Q. 2013. Planktonic Rotifers in a subtropical shallow Lake: succession, relationship to environmental factors, and use as bioindicators. *The Scientific World Journal*, **2013**: 702942.

Johannsson O E, Mills E L, O'Gorman R. 1991. Changes in the nearshore and offshore zooplankton communities in Lake Ontario: 1981-88. *Canadian Journal of Fisheries and Aquatic Sciences*, **48**(8): 1 546-1 557, https://doi.org/10.1139/f91-183.

Karatayev A Y, Burlakova L E, Dodson S I. 2005. Community analysis of Belarusian lakes: relationship of species diversity to morphology, hydrology and land use. *Journal of Plankton Research*, **27**(10): 1 045-1 053, https://doi.org/10.1093/plankt/fbi072.

Kobayashi T, Shiel R J, Gibbs P, Dixon P I. 1998. Freshwater zooplankton in the Hawkesbury-Nepean River: comparison of community structure with other rivers. *Hydrobiologia*, **377**(1-3): 133-145.

Korponai J, Mátyás K, Paulovits G, Tátrai I, Kovács N. 1997. The effect of different fish communities on the cladoceran plankton assemblages of the Kis-Balaton Reservoir, Hungary. *Hydrobiologia*, **360**(1): 211-221, https://doi.org/10.1023/a:1003125621301.

Koste V W, Tobias W. 1987. Zur Radertiefauna des Sankarani-stausees im Einzugsgebiet des Niger, Republik Mali Westafrika (Aschelminthes: Rotatoria). *Archieve fur Hydrobiologie*, **108**: 499-515.

Koste W, Shiel R. 1991. Rotifera from Australian inland waters. VII. Notommatidae (Rotifera: Monogononta). *Transactions of the Royal Society of South Australia*, **115**(3): 111-159.

Kufel L, Leśniczuk S. 2014. Hydrological connectivity as most probable key driver of chlorophyll and nutrients in oxbow lakes of the Bug River (Poland). *Limnologica*, **46**: 94-98.

Leira M, Cantonati M. 2008. Effects of water-level fluctuations on lakes: an annotated bibliography. *Hydrobiologia*, **613**(1): 171-184, https://doi.org/10.1007/s10750-008-9465-2.

Lepš J, Šmilauer P. 2003. Multivariate Analysis of Ecological Data Using CANOCO. Cambridge University Press, New York. 269p.

Lin M L, Lek S, Ren P, Li S H, Li W, Du X, Guo C B, Gozlan R E, Li Z J. 2017. Predicting impacts of south-to-north water transfer project on fish assemblages in Hongze Lake, China. *Journal of Applied Ichthyology*, **33**(3): 395-402, https://doi.org/10.1111/jai.13251.

Liu W L, Deng W, Wang G X, Li A M, Zhou J. 2009. Aquatic macrophyte status and variation characteristics in the past 50 years in Hongzehu Lake. *Journal of Hydroecology*, **2**(6): 1-8. (in Chinese with English abstract)

Maier G. 1989. The seasonal cycle of *Thermocyclops crassus* (Fischer, 1853) (Copepoda: cyclopoida) in a shallow, eutrophic lake. *Hydrobiologia*, **178**(1): 43-58, https://doi.org/10.1007/bf00006112.

Matsumura-Tundisi T, Tundisi J G. 2005. Plankton richness in a eutrophic reservoir (Barra Bonita Reservoir, SP, Brazil). *Hydrobiologia*, **542**(1): 367-378, https://doi.org/10.1007/s10750-004-9461-0.

Matthews W, Schorrs M, Meador M. 1996. Effects of experimentally enhanced flows on fishes of a small Texas (U.S.A.) stream: assessing the impact of interbasin transfer. *Freshwater Biology*, **35**(2): 349-362, https://doi.org/10.1046/j.1365-2427.1996.00494.x.

May L. 1983. Rotifer occurrence in relation to water temperature in Loch Leven, Scotland. *Hydrobiologia*, **104**(1): 311-315, https://doi.org/10.1007/bf00045983.

McQueen D J, Post J R, Mills E L. 1986. Trophic relationships in freshwater pelagic ecosystems. *Canadian Journal of Fisheries and Aquatic Sciences*, **43**(8): 1 571-1 581, https://doi.org/10.1139/f86-195.

Meng J, Yu Z D, Miao M S, Kong Q, Zhang Y R, Liu J. 2017. Differentiated responses of plankton and zoobenthos to water quality based on annual and seasonal analysis in a freshwater lake. *Polish Journal of Environmental Studies*, **26**(2): 755-764.

Northcote T G. 1988. Fish in the structure and function of freshwater ecosystems: a “Top-down” view. *Canadian Journal of Fisheries and Aquatic Sciences*, **45**(2): 361-379, https://doi.org/10.1139/f88-044.

Padial A A, Thomaz S M, Agostinho A A. 2009. Effects of structural heterogeneity provided by the floating macrophyte *Eichhornia azurea* on the predation efficiency and habitat use of the small Neotropical fish *Moenkhausia sanctaefilomenae*. *Hydrobiologia*, **624**(1): 161-170, https://doi.org/10.1007/s10750-008-9690-8.

Padisák J, Barbosa F A R, Borbély G, Borics G, Chorus I, Espíndola E, Heinze R, Rocha O, Törökné A K, Vasas G. 2000. Phytoplankton composition, biodiversity and a pilot survey of toxic cyanoprokaryotes in a large cascading reservoir system (Tietê Basin, Brazil). *SIL Proceedings, 1922-2010*, **27**(5): 2 734-2 742.

Patalas K. 1971. Crustacean plankton communities in forty-five lakes in the Experimental Lakes Area, northwestern Ontario. *Journal of the Fisheries Research Board of Canada*, **28**(2): 231-244.

Pinel-Alloul B, Méthot G, Verreault G, Vigneault Y. 1990. Zooplankton species associations in Quebec Lakes: variation with abiotic factors, including natural and anthropogenic acidification. *Canadian Journal of Fisheries and Aquatic Sciences*, **47**(1): 110-121, https://doi.org/10.1139/f90-011.

Pinto-Coelho R, Pinel-Alloul B, Méthot G, Havens K E. 2005. Crustacean zooplankton in lakes and reservoirs of temperate and tropical regions: variation with trophic status. *Canadian Journal of Fisheries and Aquatic Sciences*, **62**(2): 348-361, https://doi.org/10.1139/f04-178.

Poff N L, Allan J D, Bain M B, Karr J R, Prestegaard K L, Richter B D, Sparks R E, Stromberg J C. 1997. The natural flow regime. *BioScience*, **47**(11): 769-784.

Pourriot R, Tifnouti A, Rougier C. 1994. Spatial-distribution of zooplankton in a natural reservoir-the Lalla-Takerkoust in Morocco. *Archiv für Hydrobiologie*, **130**(1): 113-127.

Sampaio E V, López C M. 2000. Zooplankton community composition and some limnological aspects of an oxbow lake of the Paraopeba River, São Francisco River Basin, Minas Gerais, Brazil. *Brazilian Archives of Biology and Technology*, **43**(3): 285-293.

Shen C J, Song D X. 1979. Calanoida, sars, 1903. *In*: Research Group of Carcinology, Institute of Zoology, Academia Sinica eds. Fauna Sinica, Crustacea, Freshwater Copepoda. Science Press, Beijing. p.53-163. (in Chinese)

Shen Y F. 1983. Protozoa of the Tibetan Plateau. *In*: Jiang X Z, Shen Y F, Gong X J eds. Aquatic Invertebrates of the Tibetan Plateau. Science Press, Beijing. p.48-100.

Shiel R J. 1995. A guide to Identification of Rotifers, Cladocerans and Copepods from Australian Inland Waters. CRCFE, Identification Guide No 3, Murray-Darling Freshwater Research Centre, Albury, NSW.

Simões N R, Colares M A M, Lansac-Tôha F A, Bonecker C C. 2013. Zooplankton species richness–productivity relationship: confronting monotonic positive and hump-shaped models from a local perspective. *Austral Ecology*, **38**(8): 952-958, https://doi.org/10.1111/aec.12038.

Smirnov N N, Timms B V. 1983. A revision of the Australian Cladocera (Crustacea). *Records of the Australian Museum*, *Supplement*, **1**: 1-132.

Snaddon C D, Davies B R. 1998. A preliminary assessment of the effects of a small South African inter-basin water transfer on discharge and invertebrate community structure. *Regulated Rivers*: *Research & Management*, **14**(5): 421-441.

Sodré-Neto L, Araújo M F F. 2008. Spatial and temporal fluctuations in bacterioplankton and correlated abiotic variables in eutrophic environments of the Brazilian semi-arid region. *Acta Limnologica Brasiliensia*, **20**(4): 325-331.

Stemberger R S, Larsen D P, Kincaid T M. 2001. Sensitivity of zooplankton for regional lake monitoring. *Canadian Journal of Fisheries and Aquatic Sciences*, **58**(11): 2 222-2 232, https://doi.org/10.1139/f01-164.

Tackx M L M, De Pauw N, Van Mieghem R, Azémar F, Hannouti A, Van Damme S, Fiers F, Daro N, Meire P. 2004. Zooplankton in the Schelde estuary, Belgium and the Netherlands. Spatial and temporal patterns. *Journal of Plankton Research*, **26**(2): 133-141, https://doi.org/10.1093/plankt/fbh016.

Tai A Y, Chen G X. 1979. Cyclopoida. *In*: Chen C J ed. Fauna Sinica, Crustacea, Freshwater Copepoda. Science Press, Peking, China. p.406-410.

Tai A Y, Song Y Z. 1979. Harpacticoida Sars, 1903. *In*: Shen C J ed. Fauna Sinica Crustacea, Freshwater Copepoda.

Science Press, Peking, China.

Ter Braak C J F, Smilauer P. 2002. CANOCO Reference Manual and CanoDraw for Windows User's Guide. Software for Canonical Community Ordination (version 4.5). Centre for Biometry Wageningen, Wageningen.

Ter Braak C J F, Verdonschot P F M. 1995. Canonical correspondence analysis and related multivariate methods in aquatic ecology. *Aquatic Sciences*, **57**(3): 255-289.

Vanni M J. 1988. Freshwater zooplankton community structure: introduction of large invertebrate predators and large herbivores to a small species community. *Canadian Journal of Fisheries and Aquatic Sciences*, **45**(10): 1 758-1 770.

Wallace R L, Snell T W, Ricci C, Nogrady T. 2006. Rotifera Part 1: Biology, Ecology and Systematics. 2nd edn. Guides to the Identification of the Microinvertebrates of the Continental Waters of the World. Kenobi Productions Gent/Backhuys, The Netherlands.

Wang Q, Chen J Y. 1999. Formation and evolution of Hongze Lake and the Huaihe River mouth along the lake. *Journal of Lake Sciences*, **11**(3): 237-244. (in Chinese with English abstract)

Wen X L, Xi Y L, Qian F P, Zhang G, Xiang X L. 2011. Comparative analysis of rotifer community structure in five subtropical shallow lakes in East China: role of physical and chemical conditions. *Hydrobiologia*, **661**: 303-316.

Winemiller K O, Fitzgerald D B, Bower L M, Pianka E R. 2015. Functional traits, convergent evolution, and periodic tables of niches. *Ecology Letters*, **18**(8): 737-751, https://doi.org/10.1111/ele.12462.

Wissel B, Ramacharan C W. 2003. Plasticity of vertical distribution of crustacean zooplankton in lakes with varying levels of water colour. *Journal of Plankton Research*, **25**(9): 1 047-1 057, https://doi.org/10.1093/plankt/25.9.1047.

Wolcox D A, Meeker J E. 1992. Implications for faunal habitat related to altered macrophyte structure in regulated lakes in Northern Minnesota. *Wetlands*, **12**(3): 192-203.

Xiang X L, Xi Y L, Zhang J Y, Ma Q, Wen X L. 2010. Effects of temperature on survival, reproduction, and morphotype in offspring of two *Brachionus calyciflorus* (Rotifera) Morphotypes. *Journal of Freshwater Ecology*, **25**(1): 9-18, https://doi.org/10.1080/02705060.2010.9664352.

Yan N D. 1986. Empirical prediction of crustacean zooplankton biomass in nutrient-poor Canadian Shield lakes. *Canadian Journal of Fisheries and Aquatic Sciences*, **43**(4): 788-796, https://doi.org/10.1139/f86-097.

Yang L F. 1993. Further discussion on the major conditions of the existence of Ostracoda—Taking Hongze Lake in China as example. *Science in China* (*Series B*), **36**(3): 358-365.

Yang S J. 2003. Protection and sustainable use of biodiversity of west lakeside zone of Hongze Lake. *Bulletin of Soil and Water Conservation*, **23**(5): 62-65, 69. (in Chinese with English abstract)

Zhai S J, Hu W P, Zhu Z C. 2010. Ecological impacts of water transfers on Lake Taihu from the Yangtze River, China. *Ecological Engineering*, **36**(4): 406-420, https://doi.org/10.1016/j.ecoleng.2009.11.007.

Zhang Q F. 2009. The south-to-north water transfer project of China: environmental implications and monitoring strategy. *Journal of the American Water Resources Association*, **45**(5): 1 238-1 247.