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Waterbird Composition and Changes With Wetland Park Construction at Lake Dianchi, Yunnan–Guizhou Plateau

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Establishing effectively protected and managed ecosystems with high biodiversity is the broad aim of the Aichi initiative. Assessing the biodiversity of a specific ecosystem is the first step in estimating its conservation value. Most lakes on the Yunnan–Guizhou Plateau are formed by mountain faulting and are surrounded by human settlements. Lake ecosystems are fragile and frequently disturbed by pollution, agricultural activities, and tourism. The current lakeside wetland parks are intended to abate pollution and promote tourism. However, the composition of the monthly and yearly waterbird population and the impacts of the parks on waterbirds are unclear. Using direct observation and spot map census methods, we conducted 104 field surveys across 4 consecutive years at Lake Dianchi to fill the gaps in current knowledge. The results showed that Dianchi could provide habitats for more than 60,000 individual birds of 105 species, including residents, summer visitors, migrants, and winter visitors. The current oxidation ponds in wetland parks, created for water purification and tourism, were not suitable for most shorebirds. Consequently, we suggest that plans for the construction of artificial wetlands or wetland parks in this region should consider the habitat requirements of different waterbirds in different seasons. Particular attention should be given to protecting the marshlands and mudflats that wading birds require. We also suggest that increased waterbird monitoring in different seasons across different years is needed around Lake Dianchi and other wetlands on the Yunnan–Guizhou Plateau for effective conservation.

Keywords: *waterbird composition; shorebirds; wetland park; Lake Dianchi; wetland management; Ramsar convention.*

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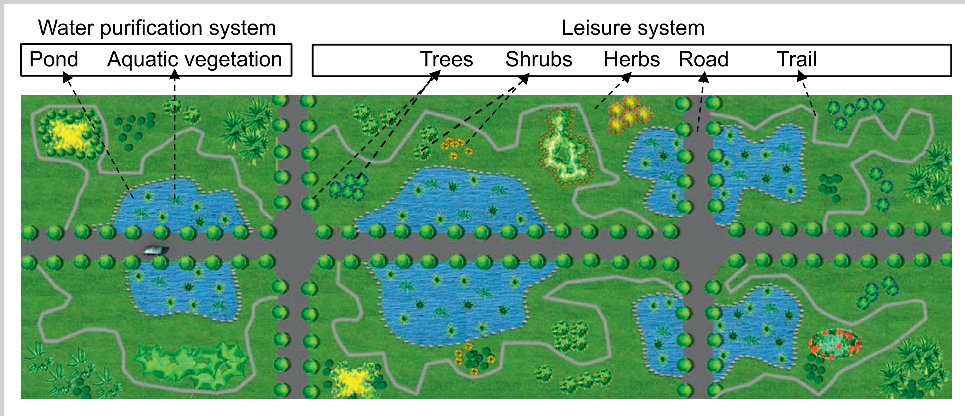
Introduction

Effectively maintained and managed ecosystems with high biodiversity are among the International Union for Conservation of Nature's Aichi targets, drawn up at the Convention on Biological Diversity (CBD 2010). In line with this, successful conservation of global waterbird populations depends on effective governance (Amano et al 2018). Assessing waterbird biodiversity is the first step in estimating its conservation value and planning suitable management strategies. In China, 84 out of 260 waterbird species are in decline (Wang et al 2018). This is a warning to humans to protect waterbirds and their habitats. Appropriate action is needed to investigate the environmental factors affecting waterbird distribution and identify more wetlands with high waterbird biodiversity. For the former, Ma et al (2010) reviewed the available literature and found that various factors influence waterbirds and that these are region specific. They suggested that management should be timed to meet the specific needs of breeding, stopover, and wintering periods based on species diversity and seasonal dynamics. For the latter, more research has focused on coastal wetlands than inland wetlands (reviewed by Wang et al 2016), and only 4 wetlands on the Yunnan–Guizhou (YGP) have been listed as Wetlands of International Importance (Ramsar sites): Dashanbao, Bitahai, Napahai, and Lashihai (Ramsar Convention Secretariat 2020). The YGP is 1 of 6 major lake zones in China and includes 13 lakes covering an area exceeding 10 km^2 (Ma et al 2011). However, no lakes among these 13 have been listed as Ramsar sites (Ramsar Convention Secretariat 2020), probably because their value for waterbird conservation is still unclear.

The YGP lies in Southwest China and mainly consists of mountainous land. Most of the lakes are tectonic in origin (caused by deformation of the Earth's crust) and are surrounded by human settlements (Wang and Dou 1998). Lake ecosystems are fragile and often overburdened by excessive discharge of domestic and industrial sewage, the overdevelopment of tourism, and other factors. Many lakes are heavily polluted; Lake Dianchi, for example, is one of the most severely polluted lakes in China (Jin 2003). Of the 13 lakes in the YGP, 9 are well-known tourist attractions in Yunnan Province (Liu et al 2012). To minimize pollution while providing suitable sites for tourism, many lakeside wetlands and other facilities have been built near lakes, such as Lake Dianchi, Lake Erhai, and Lake Yilong. Usually, these

FIGURE 1 A schematic model of lakeside wetland parks at Lake Dianchi. The design includes 2 subsystems, the central water purification system and the surrounding leisure system. The former consists of deep ponds and aquatic vegetation; the latter consists of xerophytic vegetation (trees, shrubs, herbs), roads, and trails.



artificial wetlands are oxidation ponds appended to leisure and entertainment functions, such as the pond-trail systems in the lakeside areas of Lake Dianchi and Lake Erhai. These ponds are surrounded by dry grasslands, trees, and shrubs (Figure 1).

Waterbird population composition changes seasonally and yearly as a result of climate change (Zhao et al 2019). The YGP wetlands have always been regarded as a wintering place for waterbirds. Thus, field surveys have mainly focused on the winter months (eg Quan et al 2002; Yang et al 2010; Cui et al 2014; Li and Yang 2015; Yang, Liu, He, and Li 2020; Yang, Liu, and Tian 2020). However, few studies have focused on the waterbird population composition across consecutive months and years. To assess the waterbird biodiversity of the YGP lakes for the Aichi targets and then provide scientific guidance for lake management, especially the construction of lakeside wetlands, it is essential to first ascertain the integrated waterbird composition. Related issues can then be considered. In this study, we used Lake Dianchi, the largest in YGP, as an example to (1) determine the species composition and habitat requirements of waterbirds at Lake Dianchi and (2) test the changes before and after the construction of lakeside wetland parks to propose targeted strategies for subsequent wetland restoration and wetland park construction.

Methods

Study area

Lake Dianchi (24°40′–25°02′N, 102°37′–102°48′E, hereafter Dianchi) is a permanent freshwater lake located in Kunming City, Yunnan Province, Southwest China. The water area is 281 km^2, and the manually controlled water level has been stable at 1887.5 masl over the past decade (Wu et al 2016; Kunming Dianchi Administration Bureau 2018). The average water depth is ~4.3 m (Jin et al 2006). The lake is a crescent-shaped water body extending from north to south. Dianchi is divided into 2 parts, Caohai in the north and Waihai in the south, by a traffic dam. The average length of the lake is ~40.4 km, the width is ~7.0 km, and the shoreline is ~150 km (Wang and Dou 1998). Dianchi is situated in the subtropical climatic zone, with an average annual temperature of 14.4°C, an average annual rainfall of 1036.1 mm, and an annual frost-free period of 227 days (Wang and Dou 1998).

Dianchi plays an important role in regulating the microclimate of the surrounding area. It contributes to the productivity of the local industry, agriculture, husbandry, and fisheries, and it provides recreation for humans (Jin et al 2006). However, Dianchi is a relatively closed lake with a slow water-exchange rate and low self-purification capacity. A lake reclamation campaign carried out from 1966 to 1970 caused severe damage to marsh wetlands in the Caohai area. In addition, large amounts of urban sewage and industrial wastewater have been discharged into the lake, exceeding its self-purification capacity and causing serious pollution. It has also been badly affected by cyanobacteria outbreaks in recent decades (Luo et al 2017). To control the pollution of Dianchi, the Chinese government listed it as a national sewage treatment project in the "Three Rivers and Three Lakes" (Liaohe, Huaihe, Haihe, Taihu, Chaohu, and Dianchi) scheme launched in 1995 (Liu and Qiu, 2007). As a result, some wetland parks have been constructed in the lakeside zone to purify the water and create leisure areas for citizens. Wetland parks are mainly in the form of oxidation ponds. They are small water bodies with such aquatic plants as *Phragmites australis*, *Typha orientalis*, *Acorus calamus*, *Eichhornia crassipes*, *Lemna minor*, and *Pistia stratiotes* (Wang et al 2016); outside the ponds, there are trails, trees, and lawns (Figure 1).

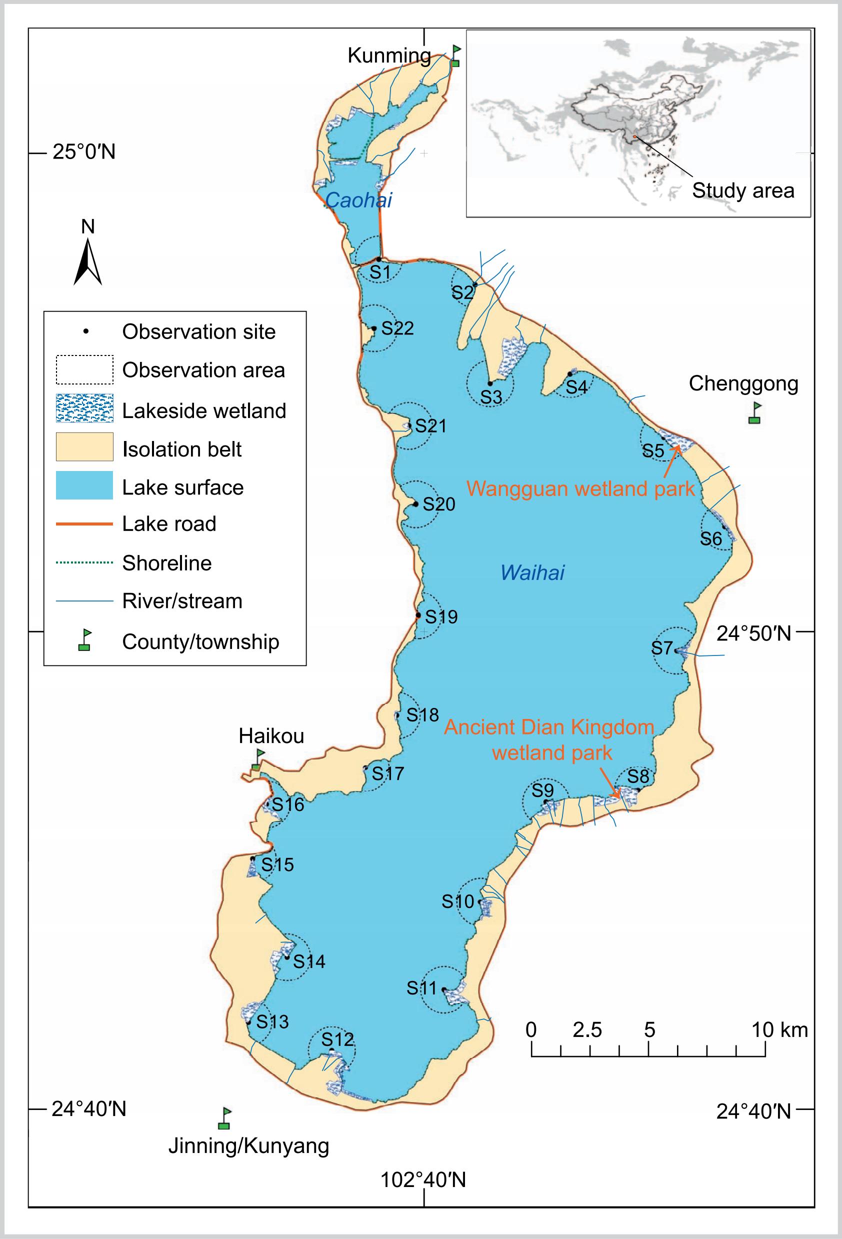
Selection of observation sites and sample plots

We surveyed all the lake surface and adjacent lakeside wetlands for Caohai. For Waihai, we used systematic sampling (every 5–7 km on the lakeshore) to set 22 fixed obstruction-free sites of approximately 1-km radius to survey the lake surface (Bibby et al 2000; Cao et al 2011). Adjacent sample plots were set on the outside of the lake shoreline and the inner side of the lake road at each observation site. Non-wetlands (village land, farmland, or gardens) with a width of at least 0.5 km were established as isolation belts to ensure that each plot was independent (Figure 2).

Selection of wetland parks

During our survey, artificial lakeside wetlands were under construction. Some wetland parks had already been built

FIGURE 2 Study area and observation sites. The upper inner graph shows the location of Lake Dianchi in the mountainous area of Asia, shaded in gray (Körner et al 2016).



before our survey and some started after. This meant that we could not obtain complete annual waterbird datasets for before and after construction for all of the wetland parks. Therefore, based on the completeness of our data collection, we selected 2 representative sample plots, S5 (Wangguan wetland park, impact 1) and S8 (Ancient Dian Kingdom wetland park, impact 2), for which there was annual waterbird composition data for both before and after construction (Figure 2). We integrated all the lakeside plots of Dianchi into 1 large plot to act as a control plot (control).

Waterbird counts

We carried out a total of 104 surveys. A preliminary survey for the selection of observation sites and plots was conducted during 1 week in February 2013. Three surveys each month (early, middle, and late) were conducted from March 2013 to May 2015. One survey was conducted in the middle of each month from June 2015 to May 2017. There were no surveys in April and November 2016 due to continued unfavorable weather (rainy, foggy, or windy). Each survey lasted for 3 consecutive days from dawn to dusk. In the case of unfavorable weather, the survey was advanced or postponed 1–2 days.

For the lake surface, we used a direct observation method to count the rare birds (fewer than 1000 individuals per species). For the more common species (more than 1000 individuals), such as *Chroicocephalus ridibundus* (black-headed gull), we used the component counts method to estimate the flock population (Bibby et al 2000; Cao et al 2011). For constructed wetlands and wetland parks, we divided each plot into several patches according to vegetation type and adopted a spot map census method to mark the species and their individuals on prepared maps (Bibby et al 2000). In

TABLE 1 Areas (ha) and their changing ratio (%) of different habitat types before and after the construction of 2 wetland parks at Lake Dianchi.

Habitat type	S5			S8			Total			
	Be	Af	CR (%)	Be	Af	CR (%)	Be	Af	CA	CR (%)
HE	4.35	3.52	–1.96	9.59	0.00	–23.93	13.94	3.52	–10.43	–12.58
HF	9.35	0.00	–21.84	2.30	15.57	33.13	11.65	15.57	3.92	4.73
LE	0.00	0.66	1.53	0.00	0.00	0.00	0.00	0.66	0.66	0.79
LF	13.70	0.00	–32.01	1.82	1.48	–0.87	15.53	1.48	–14.05	–16.96
Mix	9.99	0.00	–23.34	20.59	0.00	–51.41	30.58	0.00	–30.58	–36.91
Mudflat	4.09	0.00	–9.55	0.00	0.00	0.00	4.09	0.00	–4.09	–4.94
Pond	1.32	24.76	54.76	5.76	15.77	24.99	7.08	40.53	33.45	40.37
Total	42.81	28.93	–32.42	40.05	32.81	–18.09	82.86	61.74	–21.12	–25.49

Note: S5, Wangguan wetland park; S8, Ancient Dian Kingdom wetland park; Be, before wetland construction; Af, after wetland construction; CR, changing percentage area (%); CA, change area (ha); HE, high emerging plant habitat; HF, high floating plant habitat; LE, low emerging plant habitat; LF, low floating plant habitat; mix, mixed vegetation habitat; mudflat, mudflat habitat; pond, pond habitat.

addition, to obtain integrated information on the composition of the waterbird population of Dianchi in recent years, we obtained other waterbird distribution information from the literature and experienced birdwatchers.

Statistical analysis

Species diversity estimation: We used species accumulation curves to assess our surveys and estimate species richness (Ugland et al 2003). We defined the cumulative number of individuals in a survey as the abundance of each species. In addition, we used the maximum abundance of each species to determine the population of waterbirds at Dianchi.

Division of season and residence type: According to the phenology and the seasonal classification method widely used in China, we set the seasons as spring (March to May), summer (June to August), autumn (September to November), and winter (December to February). We determined the resident types of waterbirds according to our continuous observations and reference to *The Avifauna of Yunnan China. Vol. I: Non-Passeriformes* (Yang et al 1995).

Ecological guilds classification: Morphological form relates to ecological function in birds (cf Ma et al 2010; Pigot et al 2020); thus, we divided the waterbirds into wading birds and swimming birds. For the former, we subdivided the birds into large shorebirds (herons, storks, godwits, and others), which mainly rely on lakeside marshlands, and small shorebirds (sandpipers, plovers, and knots), which mainly rely on mudflats. We subdivided the latter into dabbling birds (dabbling ducks and gulls), which mainly rely on shallow water, and diving birds (diving ducks, grebes, and cormorants), which mainly rely on deep water.

Changes in vegetation types: We obtained satellite images of the 2 parks from Google Earth before and after wetland construction and corrected habitat information (such as vegetation type) according to the field surveys. We calculated the vegetation area of each patch before and after construction in ArcGIS 9.3 (ESRI Inc). According to the type of aquatic vegetation, we classified each patch as high emerging plant type (HE), high floating plant type (HF), low emerging plant type (LE), low floating plant type (LF), mixed vegetation type (Mix), pond type (Pond), and mudflat type (Mudflat) (see Wang et al 2016). Changes in vegetation type mainly showed an increase in impervious surface and pond, and a decrease in aquatic vegetation (Table 1; Figure 3).

Changes in waterbirds before and after the wetland parks: We used an asymmetric before-after-control-impact method to evaluate how wetland park construction affected waterbirds (Underwood 1994; Smith 2002). The species richness and Shannon–Wiener diversity index (H') of each plot (impact 1, impact 2, and control) in a single survey were used as indicators of waterbird diversity. In addition, we used the average value of the aforementioned diversity to represent "before and after construction" of impact 1, impact 2, and control. We used a general linear model to test differences in species diversity before and after wetland park constructions using IBM SPSS Statistics software (version 23). H' and species richness were respectively used as dependent variables, survey sites (control/impact, CI) and the period (before/after, BA) were used as fixed factors, and survey years were used as random factors.

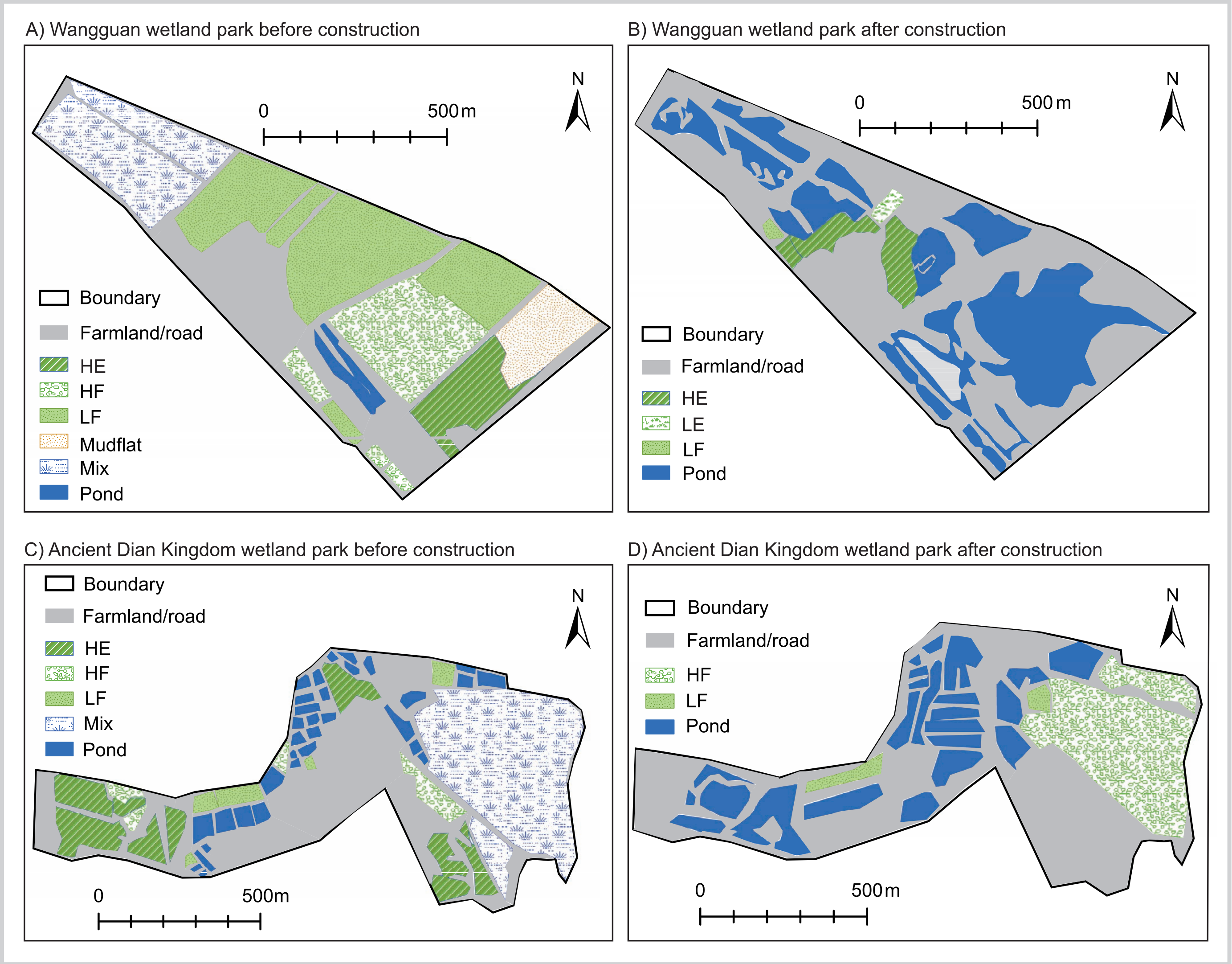
We verified that the diversity and variance of each guild—except for the H' of Podicipediformes and Lariformes—were normally distributed, and we used a paired *t*-test based on the monthly survey(s) to evaluate changes in the diversity of each guild before and after wetland park construction.

Results

Species composition

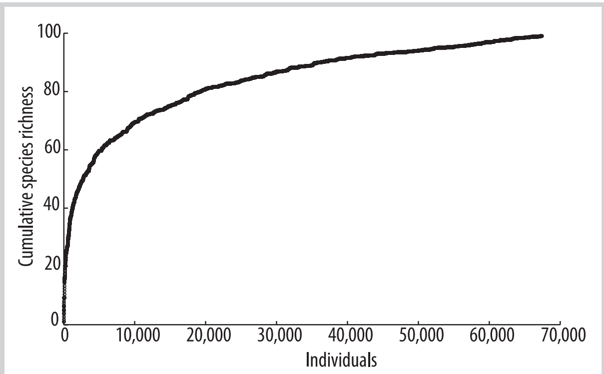
We detected 67,385 individuals, belonging to 7 orders, 15 families, and 99 species, in all surveys from February 2013 to May 2017. The species cumulation (rarefaction) curve showed that our survey represented the waterbird composition (Figure 4). The total number of species at Dianchi was 105, including 6 species from recent references or birdwatchers: *Anser anser* (greylag goose) (Xinhuanet 2017), *Porzana cinerea* (white-browed crake) (CBR 2020), *Calidris*

FIGURE 3 Changes in vegetation types before and after construction of 2 wetland parks, Wangguan wetland park (A, B), and Ancient Dian Kingdom wetland park (C, D). Habitat type: HE, high emerging plants type; HF, high floating plants type; LE, low emerging plants type; LF, low floating plants type; Mix, mixed vegetation type; Mudflat, mudflat type; Pond, pond type.



melanotos (pectoral sandpiper) (Wang et al 2017), *C. alba* (sanderling) (Wang et al 2017), *Larus vegae* (Vega gull) (Tu et al 2017), and *L. canus* (mew gull) (Tu et al 2017). Three species were globally threatened (IUCN 2020): *Aythya baeri* (Baer's pochard) was listed as critically endangered, *Calidris tenuirostris* (great knot) was listed as endangered, and *Rissa tridactyla* (black-legged kittiwake) was listed as vulnerable (Appendix S1, *Supplemental material*, https://doi.org/10.1659/MRD-JOURNAL-D-19-00055.1.S1).

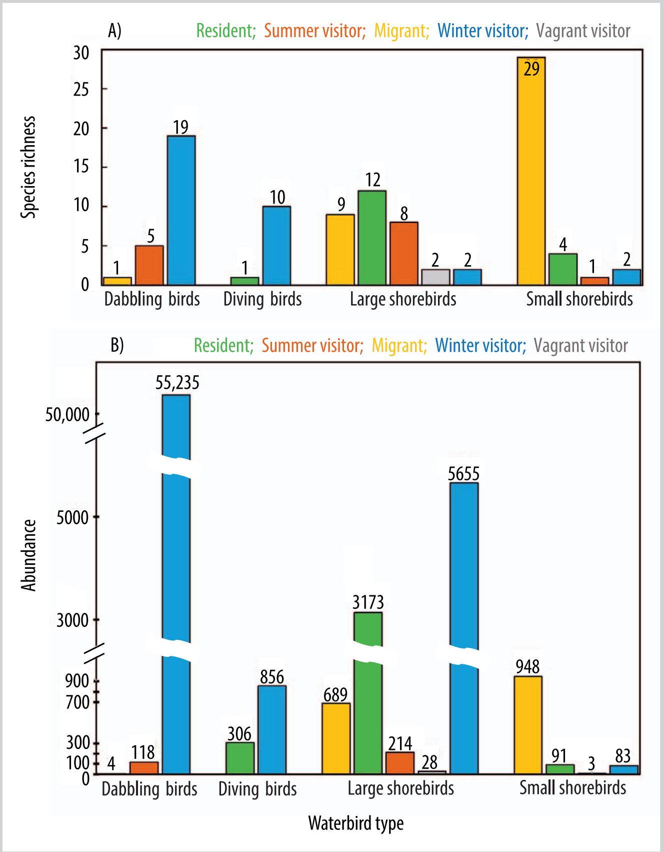
FIGURE 4 Rarefaction curves based on species and individuals of waterbirds between February 2013 and May 2017 at Lake Dianchi, China.



Ecological guilds and resident types

We found more wading species (69 species) than swimming species (36 species) in all survey periods. The former included 33 large shorebirds and 36 small shorebirds, and the latter included 25 dabbling birds and 11 diving birds. Shorebirds mainly comprised spring and autumn migrants (38 species) and resident birds (16 species). Swimming birds mainly comprised winter visitors (29 species) (Figure 5A). The winter visitors, which included more than 60,000 dabbling and large wading individuals, were the dominant guilds at Dianchi. These were followed by resident birds, mainly comprising large shorebirds (such as herons). Moreover, more than 1000 migratory shorebirds used Dianchi as a stopover site (Figure 5B).

FIGURE 5 Species diversity of waterbirds in Lake Dianchi from March 2013 to May 2017. Indicates the species richness (A) and abundance (B) of each residence type in different ecological guilds.



Impacts of wetland parks on waterbirds

The construction of wetland parks resulted in a significant decrease in species richness and H' (Table 2). For the control plot, the whole lakeside wetland held a mean (± SD) of 20.18 ± 5.87 species and 19.65 ± 3.77 species before and after the wetland parks were constructed, respectively. There were no significant differences ($F = 0.13$, $P = 0.72$) between the 2 periods. For the impact plots, S5 held 5.79 ± 5.47 species and 2.08 ± 2.00 species before and after the construction of the wetland park, respectively. There were significant differences ($F = 10.85$, $P < 0.01$) between the 2 periods: S8 supported 4.00 ± 2.21 species and 0.30 ± 1.29 species before and after wetland park construction, respectively. There were significant differences ($F = 82.28$, $P < 0.01$) between the 2 periods (Figure 6A). H' showed the same patterns as species richness (Figure 6B).

Except for the Lariformes and Anseriformes, the species richness of other guilds decreased significantly after construction of the wetland parks. Except for Gruiformes and Anseriformes, the H' of other guilds decreased significantly after construction of the wetland parks (Figure 7; Table 3).

Discussion

High waterbird diversity needs adequate protection and management

In this study, we found more than 60,000 individuals from 105 waterbird species, accounting for 40.38% of the total number of waterbirds in China (Wang et al 2018). In particular, we found that the species richness of the migrants was high. Most of the species were small shorebirds, which rely strongly on mudflats and marshlands. This finding suggests that continuous monitoring throughout consecutive months and years is important to collect complete data on waterbird population composition and propose timely management measures.

However, only 4 wetlands (Dashanbao, Napahai, Bitahai, and Lashihai) on the YGP have been listed as internationally important sites (Ramsar Convention Secretariat 2020). Using the data from our field surveys over the past decade, literature, and the website of *BirdReport* of China (http://www.birdreport.cn), we analyzed the species composition of Dianchi and the 4 Ramsar wetlands. We found that the

TABLE 2 Asymmetrical analysis of variance comparing waterbird diversity (species richness and H'_e) before and after wetland park construction at 2 affected sites and 1 control site, using a "beyond before-after-control-impact" design. Significant differences are marked in bold type.

Source		Species richness					H'_e				
		SS	*df*	MS	F	Sig	SS	*df*	MS	F	Sig
CI	Hypothesis	2489.47	1.00	2489.47	131.99	**0.00**	9.79	1.00	9.79	53.06	**0.00**
	Error	268.55	14.24	18.861			9.57	51.91	0.184		
BA	Hypothesis	127.69	1.00	127.69	7.58	0.09	4.29	1.00	4.29	9.52	0.08
	Error	39.42	2.34	16.847			0.97	2.15	0.451		
Year	Hypothesis	104.52	2.00	52.26	1.46	0.34	0.38	2.00	0.19	0.39	0.72
	Error	142.37	3.97	35.845			0.95	1.98	0.480		
BA×CI	Hypothesis	96.70	1.00	96.70	73.60	**0.00**	5.98	1.00	5.98	66.74	**0.00**
	Error	317.42	241.60	1.314			0.27	2.98	0.090		
BA×CI×year	Hypothesis	0.09	2.00	0.04	0.00	1.00	0.16	2.00	0.08	0.33	0.72
	Error	4802.29	257.00	18.686			60.99	257.00	0.237		

Note: SS, sum of squares; *df*, degrees of freedom; MS, mean square; Sig, significance; C, control; I, impact; B, before; A, after.

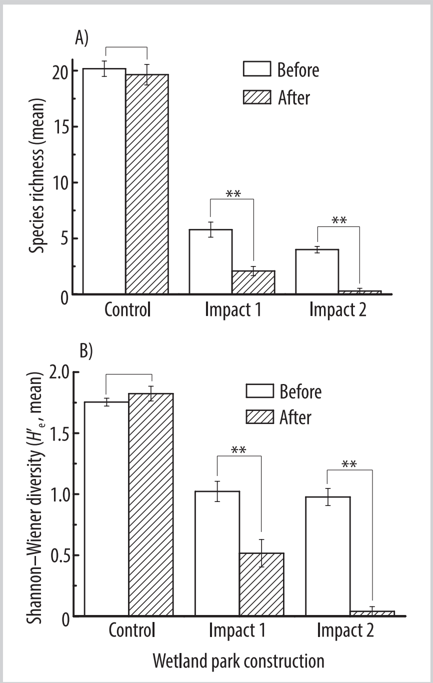


FIGURE 6 Differences in species richness (A) and H'_e (B) before and after the construction of 2 wetland parks at Lake Dianchi. The control represented the entire lakeside wetlands of Lake Dianchi; impact 1 represented the Wangguan wetland Park (S5), and impact 2 represented the Ancient Dian Kingdom wetland park (S8).

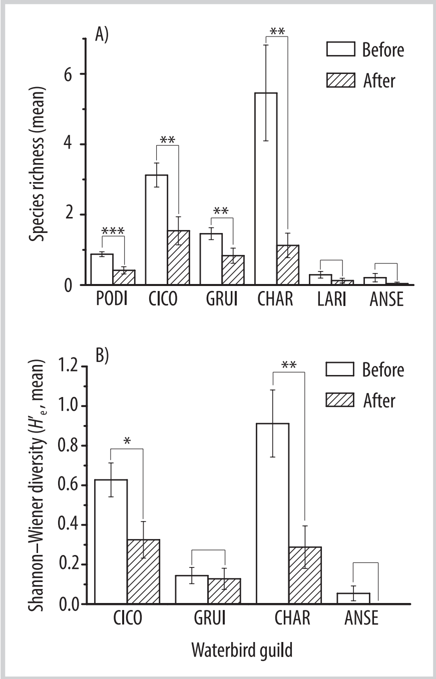


FIGURE 7 Comparisons of species richness (A) and H'_e (B) for different waterbird guilds before and after the construction of 2 wetland parks at Lake Dianchi. PODI, Podicipediformes; CICO, Ciconiiformes; GRUI, Gruiformes; CHAR, Charadriiformes; LARI, Lariformes; ANSE, Anseriformes. The H'_e of Podicipediformes and Lariformes were not compared because each had just 1 species. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

waterbird species richness of Dianchi was higher than that of any of the Ramsar sites (Table 4). Furthermore, in recent years, Dianchi has supported 3 species considered endangered according to the International Union for Conservation of Nature (Appendix S1, *Supplemental material*, https://doi.org/10.1659/MRD-JOURNAL-D-19-00055.1.S1). According to the Ramsar Convention Manual, "A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds" (Ramsar Convention Secretariat 2013). Dianchi has recently met this criterion every year (see Wang et al 2016; Wang and Yang 2020). Therefore, we suggest that monitoring and protection for Dianchi should be strengthened in the future.

Wetland park construction needs to consider the habitat requirements of waterbirds

The zones adjacent to mountainous lakes on the YGP are narrow and disturbed by human activities (such as grazing and tourism). Our study found that the lakeside zone around

TABLE 3 Waterbird diversity differences before and after the wetland parks by paired *t*-test. The H'_e of Podicipediformes and Lariformes were not tested because each had just 1 species. Significant differences are marked in bold type.

Order	Diversity index	Mean	SD	SE	*t*	*df*	*P*
Podicipediformes	SR	0.46	0.59	0.12	3.82	23.00	**0.001**
Ciconiiformes	H'_e	0.30	0.55	0.11	2.71	23.00	**0.013**
	SR	1.58	2.28	0.47	3.40	23.00	**0.002**
Gruiformes	H'_e	0.02	0.27	0.05	0.30	23.00	0.767
	SR	0.63	0.92	0.19	3.31	23.00	**0.003**
Charadriiformes	H'_e	0.62	1.07	0.22	2.86	23.00	**0.009**
	SR	4.33	7.10	1.45	2.99	23.00	**0.007**
Lariformes	SR	0.17	0.56	0.12	1.45	23.00	0.162
Anseriformes	H'_e	0.05	0.18	0.04	1.45	23.00	0.162
	SR	0.17	0.64	0.13	1.28	23.00	0.213

Note: *df*, degrees of freedom; SR, species richness; H'_e, Shannon–Wiener diversity index.

TABLE 4 Waterbird species richness at Lake Dianchi and 4 Ramsar wetlands on the Yunnan–Guizhou Plateau.

Wetland	Species richness	Number of threatened species	Abundance	Data source
Dianchi	105	3	67,385	This study
Bitahai	40	1	186	Our field survey; Han et al (2010); CBR (2020)
Dashanbao	54	2	5,665	Our field survey; CBR (2020)
Lashihai	68	3	14,649	Our field survey; Quan et al (2002); Liu (2004); Liao et al (2017); CBR (2020)
Napahai	77	4	4,153	Our field survey; Han and Peng (2012); CBR (2020)

Dianchi provided important habitats for many shorebirds. Therefore, monitoring (including multiyear and full-month monitoring) and management of the lakeside zone of Dianchi, and other lakes in the YGP, should be strengthened.

Furthermore, we found that the construction of wetland parks at the lakeside in Dianchi significantly reduced the diversity of waterbirds. This was mainly related to changes in aquatic vegetation, because vegetation is one of the most important factors affecting the distribution of waterbirds (Ma et al 2010). Our previous research found that the low emerging plants, mixed vegetation, and mudflat habitats held high species diversity, while low floating plants and pond habitats had low species diversity (Wang et al 2016). The construction of wetland parks resulted in the conversion of aquatic vegetation to pond habitats and the loss of mudflat and mixed vegetation habitats. Therefore, most shorebirds have dramatically decreased in number, and their diversity has also decreased.

Although ecotourism may increase employment and income from tourism, it can also create some negative ecological impacts. For example, ecotourism in wetlands in Sri Lanka has increased human disturbance and decreased biodiversity (Fernando and Shariff 2013). Most waterbirds avoid potential threats from humans (Dear et al 2015; Kumar et al 2016). Therefore, the decrease in waterbird diversity after the construction of wetland parks in Dianchi might also be related to human disturbance. In addition, park roads (visitor corridors) fragmented the habitats of some waterbirds and reduced diversity (Sarkar et al 2014). Wetland parks (including area size and vegetation configuration) should therefore be designed to cater adequately for humans and wildlife. This will be an essential task for ecologists and managers.

Conclusions

We conducted an intensive investigation of Dianchi, the largest wetland on the YGP. It showed that Dianchi was an important wintering place for waterbirds and a breeding and stopover place for other seasonal waterbirds. The results suggest that the monitoring of waterbirds should be increased in all seasons, especially during migration in spring and autumn. The current oxidation pond style of wetland parks aimed at water purification and tourism is not suited to most waterbirds. We suggest that designs for artificial wetlands or wetland parks at Dianchi and other wetlands on the YGP should consider the habitat requirements of different waterbirds in different seasons and focus on the protection of mudflats, which small wading birds require.

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Supplemental material

APPENDIX S1 Checklist of waterbirds.

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