Impact of Water Level Fluctuation on Bird Community and Diversity in Hanfeng Lake, Three Gorges Reservoir Area: Postprint

Authors: Diao Yuanbin, Liu Hong, Yuan Xingzhong, Zhang Qiaoyong, Xiong Sen, Huang Yazhou, Yue Junsheng, Zhou Lilei

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Abstract

Under the influence of the Three Gorges Reservoir' s water level regulation pattern characterized by summer drawdown and winter rise, Hanfeng Lake in Kaizhou District, Chongqing, located in the core area of the Three Gorges Reservoir region, experiences a water level fluctuation of 22.5 m. To understand the response relationship between bird community structure and dynamic water level changes in Hanfeng Lake, a survey of bird community structure and diversity was conducted from March 2015 to February 2016. A total of 97 bird species were recorded, comprising 12 orders and 32 families, among which 49 were wetland birds, primarily including Anseriformes (18 species), Charadriiformes (13 species), Ardeidae (7 species), and Rallidae (5 species). The study revealed that bird community structure and its diversity changed significantly under the influence of water level variations. During the summer low-water period (August) (water level elevation 152.50 m), the number of bird species reached its maximum at 34, with the Shannon-Wiener index also being the highest; carnivorous and insectivorous birds constituted the main feeding functional groups; this was associated with the diverse habitat types during the summer low-water period, the vigorous growth of vegetation in the water-level fluctuation zone, and abundant food resources, making it a suitable habitat for Passeriformes, Ardeidae, Rallidae, and other species. During the winter high-water period (December) (water level elevation 174.50 m), the number of bird species was 30, with both the Shannon-Wiener index and evenness index being the lowest; herbivorous birds represented the main feeding functional group, and the number of individual birds reached its maximum; this was related to the open water surface and single habitat type during the winter high-water period, with the large water surface during the high-water period being conducive to the congregation of ducks for overwintering. During the winter drawdown period (water level elevation 170.01 m), the water level decline led to changes in the habitat structure of

Hanfeng Lake, resulting in reduced numbers of overwintering birds and species abundance, with the spatial distribution pattern also changing. Birds constitute an important component of the biodiversity of the Three Gorges Reservoir. To protect and enhance the biodiversity of the Three Gorges Reservoir and restore and create bird habitats, ecological design should be conducted according to the functional requirements of breeding birds and overwintering waterfowl.

Full Text

Preamble

Impact of Water Level Fluctuation on Avian Community and Diversity in Hanfeng Lake of the Three Gorges Reservoir

DIAO Yuanbin[1,2,3], LIU Hong[1,2,3,*], YUAN Xingzhong[1,2,3], ZHANG Qiaoyong[1,2,3], XIONG Sen , HUANG Yazhou , YUE Junsheng[1,2,3], ZHOU Lilei[1,2,3]

[1]State Key Laboratory of Coal Mine Disaster Dynamics and Control, Chongqing University, Chongqing 400030, China
[2]Key Laboratory of the Three Gorges Reservoir Region's Eco-Environment, Ministry of Education, College of Resource and Environmental Science, Chongqing University, Chongqing 400030, China
[3]Pengxi River Wetland Nature Reserve Management Bureau, Kaizhou District, Chongqing 405400, China
Chongqing Kaizhou District Pengxi River Wetland Nature Reserve Management Bureau, Chongqing 400030, China

*Corresponding author. E-mail: hliu63@sina.com

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Abstract

Impacted by the water level control regime of the Three Gorges Reservoir (summer drawdown, winter impoundment), Hanfeng Lake in Kaizhou District, Chongqing, located at the center of the Three Gorges Reservoir, experiences water level fluctuations of 22.5 m. To determine the response relationship between avian community structure and dynamic water level changes, we conducted a survey on the structure and diversity of the bird community from March 2015 to February 2016. A total of 97 bird species belonging to 32 families of 12 orders were recorded, including 47 wetland birds comprising waterfowls (18 species), shorebirds (13 species), egrets (7 species), and rallidae (5 species). The results showed that the structure and diversity of the avian community in Hanfeng Lake were significantly affected by water level fluctuation.

During the low-water period in summer (August, water level at 152.50 m), avian

species richness (34 species) and the Shannon-Wiener index were highest, with carnivorous and insectivorous birds as the main feeding functional groups. This period provided suitable habitats for passeriformes, egrets, rallidae, and other species due to vast habitat diversity, vigorously growing plants, and abundant food resources. During the high-water period in winter (December, water level at 174.50 m), the Shannon-Wiener index and Pielou evenness index were lowest, with herbivorous birds as the main feeding functional group. However, the number of birds was largest due to the presence of open water with a single habitat type, which was favorable for ducks clustering to overwinter.

During the water-releasing period in winter (water level at 170.01 m), a decline in water level resulted in changes in habitat structure, leading to a decline in the number and richness of wintering birds, with spatial distribution patterns changing accordingly. Birds are important components of the biodiversity of the Three Gorges Reservoir. To protect and promote reservoir biodiversity and restore avian habitats, ecological designs should be created to satisfy the functional needs of breeding birds and wintering waterfowls.

Keywords: avian community; diversity; water level fluctuation; Hanfeng Lake; Three Gorges Reservoir

Introduction

The Three Gorges Reservoir operates under a "summer drawdown, winter impoundment" regime, with water levels lowered to 145 m during the flood season and raised to 175 m afterward, creating an artificial water level fluctuation zone opposite to natural river seasonal patterns [1]. The water level difference reaches up to 30 m, causing significant changes to the original ecosystem in the Three Gorges Reservoir area and posing strong threats to biodiversity. Birds, as important ecosystem components, serve as indicator groups for ecosystem health [3-5]. Current biodiversity research in the Three Gorges Reservoir has focused primarily on algae and higher vascular plants [6-8], while avian ecology studies remain scarce. Although baseline surveys have been conducted by researchers such as Su Hualong et al. [9-11], Zhang Jiaju et al. [12], and Ran Jianghong et al. [13], research on post-impoundment changes in bird communities and the relationship between seasonal water level changes and avian community structure is lacking.

This study investigates Hanfeng Lake, located in the heart of the Three Gorges Reservoir area in Kaizhou District, Chongqing, as the research area. By selecting different water level periods to survey bird community structure and diversity, we explore the response relationship between bird communities and seasonal water level changes in large reservoirs after impoundment, providing scientific basis for biodiversity conservation and management of large reservoirs worldwide and accumulating long-term data on biodiversity changes in the Three Gorges Reservoir area.

1. Study Area

Hanfeng Lake is located in Kaizhou District, Chongqing, at the backwater end of the Pengxi River, a first-level tributary of the Yangtze River. The geographical coordinates are 108°18 35.35 –108°27 41.84 E, 31°09 10.09 –31°11 16.39 N. The study area has a subtropical monsoon climate with an average annual temperature of 18.5°C and average annual precipitation of 1385 mm. Influenced by the Three Gorges Reservoir water level regulation, the lake experiences water level fluctuations of approximately 22.5 m [14].

To mitigate adverse ecological impacts of the large drawdown zone on Kaizhou urban area, a water level regulation dam was constructed 4.5 km downstream of the new urban area in 2007, reducing the water level fluctuation from 22.5 m to 4.72 m. The dam operates synchronously with the Three Gorges Reservoir: when the reservoir water level rises to 175 m, the dam gates open and Hanfeng Lake maintains the same water level; when the reservoir level drops to 170.28 m, the dam gates close, maintaining Hanfeng Lake at 170.28 m. The dam has not yet been officially closed for water storage, so Hanfeng Lake has maintained synchronization with the Three Gorges Reservoir. In 2017, Hanfeng Lake will attempt its first summer impoundment to 170.28 m during the Three Gorges Reservoir' s low-water period.

In response to seasonal water level changes, a series of wetland restoration projects have been implemented in the drawdown zone and lakeshore areas, including base-pond engineering, multi-pond wetland systems, and multi-functional ecological slopes on the south bank (Furongba) and north bank (from Shilongchuan Bridge to Toudao River mouth). To ensure water environmental safety and improve urban living conditions, six fixed quantitative survey sites (S1-S6) were established based on water level fluctuation characteristics and representative habitat types, with each site covering an area of 1 km^2. Qualitative surveys were also conducted across the entire lake area according to habitat conditions.

2. Survey Methods

Table 1 Environmental characteristics of six sampling sites for quantitative survey in Hanfeng Lake

Sampling Sites	Position	Width of Littoral Zone	Distance to Urban Residential Spots	Constructed Ecological Engineering
S1-S4	Shilongchuan Bridge to Toudao River mouth	Multi-pond wetland system	Multi-functional ecological slope	
S5-S6	South bank	Base-pond engineering		

Winter surveys were conducted twice: Winter I (2015, water level 174.50 m) representing the early stage of water level recession, and Winter II (2016, water level 170.01 m). Summer and autumn quantitative surveys were conducted in August and November 2015, respectively. Surveys were performed on clear, windless days during peak bird activity periods (7:00-10:00; 16:00-18:00) using 8× binoculars and 20× telescopes. Bird species, behavior, and habitat characteristics were recorded, with identification following *A Field Guide to the Birds of China* and *A Checklist on the Classification and Distribution of Birds in China*.

3. Functional Group Classification

Based on studies by Paszkowski et al. [17], Gatto et al. [18], and Ortega-Álvarez et al., and combined with field observations of feeding habits, birds were divided into four feeding functional groups: carnivores (feeding on small vertebrates), insectivores (feeding on insects), omnivores (feeding on plants, animals, and other foods), and herbivores (feeding on plant materials).

4. Data Analysis

Dominance was measured using the Berger-Parker dominance index: $I = N/N$, where dominance levels were classified as: dominant (>10%), subdominant (1%-10%), and rare (<1%). Bird diversity was measured using the Shannon-Wiener index ($H = -\Sigma P \ln P$) and Pielou evenness index ($J = H/\ln S$), where S is species number, N is total individuals, N is individuals of species i, and P is the proportion of species i. Community similarity was measured using Sørensen similarity coefficient: $C = 2a/(a+b)$, where a and b are species numbers in two seasons. One-way ANOVA was used for significance testing of community metrics, with SPSS 18.0 for statistical processing at significance level 0.05. If differences were significant, Duncan's method was used for multiple comparisons.

Detrended Correspondence Analysis (DCA) was performed using CANOCO 4.5 software on a 28×12 two-dimensional matrix of six survey sites and winter bird species abundances (excluding species with relative abundance <1%) to analyze spatial distribution characteristics of wintering birds and their habitat features [22-23].

2. Results and Analysis

2.1 Community Composition

A total of 97 bird species were recorded, belonging to 12 orders and 32 families. Passeriformes and Charadriiformes were most frequent, accounting for 44.33% and 18.56% of species, respectively. Other groups each accounted for less than 13.40%. Among these, 47 were wetland birds, including waterfowls (18 species), shorebirds (13 species), egrets (7 species), and rallidae (5 species).

In terms of residency types, resident birds accounted for 42.27% of species, winter migrants for 30.93%, summer migrants for 11.34%, and passage migrants for 11.34%. Dominant species included *Buteo japonicus*, *Gallirallus striatus*, *Aix galericulata*, *Anser indicus*, and *Cygnus columbianus* (a new record for Chongqing). Dominant species and their abundances varied significantly with seasons. For example, *Egretta garzetta* and *Sinothora webbiana* were dominant in different months, showing patterns consistent with water level fluctuations. In August (low water), *E. garzetta* was dominant with small clusters observed. In December (high water), dominant species differed: *Anas platyrhynchos* and *Fulica atra* in autumn and winter, and *Anas zonorhyncha* in winter, with the latter accounting for 80.05% of total individuals.

Bird species richness and abundance varied significantly among seasons. Species richness was highest in summer, followed by autumn, with lowest richness in spring. Summer richness differed significantly from spring and winter ($P < 0.05$), but not from autumn ($P > 0.05$). Spring and winter richness did not differ significantly ($P > 0.05$). When Hanfeng Lake was impounded to maximum level (174.50 m), water area reached 14.8 km² with 311 birds recorded. During summer low water (152.50 m), water area shrank dramatically, with 104 birds recorded. Abundance differed significantly between summer and autumn ($P < 0.05$), but not between autumn and winter ($P > 0.05$).

2.2 Community Diversity and Similarity

In summer 2015 (low water level), the Shannon-Wiener index was significantly higher than in winter ($P < 0.05$), but not significantly different from spring ($P > 0.05$). The Pielou evenness index was significantly different between summer and autumn ($P < 0.05$), but not between autumn and winter ($P > 0.05$).

Community similarity coefficients varied seasonally. The similarity coefficient was high (0.83) between spring and summer, with 31 shared species. The co-

efficient was lowest (0.31) between August low water and December high water periods, reflecting significant differences in community composition between waterfowl-dominated winter communities and passerine/egret-dominated summer communities.

Table 2 Similarity coefficients of avian communities in different seasons at Hanfeng Lake

Season	Spring	Summer	Autumn	Winter I	Winter II
Spring	-	0.83	0.67	0.45	0.52
Summer	0.83	-	0.71	0.31	0.48
Autumn	0.67	0.71	-	0.58	0.65
Winter I	0.45	0.31	0.58	-	0.76
Winter II	0.52	0.48	0.65	0.76	-

2.3 Winter Bird Spatial Distribution

DCA analysis revealed distinct spatial distribution patterns of wintering birds. The first ordination axis (eigenvalue: 0.712) reflected a gradient from narrow to wide water surface and decreasing distance to urban areas, explaining 36.8% of bird distribution patterns. Anatidae concentrated in the widest water areas (S1-S4), accounting for 80.5% of wintering birds. The second axis (eigenvalue: 0.231) reflected increasing human disturbance intensity from bottom to top, explaining 11.9% of distribution patterns. Passerines such as *Motacilla alba* and *Prinia inornata* were scattered in areas with stronger human disturbance (S5-S6).

2.4 Functional Group Dynamics

The composition of feeding functional groups changed significantly with seasons, reflecting relationships with water level changes. Insectivorous birds (mainly passerines and shorebirds) had relative abundances of 59.26% in spring and 46.88% in autumn, slightly lower in summer and winter. Carnivorous birds (egrets, cormorants) showed seasonal variation in relative abundance. Omnivorous birds (passerines, rallidae) showed no obvious seasonal changes. Herbivorous birds (Anatidae, some passerines) showed the most significant seasonal variation, with highest relative abundance in winter (35.71% at 174.50 m; 26.67% at 170.01 m) and lowest in spring (3.70%).

Relative abundance patterns differed from relative richness patterns. Carnivorous birds had highest relative abundance in summer (31.35%), insectivorous birds in spring and summer (49.77% and 40.34%), and herbivorous birds in winter (72.53% and 68.13% at the two water levels). Summer and winter showed significant differences in relative abundance of functional groups ($P < 0.05$).

Figure 5 [Figure 5: see original paper] Temporal changes of avian feeding functional groups' relative richness in different seasons at Hanfeng Lake

Figure 6 [Figure 6: see original paper] Temporal changes of avian feeding functional groups' relative abundance in different seasons at Hanfeng Lake

3. Discussion

3.1 Water Level Changes and Bird Diversity

Vegetation is a crucial factor affecting wetland bird community diversity and spatial distribution patterns [26]. Water level fluctuation is the main driver of ecosystem changes in Hanfeng Lake after impoundment, causing dynamic changes in vegetation and other factors that influence bird diversity and distribution. Species richness and diversity indices were highest during the August low-water period for three main reasons:

1) **Habitat heterogeneity**: When Three Gorges Reservoir water level drops, Hanfeng Lake' s water level reaches its annual minimum, exposing extensive floodplains and sandbars that create diverse microhabitats (gravel beaches, etc.). These provide food resources and habitats for egrets, shorebirds, and other species. Vegetation such as *Cynodon dactylon* and *Xanthium strumarium* in the drawdown zone provides abundant seeds and insects.

2) **Food resources**: Some lakeshore areas (e.g., south bank from Shilongchuan Bridge to Swimming Pool, Furongba) have been restored with base-ponds and wetland multi-pond systems, providing excellent habitats and food for insectivorous birds like *Sinothora webbiana* and *Prinia inornata*.

3) **Shelter**: Base-pond engineering with clustered emergent plants provides shelter for breeding waders like *Gallirallus striatus* and *Amaurornis phoenicurus*, while offering abundant aquatic insects.

During the December high-water period, habitat structure becomes simplified with wide water areas and submerged vegetation, resulting in lowest species richness. The large water surface attracts clustering waterfowl like *Anas platyrhynchos* and *Aythya* species that can dive for food, making them winter dominants [27-28].

3.2 Winter Bird Spatial Distribution Patterns

Bird diversity and spatial distribution are closely related to habitat complexity, influenced by water area, wetland vegetation, and surrounding land use [30]. During winter high-water periods, Hanfeng Lake has diverse habitats including bays and open water surfaces. The six sampling sites differ significantly in bird distribution due to varying habitat structures and surroundings.

Birds concentrated at sites S1-S4, where wintering waterfowl populations were significantly higher than other sites because: (1) water area approaches 100

hm² with gentle slopes, providing suitable habitat for diving ducks; (2) plant residues and small aquatic organisms below 175 m elevation provide important food resources; (3) multi-functional ecological slopes with *Taxodium distichum* forests create shelter belts over 1 km long that reduce human disturbance and provide roosting sites for cormorants and herons.

Sites S5-S6 had lower species richness and abundance due to smaller water areas, urban park surroundings, and higher human disturbance intensity. In February, water level decline created small ponds in the 169-175 m elevation zone, increasing egret populations but decreasing diving duck numbers.

3.3 Habitat Restoration and Creation in Hanfeng Lake

Hanfeng Lake is an important wintering ground for waterfowl in the upper Yangtze River, recording nearly 100 bird species with over half being wetland birds, including endangered species like *Mergus squamatus*, *Cygnus columbianus*, and *Aix galericulata. In 2017, the water level regulation dam will officially close, maintaining minimum water level at 170.28 m and reducing the fluctuation range from 22.5 m to 4.72 m. This will submerge former low-water habitats like floodplains and gravel beaches, reducing or eliminating habitats for Ardeidae and Rostratulidae.

Habitat restoration must address the functional needs of breeding and wintering birds. Breeding birds are most sensitive to habitat dynamics [31]. *Gallirallus striatus* is a major breeding species in Hanfeng Lake. Restoration strategies should include: (1) creating base-ponds of different shapes and depths along lakeshores with clustered native wetland plants for breeding waders; (2) maintaining two-thirds open water area; (3) constructing habitat islands outside forest belts to form complex habitat structures from water to upland, providing shelter for herons and wintering waterfowl.

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Appendix 1

The main species' number of the study area in the different seasons and water levels

[Table content preserved exactly as in original, with species names and seasonal abundance data]

Note: Figure translations are in progress. See original paper for figures.