

Study on the relationship between changes in benthic organisms in Dongting Lake over the past 20 years and water quality improvement

Suyang Deng^{1,*}, Kexin Wang², Xiangyin Chen³

¹Nanjing International School, Nanjing, China

²University of California, Davis, Davis, USA

³Emerson College, Boston, USA

*Corresponding Author. Email: banzhuren@yishan.org

Abstract. Benthic organisms have relatively limited mobility and long life cycles, enabling them to comprehensively reflect long-term changes in water quality, sediment conditions, and hydrological conditions. They are therefore important indicators for assessing the ecological health of lakes. This study integrates survey data on benthic animals in Dongting Lake from 2001 to 2025, with a particular focus on reviewing publicly available data from 2016 to 2025, and conducts stage-based visualization of three categories of indicators: phytoplankton, zooplankton, and benthic animals. The results show that the decline in total phosphorus concentrations and the improvement in water quality in Dongting Lake have provided a foundation for ecological restoration. However, publicly available data do not constitute a continuous time series collected annually using consistent methods. Data for the entire lake in 2020 and 2025 show that plankton density increased markedly, whereas benthic animal density remained relatively similar. Nevertheless, the Shannon-Wiener index of benthic animals was only 0.7 in 2025, suggesting that similar individual abundance does not necessarily indicate the recovery of community structure. Exploratory sampling in the nearshore waters of Junshan and Piaowei also revealed relatively few taxa and pronounced local dominance. Ecological restoration in Dongting Lake is jointly constrained by water quality, sediment conditions, hydrological connectivity, navigation, and shoreline habitats. Long-term monitoring based on fixed sampling sites, consistent seasons, and standardized taxonomic identification levels is therefore still needed.

Keywords: Dongting Lake, benthic organisms, plankton, water quality improvement, hydrological connectivity, citizen science

1. Introduction

Benthic organisms are useful indicators of lake ecological health because their limited mobility and relatively long life cycles integrate changes in water quality, sediment conditions, and hydrology. Dongting Lake has undergone pollution-control and restoration measures since 2015, yet improvements in physicochemical

indicators alone cannot demonstrate recovery of benthic community structure. This study therefore reconstructs stage-based changes from available surveys between 2001 and 2025, evaluates the scope and comparability of public data from 2016 to 2025, and combines those records with exploratory field observations and a public questionnaire. The analysis emphasizes the evidentiary limits created by inconsistent sampling designs, rather than treating the assembled sources as a continuous annual time series.

2. Research background and methods

2.1. Research background

Dongting Lake is connected to the Yangtze River and the Xiang, Zi, Yuan, and Li Rivers and is an internationally important wetland. Urban expansion, agricultural non-point source pollution, sand mining, navigation, and shoreline modification have previously resulted in increased nitrogen and phosphorus loads, sediment disturbance, and habitat fragmentation. Since 2015, measures such as total phosphorus control, wetland restoration, and the ten-year fishing ban in the Yangtze River have been gradually implemented. Water quality in Dongting Lake has subsequently improved. However, whether improvements in water quality indicators have been accompanied by the recovery of benthic communities remains to be determined through biological evidence.

2.2. Literature and data methods

This study reviewed the publicly available Bulletins on Aquatic Biological Resources and Habitat Conditions in the Yangtze River Basin for 2019, 2020, and 2022–2025, published by the Ministry of Agriculture and Rural Affairs and the Yangtze River Basin Fishery Administration and Supervision Office. Peer-reviewed articles and publicly available information from the Department of Ecology and Environment of Hunan Province were also consulted. Included data were required to specify the geographic scope of Dongting Lake, sampling year, taxonomic level, and density unit. Data reporting only integrity grades or covering only specific areas of the lake were separately identified and were not combined with whole-lake averages.

The "changes over the past 20 years" referred to here represent a comprehensive reconstruction based on data from different years and different regions. The various surveys were not fully consistent in terms of sampling sites, seasons, mesh sizes, taxonomic identification levels, and measurement methods. Therefore, the data were used only to identify temporal stages of change and spatial differences. No regression analysis of a continuous time series was conducted, nor was a single causal relationship inferred from simple correlations.

2.3. Field survey and questionnaire

The research team collected one sediment sample from the nearshore area of Junshan, as well as one shallow-water sample and one deep-water sample from the nearshore area. Two shallow-water samples and two deep-water samples were collected from the central part of the lake. Benthic samples were collected using a Peterson grab sampler. After sieving and washing, preliminary morphological identification was conducted under a stereomicroscope. The public questionnaire included questions concerning perceptions of water quality, identification of benthic organisms, estimates of species richness, pollution tolerance, biological indicator functions, food-web relationships, and trade-offs in ecological conservation. Convenience sampling was used for the questionnaire, and the results were intended only to describe the cognitive characteristics of the respondents in this survey and were not used for population-level inference or significance testing.

3. Changes in benthic communities and publicly available data from 2016 to 2025

3.1. Historical surveys reveal pronounced spatiotemporal heterogeneity

In 2001, 51 species of benthic animals were recorded in eastern Dongting Lake. Oligochaetes, mollusks, and aquatic insects accounted for 35.3%, 29.4%, and 27.5%, respectively, and the Shannon-Wiener index was 1.47. In 2012, an annual average of 53 species was recorded across the entire lake, while the Shannon-Wiener index in eastern Dongting Lake increased to 2.67. However, pollution-tolerant oligochaetes continued to occur frequently [1]. These findings suggest that although some local waters may have improved, benthic communities remained constrained by organic pollution and sediment conditions.

In April 2019, a total of 49 benthic animal taxa were recorded at 54 sampling sites in western Dongting Lake, with an average density of 136.20 individuals/m² and an average wet weight of 167.13 g/m². Connected lakes had relatively high species richness, whereas the β -diversity of modified shoals was only 0.48. A generalized linear model further showed that hydrological connectivity, sediment type, and the ratio of transparency to water depth were important variables explaining differences in benthic communities [2]. These results cannot be considered representative of the entire lake, but they clearly demonstrate that even when "water quality is similar," connectivity and habitat heterogeneity can still alter benthic communities.

3.2. Data coverage from 2016 to 2025 and visualization of three biological groups

The review found that no complete annual sequence of phytoplankton, zooplankton, and benthic animal data for Dongting Lake, collected using consistent methods, was publicly available for 2016–2025. According to the Ministry of Ecology and Environment, 67 sampling sites were established in the Dongting Lake region from 2016 to 2021 for surveys of multiple groups of aquatic organisms, but the annual raw data were not all made publicly available in downloadable tabular form [3]. Beginning in 2019, a bulletin-based reporting system was gradually established. Publicly available information for 2021–2024 mainly provides aquatic biological integrity grades. For example, the 2022 bulletin reported an aquatic biological integrity index of 55.0 for Dongting Lake, 13.3 points higher than in 2021; the fish-status, key-species status, and habitat-status indices were 60.0, 30.0, and 75.0, respectively. Despite those increases, the overall rating remained "Poor," with limited species and key protected species and extensive shoreline hardening in populous lakeside areas identified as continuing constraints [4]. At present, the representative years for which detailed whole-lake data on the number of species or taxa, density, and biomass of the three biological groups can be clearly extracted are 2020 and 2025. Table 1 summarizes the staged coverage and comparability of the available records, and Figure 1 visualizes the same evidence alongside density comparisons for the three groups.

Table 1. Publicly available data coverage for aquatic biological indicators in Dongting Lake, 2016–2025

Period	Status of Publicly Available Data	Available Indicators	Comparability Treatment
2016-2018	Monitoring was conducted, but no annual public data for the three groups using consistent criteria were identified	Monitoring scope and project descriptions	No data imputation or interpolation
2019	First basin-wide bulletin; additional thematic studies available	Some zooplankton and benthic animal data	Local data reported separately

Table 1. Continued

2020	Whole-lake surveys of the three biological groups	Taxa, density, and aquatic ecological assessment	Used as a stage-specific baseline
2021-2024	Bulletins mainly report integrity grades	"Poor" in 2021–2023; "Fair" in 2024	Grades not converted into continuous numerical values
2025	Bulletin provides detailed indicators for the three groups	Number of species, Shannon index, density, and biomass	Compared with 2020 only in separate panels

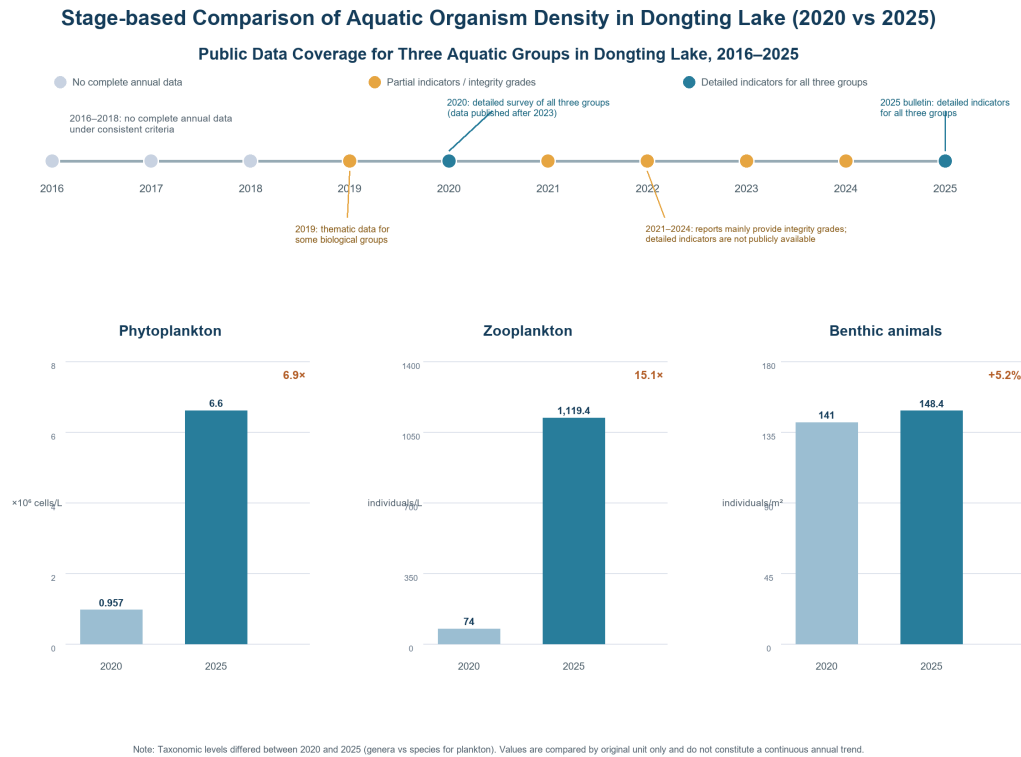


Figure 1. Stage-based comparison of publicly available data coverage and the density of three groups of aquatic organisms in Dongting Lake, 2016–2025 (sources: [3–8])

The 2020 whole-lake survey recorded 73 genera of phytoplankton, with an average density of 9.57×10^5 individuals/L; 48 genera of zooplankton, with an average density of 74 individuals/L; and 57 species of benthic animals, with an average density of 141 individuals/m² [5]. The 2025 bulletin recorded 196 species of phytoplankton, with an average density of 6.6×10^6 cells/L; 113 species of zooplankton, with an average density of 1,119.4 individuals/L; and 30 species of benthic animals, with an average density of 148.4 individuals/m² [9]. Based on density, phytoplankton abundance was approximately 6.9 times that of 2020, zooplankton abundance was approximately 15.1 times that of 2020, whereas benthic animal density increased by only approximately 5.2%.

This comparison cannot be directly interpreted as evidence that the ecosystem has "continued to improve." First, phytoplankton and zooplankton were counted at the genus level in 2020 but at the species level in 2025,

making changes in richness impossible to compare directly. Second, the sampling seasons, locations, and identification protocols may have differed between the two years. Third, increases in plankton density may reflect enhanced productivity, but may also be associated with algal proliferation resulting from changes in nutrient availability, temperature, and hydrological conditions. The Shannon-Wiener index of benthic animals was only 0.7 in 2025. Although their density was close to that in 2020, the community may have been concentrated in a small number of dominant taxa. Therefore, the "number of species/taxa–diversity–density–biomass" dimensions should be interpreted together, rather than using a single numerical indicator to represent ecological health. The 2025 values for all four indicator dimensions are reported in Table 2.

Table 2. Indicators of three groups of aquatic organisms in Dongting Lake in 2025 (Yangtze River Basin Office of the Ministry of Agriculture and Rural Affairs, published in 2026)

Group	Number of Species	Shannon-Wiener Index	Mean Density	Mean Biomass
Phytoplankton	196 species	2.2	6.6×10^6 cells/L	2.9 mg/L
Zooplankton	113 species	1.1	1,119.4 individuals/L	0.8 mg/L
Benthic animals	30 species	0.7	148.4 individuals/m ²	52.3 g/m ²

3.3. Exploratory results of field sampling in 2026

Preliminary observations of sediment samples collected from the nearshore area of Junshan identified a small number of taxa, including midge larvae, *Bellamya* spp., and mayfly nymphs. Because only one nearshore sediment sample was collected and identification was based primarily on morphological characteristics, these findings can only indicate that relatively few taxa were observed in the present sample. They cannot be used to infer that species diversity has "significantly declined" across Junshan or Dongting Lake as a whole. The relatively low observed richness may have resulted jointly from fine-grained nearshore sediment, shoreline and navigation disturbance, water-level fluctuations, the sampling season, and the limited sample size. Representative organisms observed in these nearshore samples are shown in Figure 2.

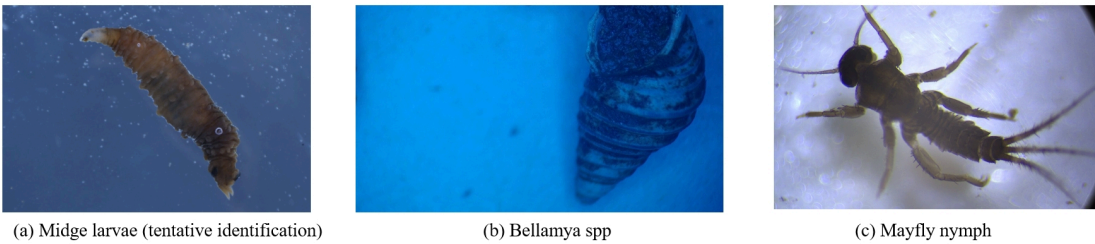


Figure 2. Representative benthic animals observed in the nearshore samples collected in this study (species-level identification still requires verification using taxonomic keys or molecular evidence)

4. Water quality improvement and its mechanisms

4.1. Declining total phosphorus provides a foundation for recovery but is not a sufficient condition

Elevated total phosphorus concentrations can promote algal proliferation. After algae settle, their decomposition increases microbial oxygen consumption, causing hypoxia at the sediment–water interface and the accumulation of reduced substances. The decline of submerged aquatic vegetation also reduces the space

available for snails, mussels, and aquatic insects for attachment, refuge, and reproduction. Public monitoring data from Hunan Province show that the total phosphorus concentration in Dongting Lake decreased from 0.112 mg/L in 2015 to 0.060 mg/L in 2022, and further declined to 0.054 mg/L in 2023, representing an approximately 51.8% decrease from the 2015 level [10]. Reductions in pollutant loads can help alleviate eutrophication pressure, but internal loading from sediments, sediment homogenization, and habitat fragmentation may delay biological recovery.

Mechanistic pathway

Decline in total phosphorus → reduced risk of excessive algal proliferation → reduced organic matter deposition and oxygen consumption in bottom waters → improved sediment–water interface conditions; at the same time, aquatic vegetation, sediment heterogeneity, and river–lake connectivity must also be restored before benthic communities can potentially be stably re-established.

4.2. Cascading effects of navigation, channel regulation, and Yangtze finless porpoise habitat

Vessel propulsion, dredging, and sand mining can increase suspended solids, cause sediment resuspension, intensify localized noise, and alter sediment structure, directly reducing suitable habitat for benthic animals. Changes in benthic animals and small fish may in turn affect fish resources through the food web, thereby altering the foraging conditions of Yangtze finless porpoises. High-frequency vessel traffic may also increase the risks of avoidance behavior and vessel collisions for finless porpoises. The 2023 bulletin pointed out that the existing scale of fisheries-related engineering activities, including sand mining and channel regulation, remained substantial [7].

The research team observed dense vessel traffic, anthropogenic shoreline disturbance, and suspected signs of illegal fishing in waters frequented by finless porpoises. Because the present survey did not include continuous video recording, vessel-number documentation, or evidence collection for law enforcement purposes, this study treats these observations only as field leads requiring further verification and does not characterize them as established violations. Future research could cross-validate these observations through vessel traffic counts conducted during fixed time periods, underwater acoustic recordings, turbidity monitoring, and publicly available enforcement data from fishery administration authorities, thereby converting field observations into testable evidence.

5. Public awareness and public participation

5.1. Questionnaire results and limitations

The descriptive results of the questionnaire indicate that the respondents generally exhibited relatively strong recognition of ecological value and a sound understanding of basic causal relationships, but their professional knowledge was fragmented and lacked depth. Most respondents could readily identify visible abnormalities such as greenish water, black and malodorous water, and dead fish, and generally recognized the ecological value of aquatic organisms. In the benthic organism identification question, bloodworms or chironomid larvae were the most frequently selected option, but the proportion remained below half. Some respondents also selected snails or river mussels, while others selected "I don't know." For estimates of species richness, "more than 50 species" was the most frequently selected option, but a considerable proportion of respondents still underestimated or were unaware of the richness of benthic animals in Dongting Lake. Overall, respondents demonstrated relatively limited knowledge of species identification, pollution tolerance, biological indicator functions, species richness, food-web relationships, long-term monitoring, and habitat management.

The public's understanding of the water environment and benthic organisms of Dongting Lake remains relatively fragmented, relying primarily on sensory observations and general ecological concepts. This indicates that there is still room for improvement in the coverage, professional depth, and systematic nature of existing ecological outreach and science education. Because the survey employed convenience sampling and the respondent population was unevenly distributed in terms of age, occupation, place of residence, and the proportions of local residents and tourists, these results can only serve as descriptive data for the respondents in this survey and cannot be generalized to residents of Yueyang City or the Dongting Lake region as a whole. Future studies could adopt stratified sampling and administer the same set of knowledge questions before and after science outreach activities to assess whether public knowledge has actually improved.

5.2. Implementation pathways for enhancing public awareness

First, protected-area authorities and fishery administration departments could establish quarterly public open days. Without disturbing protected species or habitats, these activities could demonstrate the use of Peterson grab samplers, sample sieving and washing, and identification procedures, while simultaneously publishing one-page monitoring briefs that explain the number of taxa, density, diversity, and water quality grades using standardized units. Second, local environmental NGOs could organize citizen-science monitoring at fixed sampling sites, inviting volunteers to photograph samples and record water temperature and transparency, with professional personnel subsequently verifying species identifications and accumulating traceable data over the long term. Third, schools could incorporate benthic organisms into biology and environmental science curricula and conduct microscopic observations, science-popularization exhibitions, and short-video production. Students could be guided to compare pollution-tolerant species with sensitive species while learning about sampling errors and the boundaries of available evidence. Fourth, media organizations and museums could establish interactive "lake surface–lake bottom" displays that place total phosphorus, dissolved oxygen, aquatic vegetation, and benthic communities within the same causal chain, thereby avoiding a sole focus on individual flagship species. The value of long-term monitoring lies in distinguishing short-term fluctuations from genuine trends, enabling the public to determine whether environmental governance has progressed from improvements in water quality to the recovery of community structure, while also providing stable evidence for protected-area management, assessment of navigation-channel engineering projects, and reporting of suspected illegal activities.

6. Conclusions and research limitations

The overall context of Dongting Lake over the past 20 years has been characterized by strengthened pollution control, improved water quality, and persistent habitat pressures. Total phosphorus declined substantially from 2015 to 2023, while aquatic biological integrity grades in 2024–2025 improved compared with those in 2021–2023. However, the Shannon-Wiener index of benthic animals remained low in 2025, and field samples also exhibited relatively few taxa and pronounced local dominance. The existing evidence more strongly supports the conclusion that "improved water quality provides conditions for recovery" than the claim that benthic communities have undergone comprehensive recovery.

The main limitations of this study include the discontinuity of the years covered by publicly available data and differences in survey methods and taxonomic identification levels; the fact that only one sediment sample was collected in the field, with no seasonal or quantitative replicates; the use of convenience sampling for the questionnaire and the uneven composition of respondents, which prevents population-level inference; and the fact that suspected illegal fishing observed in the field did not constitute evidence for law enforcement

purposes. Future research should establish a monitoring protocol based on fixed sampling sites, standardized seasons, standardized mesh sizes, and consistent taxonomic identification levels, with repeated sampling for at least 3–5 consecutive years. Water quality, sediment conditions, water depth, hydrological connectivity, and navigation intensity should also be recorded simultaneously. Only through such an approach can the effectiveness of efforts to "protect the clear waters of the Yangtze River" be scientifically assessed to determine whether environmental governance has truly extended from the lake surface to the lake bottom.

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