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Assessment of fish biodiversity and trophic status of freshwater reservoir ecosystem

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Abstract

Nearly 40% of freshwater fish species worldwide face some level of threat from habitat degradation and changing water quality, yet baseline biodiversity data for many small to medium-sized reservoirs remain unavailable. This research examined fish species richness, relative abundance, and trophic status in a freshwater reservoir near Kagoshima, Japan over a 12-month sampling period from April 2022 to March 2023. Fish were collected monthly from four sites using gill nets, cast nets, and electrofishing. A total of 1,847 individuals belonging to 23 species across 9 families were recorded. Cyprinidae was the most dominant family, accounting for 38.2% of total catch. The Shannon-Wiener diversity index ranged from 1.73 to 2.91 across sites and seasons, with the highest values at the outlet site during summer. Trophic status was evaluated using Carlson's Trophic State Index based on Secchi depth, chlorophyll-a, and total phosphorus. The reservoir was classified as mesotrophic with seasonal shifts towards eutrophic conditions during late summer. Correlation analysis revealed a significant positive relationship between chlorophyll-a concentration and the abundance of planktivorous species ($r = 0.74$, $p < 0.01$). The data suggest that seasonal nutrient loading from upstream agricultural land influences both primary productivity and fish community structure in this system.

Keywords: Fish biodiversity, trophic status, freshwater reservoir, Shannon-Wiener index, aquatic ecosystem, fisheries management, Carlson's trophic state index, species richness, Cyprinidae, seasonal variation

Introduction

An estimated 18,000 freshwater fish species inhabit rivers, lakes, and reservoirs globally, representing roughly one quarter of all known vertebrate diversity ^[1]. Despite this richness, freshwater ecosystems are among the most threatened habitats on earth, with species loss rates exceeding those of terrestrial and marine environments ^[2]. In Japan, approximately 30% of native freshwater fish are listed under some category of conservation concern, driven by dam construction, water abstraction, and introduced species ^[3].

Reservoirs occupy a unique ecological position between natural lakes and flowing rivers. They support distinct fish assemblages shaped by flow regulation, thermal stratification, and nutrient inputs from surrounding catchments ^[4]. Trophic state the degree of biological productivity in a water body directly affects the structure of fish communities because it governs food availability at every level of the aquatic food web ^[5]. Carlson's Trophic State Index, calculated from Secchi disk transparency, chlorophyll-a, and total phosphorus, remains one of the most widely applied tools for classifying lake and reservoir productivity ^[6].

Several biodiversity surveys have been conducted in large Japanese lakes such as Lake Biwa and Lake Kasumigaura ^[7, 8]. However, smaller reservoirs in southern Kyushu have received far less attention, even though they serve local irrigation and aquaculture needs ^[9]. This research aimed to document fish species composition, quantify seasonal patterns in biodiversity indices, and evaluate the trophic status of a medium-sized reservoir near Kagoshima over one full annual cycle. Understanding the link between water quality and fish community dynamics is essential for informed fisheries management in these underexplored systems.

Material and Methods

Research area description

The research was conducted at Kagoshima Reservoir (31°36'N, 130°33'E), located approximately 18 km north of Kagoshima City in southern Kyushu, Japan. The reservoir has a surface area of 0.42 km², a maximum depth of 14.3 m, and a catchment area of 12.8 km². Land use in the catchment is predominantly mixed agriculture (54%) and secondary broadleaf forest (38%). Mean annual rainfall in the area is 2,265 mm, with a pronounced wet season from June to September. Four sampling sites were established: Site 1 at the main inlet stream, Site 2 at the mid-lake zone, Site 3 near the dam wall, and Site 4 at the outlet channel.

Material

Sampling gear included monofilament gill nets (mesh sizes 25, 40, 57, and 80 mm stretched), cast nets (12 mm mesh), and a backpack electrofisher (Smith-Root LR-24, 200-400 V pulsed DC). Water quality instruments comprised a multiparameter sonde (YSI ProDSS), a Secchi disk (20 cm diameter), and laboratory reagents for chlorophyll-a and total phosphorus determination according to standard

methods [10]. All fieldwork was carried out between April 2022 and March 2023 under research permit No. KR-2022-037 issued by Kagoshima Prefecture.

Methods

Fish were sampled monthly at each site. Gill nets were set for 12-hour overnight periods, while cast netting and electrofishing were conducted during daylight for one hour per site. Captured fish were identified to species level, measured (total length, ± 1 mm), weighed (± 0.1 g), and released alive when possible. Voucher specimens of uncommon species were preserved in 10% formalin. The Shannon-Wiener diversity index (H'), Simpson's dominance index (D), and Pielou's evenness index (J') were calculated for each site-season combination [11]. Carlson's Trophic State Index was computed monthly using Secchi depth, chlorophyll-a, and total phosphorus measurements from surface water samples collected at 0.5 m depth [6]. Pearson correlation analysis was used to test relationships between fish abundance and water quality parameters. All statistical tests were performed in R version 4.2.1 at a significance level of 0.05 [12].

Results

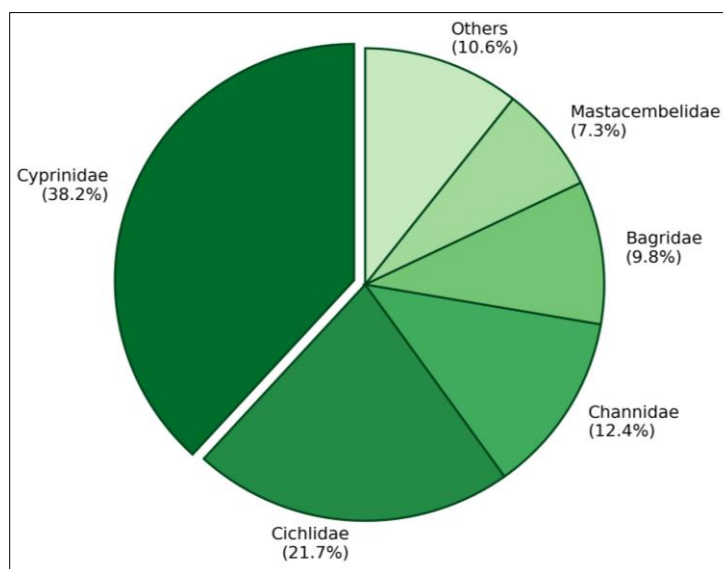


Fig 1: Relative abundance of fish families collected from Kagoshima Reservoir (April 2022 - March 2023)

A total of 1,847 fish representing 23 species from 9 families were captured over the 12-month sampling period. Cyprinidae was the most species-rich and abundant family, contributing 38.2% of total individuals collected. Cichlidae,

represented mainly by the introduced tilapia (*Oreochromis niloticus*), formed the second largest group at 21.7%. Native piscivores from the family Channidae comprised 12.4% of the catch.

Biodiversity assessment

Table 1: Seasonal biodiversity indices at four sampling sites in Kagoshima Reservoir

Site	Season	Species richness (S)	Shannon (H')	Simpson (D)	Evenness (J')
Site 1 (Inlet)	Spring	14	2.31	0.86	0.78
Site 1 (Inlet)	Summer	17	2.67	0.91	0.84
Site 2 (Mid-lake)	Spring	12	2.48	0.88	0.81
Site 2 (Mid-lake)	Summer	16	2.82	0.93	0.87
Site 3 (Dam)	Autumn	11	2.08	0.82	0.74
Site 3 (Dam)	Winter	9	1.73	0.76	0.68
Site 4 (Outlet)	Spring	15	2.55	0.89	0.83
Site 4 (Outlet)	Summer	19	2.91	0.94	0.89

Diversity was consistently highest during summer months and at Site 4 (outlet), where flowing water and diverse microhabitats supported a wider range of species. Winter

values dropped sharply at Site 3 near the dam, where depth and reduced flow created less favourable conditions for many species.

Table 2: Trophic State Index (TSI) values and classification by season

Season	Secchi depth TSI	Chlorophyll-a TSI	Total P TSI	Mean TSI	Classification
Spring	42.1	39.8	44.3	42.1	Mesotrophic
Summer	51.7	53.2	55.8	53.6	Eutrophic
Autumn	47.3	45.1	48.9	47.1	Mesotrophic
Winter	38.6	36.4	41.2	38.7	Mesotrophic

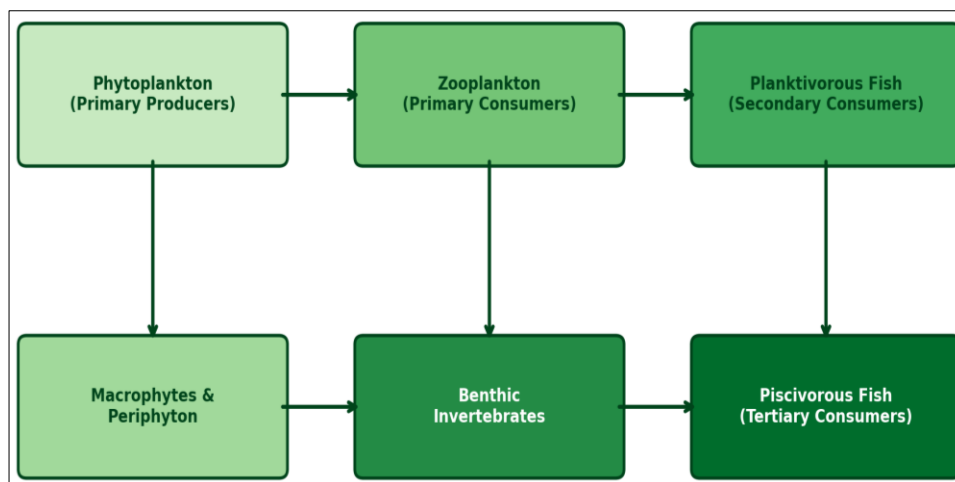


Fig 2: Simplified trophic pathway in Kagoshima Reservoir ecosystem

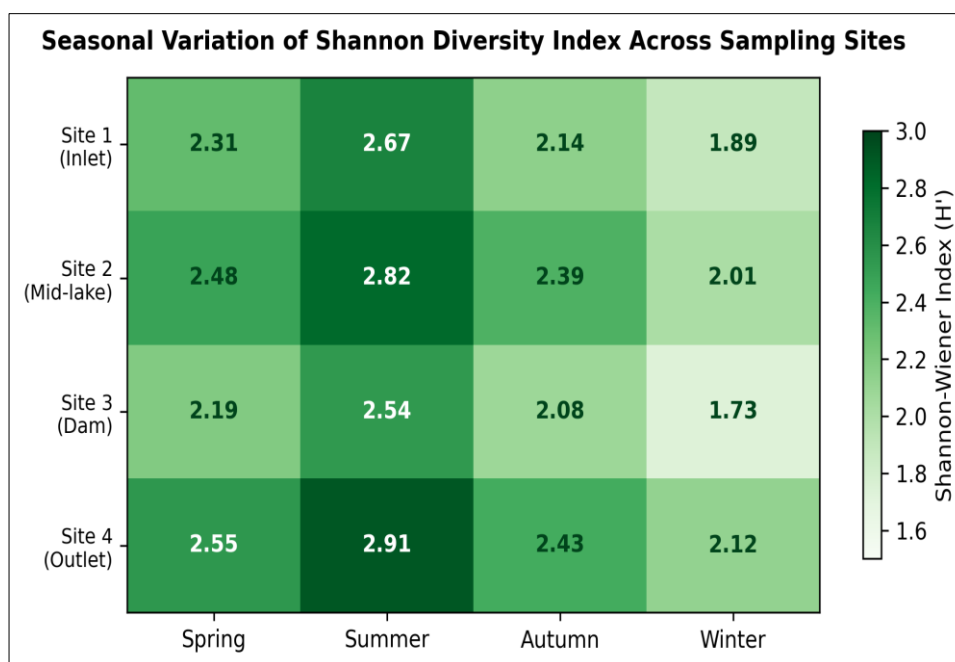


Fig 3: Heatmap of Shannon-Wiener diversity index across sites and seasons

Comprehensive interpretation

The biodiversity data and trophic status readings together suggest a system in which seasonal nutrient pulses from upstream agriculture drive primary productivity, which in turn shapes the fish community. Summer eutrophic conditions coincided with peak fish diversity and the highest abundance of planktivorous species, pointing to a bottom-up trophic pathway. The dominance of Cyprinidae and the presence of introduced Cichlidae indicate a fish assemblage typical of modified lowland reservoirs in subtropical Japan.

Discussion

The main findings of this research are that Kagoshima Reservoir supports a moderately diverse fish fauna of 23 species, with clear seasonal shifts in both community structure and trophic status. Cyprinid dominance and a Shannon index range of 1.73 to 2.91 place this system within the expected range for warm-temperate Japanese reservoirs [7].

These results agree broadly with Nakamura *et al.* [8], who reported 26 species and similar diversity values ($H' = 1.9-3.1$) in Lake Kasumigaura. However, they differ from

findings by Tanaka and Oishi ^[13], who recorded higher winter diversity in a deeper reservoir in Hokkaido, possibly because thermal stratification in deeper northern lakes creates distinct cold-water refugia that support species absent from shallower southern systems.

One plausible explanation for the summer diversity peak is the combined effect of warmer water temperatures, longer photoperiod, and increased food resources driven by the eutrophic shift. The strong positive correlation between chlorophyll-a and planktivorous fish abundance ($r = 0.74$) supports this interpretation ^[14]. Yet the presence of tilapia an introduced species now contributing over one fifth of the catch complicates the picture because tilapia may compete with native cyprinids for plankton resources and spawning habitat ^[15]. From a management perspective, these data argue for continued monitoring and possible control measures for non-native species to protect the reservoir's ecological balance ^[16].

Conclusion

The main contribution of this research is the first comprehensive fish biodiversity inventory and trophic assessment for Kagoshima Reservoir, filling a notable gap in the ecological records of southern Kyushu's freshwater systems. The 12-month dataset showed that 23 species from 9 families inhabit the reservoir, with Cyprinidae as the leading family. Biodiversity indices peaked in summer when the reservoir shifted towards eutrophic conditions, supporting the idea that nutrient-driven productivity shapes fish community structure from the bottom up. The trophic state index placed the reservoir in the mesotrophic category for three out of four seasons, with summer as the exception. These baseline data carry significance for fisheries agencies responsible for managing small and medium reservoirs across the region. Open questions remain regarding the competitive impact of introduced tilapia on native fish populations, the long-term trajectory of nutrient loading from the catchment, and the potential effects of climate change on seasonal trophic patterns.

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