

# Ichthyofaunal diversity in the community-managed Jagadishpur Reservoir (Ramsar site) and Gajedi Lake, Lumbini Province, Nepal

SANTOSHI SHRESTHA<sup>1,✉</sup>, KUMAR KHATRI<sup>2</sup>, NRIPESH SHRESTHA<sup>3</sup>, RAM CHANDRA POUDEL<sup>4</sup>,  
KUMAR SAPKOTA<sup>1</sup>

<sup>1</sup>Central Department of Zoology, Tribhuvan University, Kirtipur, Kathmandu 44618, Nepal. Tel./fax.: +977-1-4331896, ✉email: santoshi.shrestha@cdz.tu.edu.np

<sup>2</sup>Central Department of Environmental Science, Tribhuvan University, Kirtipur, Kathmandu 44618, Nepal

<sup>3</sup>Bhaktapur Multiple Campus, Tribhuvan University, Nagarkot Street, Bhaktapur 44800, Nepal

<sup>4</sup>Nepal Academy of Science and Technology, Khumaltar, Lalitpur 3323, Nepal

Manuscript received: 13 April 2025. Revision accepted: 26 June 2025.

**Abstract.** Shrestha S, Khatri K, Shrestha N, Poudel RC, Sapkota K. 2025. Ichthyofaunal diversity in the community-managed Jagadishpur Reservoir (Ramsar site) and Gajedi Lake, Lumbini Province, Nepal. *Biodiversitas* 26: 3262-3272. This study aimed to establish baseline information on fish species diversity in the Jagadishpur Reservoir and Gajedi Lake, located in Lumbini Province, Nepal, managed under community-based systems. The study was conducted between 2018 and 2022 across three different seasons at five sampling stations using cast nets. Thirty-nine native fish species representing 27 Genera, 18 Families, and 9 Orders were recorded. Among them, Cypriniformes was the dominant order and Danionidae the most widespread family in both water bodies. In Jagadishpur Reservoir, *Rasbora daniconius* was the most abundant species, followed by *Puntius sophore*, whereas *Amblypharyngodon mola* and *Trichogaster fasciata* were the most common in Gajedi Lake. The Shannon-Wiener diversity index ( $H'$ ) ranged from 1.54 to 2.77, indicating moderate biodiversity. Pielou's evenness index ( $J$ ), ranging from 0.72 to 0.93, suggested a relatively even species distribution. Notably, *Badis badis* and *Macrognathus lineatomaclulatus* were observed only once in the Jagadishpur Reservoir and Gajedi Lake, respectively. Both water bodies were found to be slightly alkaline. The Redundancy Analysis (RDA) results revealed low adjusted  $R^2$  values for the two lentic systems, suggesting that while environmental variables do influence fish community structure, a substantial portion of the variation remains unexplained, likely due to the complex biotic interactions and unmeasured factors. The findings show that both wetlands support a rich diversity of native fish species and that they contribute to the understanding of fish richness and associated water quality parameters, and provide valuable insights for planning sustainable fishing practices, guiding future research, and informing conservation strategies.

**Keywords:** Fish composition, fish diversity, Gajedi Lake, Jagadishpur Reservoir, Nepal

## INTRODUCTION

Freshwater ecosystems are critical reservoirs of biodiversity as they support a wide array of aquatic organisms where fishes have a crucial role in ecological balance, uplifting livelihoods, and ensuring food security (Funge-Smith and Bennett 2019; Hasan et al. 2019; Faghihinia et al. 2021; Khowhit et al. 2024; Wanjari et al. 2025). In both lotic and lentic environments, fish assemblages serve as sensitive bioindicators of environmental conditions and ecosystem integrity (Hasan et al 2020; Zogaris et al. 2023; Zhang et al. 2024). Their composition and distribution are influenced by various physicochemical and hydrological factors including temperature, flow dynamics, dissolved oxygen levels, pH, and substrate characteristics (Anna et al. 2017; Zhuang et al. 2024). Understanding the relationships between environmental variables and fish assemblages is crucial for conservation planning, sustainable fisheries management, and predicting the impacts of anthropogenic activities, including dam construction, pollution, and climate change (Valen et al. 2020; Wang et al. 2021; Zogaris et al. 2023). Studies in tropical and subtropical regions have shown variations in hydrological and physicochemical parameters, which can lead to significant

spatial and temporal shifts in fish communities (Rashid et al. 2025; Wu et al. 2025). Globally, the research in the field indicated that the environmental gradients significantly influence freshwater fish assemblages, affecting species richness, composition, and abundance (Agarwal et al. 2019; Soo et al. 2021). Understanding these relationships is essential for documenting biodiversity patterns and planning conservation and management strategies in the face of accelerating environmental changes.

As Nepal, situated within the Indo-Malayan biogeographic realm, exhibiting remarkable heterogeneity in its freshwater habitats, its western freshwater systems, comprising a mosaic of rivers and natural lakes across diverse altitudinal and climatic gradients support a rich ichthyofauna (Shrestha 2019; Pokharel et al. 2020; Khatri et al. 2024). However, the freshwater systems of Nepal, enriched with diverse aquatic habitats support 240 indigenous species (Grill et al. 2020), there remains a significant gap in systematic studies regarding the fish diversity and distribution patterns across the country (Rajbanshi 2012; Khatri et al. 2020). Despite growing awareness of biodiversity conservation and ecosystem services, comprehensive data on fish distribution patterns, and their ecological correlates in this region are still scarce.

Jagdishpur Reservoir, a designated Ramsar Site, serves as an important habitat for various fish species as well as migratory birds, including Sarus Crane, an endangered species (Bhusal et al. 2020). Gautam et al. (2010) reported 24 native fish species including four exotic species from Jagdishpur Reservoir. On the other hand, the Gajedi Lake is a natural lake that supports a diverse habitat for native fish species as well as critically endangered bird species *Ixobrychus flavicollis* (Regmi et al. 2023). Wetlands like Jagdishpur Reservoir and Gajedi Lake are complex ecosystems that also support a wide range of fauna, including insects, mollusks, amphibians, and mammals (Dhakal et al. 2020; Budhathoki et al. 2022). In both lentic systems, community stewardship initiatives have been implemented to reverse environmental degradation and promote sustainable fisheries. In recent years, community-based management has emerged as a pivotal strategy for conserving aquatic biodiversity and ensuring the sustainable use of freshwater resources in Nepal (Lamsal et al. 2015; Karki and Yokota 2024). By empowering local communities to actively participate in habitat restoration, regulate fishing practices, and control pollution, these initiatives have shown promising results in enhancing ecological resilience and maintaining fish diversity.

However, despite their ecological and socio-economic importance, there is a notable lack of basic data on fish diversity and environmental conditions in Jagdishpur Reservoir and Gajedi Lake (lentic systems). Very few comprehensive studies have been conducted to document the composition, distribution, and status of fish communities. This knowledge gap limits our understanding of how these ecosystems are responding to environmental changes and management interventions. Therefore, this study aims to address this gap by providing a thorough assessment of fish diversity and its relationship with key environmental variables, thereby contributing to a broader

aspect of freshwater biodiversity dynamics in the Himalayan foothill region.

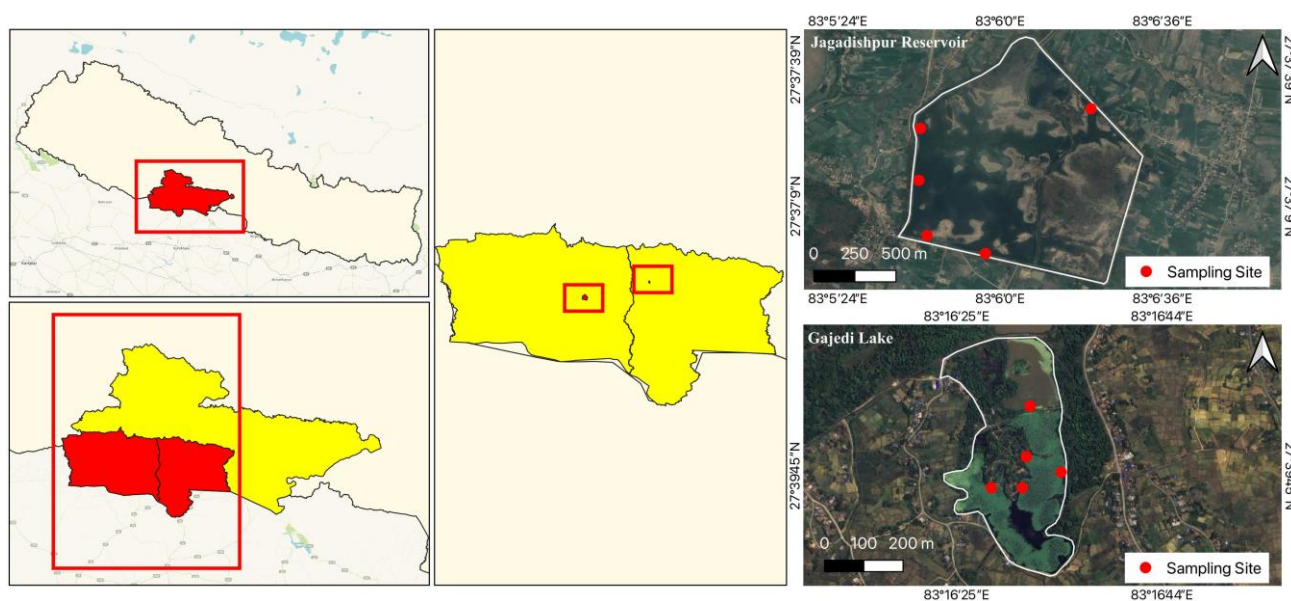
## MATERIALS AND METHODS

### Study area

This study was conducted in Lumbini Province, Nepal, especially Jagdishpur Reservoir in Kapilvastu District and Gajedi Lake in Rupandehi District from 2018 to 2022, covering the pre-monsoon, winter, and post-monsoon seasons for fish along with water sampling (Figure 1). The Jagdishpur Reservoir (27°37'N, 83°06'E; elevation 197 masl) with a surface area of 225 hectares is situated in Kapilvastu Municipality (MoFE 2018). The Gajedi Lake (27°39'51"N, 83°16'34"E; elevation 133 masl) with a surface area of 19 hectares, is located in Danapur, Kanchan Rural Municipality near the pilgrimage site of Lumbini (Dhakal et al. 2020).

### Fish sampling and identification

Fish samples were collected with the help of local fishermen using cast nets from five randomly selected sites in each lentic system, covering most directions. The collected fish species were immediately counted on the spot and preserved in 70% ethanol for subsequent analysis at the Central Department of Zoology, Tribhuvan University, Nepal. The measurements of morphological features and specimen identification were done following standard literatures (Shrestha 1981, 1994; Talwar and Jhingran 1991; Jayaram 2012; Shrestha 2019; Vishwanath 2021). The voucher specimens were deposited at the Central Department of Zoology Museum of Tribhuvan University (CDZMTU).



**Figure 1.** Map showing the sampling areas and sampling sites in Jagdishpur Reservoir (Ramsar site) and Gajedi Lake, Lumbini Province, Nepal

### Water sampling and physiochemical parameters

Water samples were collected from five sites in each of the two lentic systems. At each site, selected physicochemical parameters such as pH and temperature were measured on-site using multimeter probes (Hanna Probe), while water transparency was measured using a Secchi disc. Additionally, 1000 mL water samples from each site were collected in High-Density Polyethylene (HDPE) bottles and stored at 4°C in an icebox until further analysis. These samples were analyzed for free carbon dioxide (CO<sub>2</sub>), total alkalinity and total hardness. Furthermore, 300 mL water samples were collected from each site in Biochemical Oxygen Demand (BOD) bottles and fixed (KI and MnSO<sub>4</sub>) on-site for the determination of Dissolved Oxygen (DO). The DO, free CO<sub>2</sub>, total hardness (as CaCO<sub>3</sub>), and total alkalinity were determined using standard methods, following APHA (2005) at the laboratory of Tribhuvan Multiple Campus, Palpa, Nepal.

### Statistical analysis

Descriptive statistical analysis was performed for fish and water quality parameters, along with the calculation of species diversity indices including Shannon-Wiener diversity index (H') (Shannon 1948), Simpson's index of diversity (1-D) (Simpson 1949), Pielou's Evenness (J) (Pielou 1966), and Margalef's diversity index (D<sub>Mg</sub>) (Margalef 1973). Due to the skewed nature of the data, a non-parametric test was employed to assess significant variations in parameters across different seasons. The threat status of the fish species was categorized in accordance with the IUCN Red List (2025). Similarity Percentage (SIMPER) analysis was conducted to evaluate the percentage contribution and average dissimilarity among seasons (Clarke and Warwick 2001). Redundancy Analysis (RDA) was applied to assess the potential relationships between fish species abundance and environmental variables. The statistical significance of the RDA relationship was tested using a Monte Carlo permutation test with 999 permutations (p<0.001). Prior to RDA, taxa abundance data were Hellinger transformed (Legendre and Gallagher 2001). All statistical analyses, SIMPER, diversity indices, Mann Whitney test, Kruskal-Wallis test, and RDA were conducted using R Studio software (version 4.2).

## RESULTS AND DISCUSSION

### Fish community composition

A total of 5288 fish individuals representing 36 species belonging to 9 Orders, 18 Families, and 27 Genera were recorded from Jagadishpur Reservoir and Gajedi Lake (Figure 2). Mann-Whitney U test revealed no significant variation (p<0.05) (U: 565, Z: 0.98, p: 0.32) in the fish assemblages between the two systems. A total of 34 species belonging to 8 Orders, 17 Families, and 26 Genera were observed in the Jagadishpur Reservoir, whereas 29 fish species belong to 8 Orders, 14 Families, and 21 Genera were observed in the Gajedi Lake (Table 1).

In the Jagadishpur Reservoir, Order Cypriniformes was represented by 5 families and 15 species followed by Anabantiformes (4 families with 6 species); Siluriformes (3 families 4 species), Synbranchiformes (1 family with 4 species), Perciformes (1 family with 2 species) whereas Beloniformes, Gobiformes, and Osteoglossiformes represented by one family with one species each (Table 1, Figure 3). In the Gajedi Lake, Cypriniformes was represented by 5 families and 16 species, followed by, Anabantiformes and Siluriformes (2 family, 3 species each); Synbranchiformes (1 family with 3 species), and Beloniformes, Gobiformes, Mugiliformes and Perciformes was represented by only one family with one species each. In both the systems, Cypriniformes and Danionidae were the dominant order and family, respectively Families, Badidae, Heteropneustidae, Nandidae and Notopteridae were recorded only in Jagadishpur Reservoir whereas Mugilidae only in Gajedi Lake (Table 1, Figure 4).

This study revealed a moderately diverse ichthyofaunal assemblage in both Jagadishpur Reservoir and Gajedi Lake, suggesting that the two sites support relatively similar fish communities in terms of diversity and abundance. The family Danionidae (Order: Cypriniformes) exhibits wide diversity, comprising 374 species across 39 genera, most of which are small and brightly colored fish. Similarly, Cyprinidae is considered a taxonomically rich group, and is one of the most abundant freshwater fish families in Asia (Kottelat 2013). The presence of exclusive taxa in the two different water bodies may be driven by microhabitat preferences, trophic requirements, or water quality parameters unique to each location (Moniruzzaman et al. 2021). Additionally, substrate type and water depth may influence the structure, diversity, and composition of fish communities (Wilborn et al. 2018).

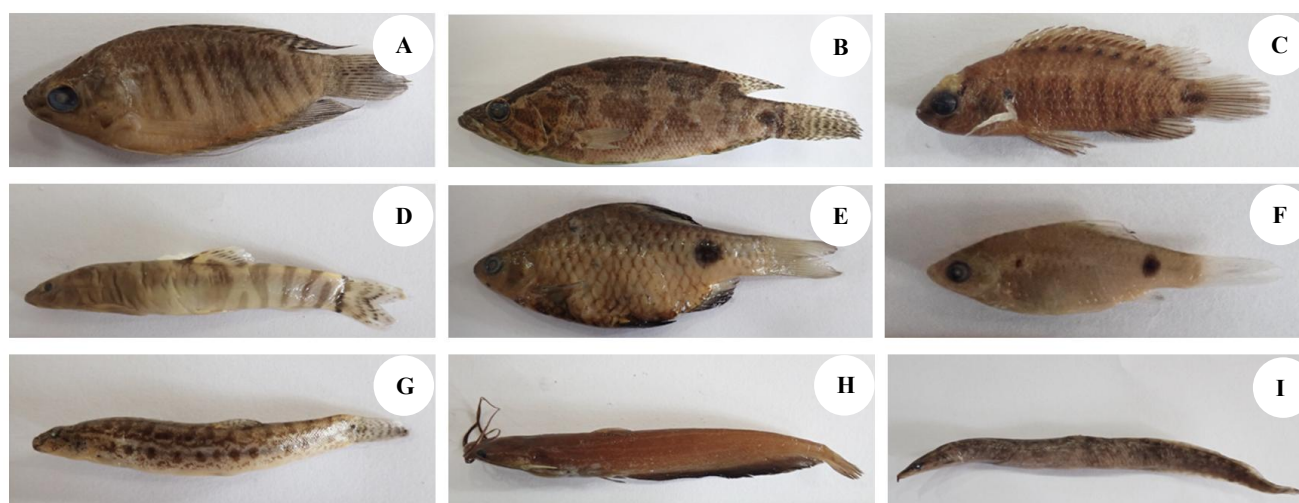
### Fish richness, abundance, and diversity

Of the 36 fish species recorded, 22 were common to both systems, 7 species were recorded exclusively from the Jagadishpur Reservoir, while 2 species were unique to the Gajedi Lake. A total of 26 species were found in all seasons across both systems. Only two species, *Badis badis* and *Macrogonathus lineatamaculatus* were observed only once during pre-monsoon and post monsoon of which former was reported from Jagadishpur Reservoir while later one from Gajedi Lake. This result highlighted a considerable overlap in species assemblages suggesting similar environmental conditions or habitat characteristics that support these species across both ecosystems (Montgomery et al. 2021). The unique occurrences may be attributed to site-specific factors such as water quality, habitat heterogeneity, microhabitat preferences, resource availability, low population density or a strong seasonal presence influenced by breeding cycles (Oli et al. 2013; Muthukumaravel et al. 2021; Pinna et al. 2023). The highest number of species was recorded from the Jagadishpur Reservoir during the pre-monsoon (30 species), whereas the lowest was from the Gajedi Lake during winter (22 species).

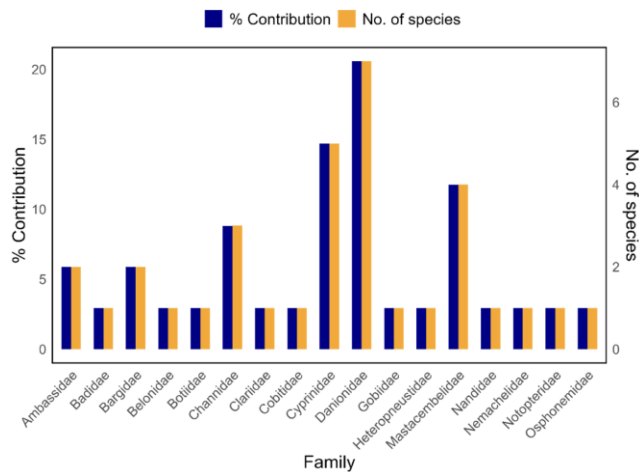
**Table 1.** Ichthyofaunal diversity of Jagadishpur Reservoir and Gajedi Lake in Lumbini Province, Nepal, with IUCN Red List status

Order	Family	Genus	Species	Jagadishpur	Gajedi	IUCN Red list status
Anabantiformes	Badidae	<i>Badis</i>	<i>B. badis</i> (Hamilton, 1822)	●	-	LC
	Channidae	<i>Channa</i>	<i>C. gachua</i> (Hamilton, 1822)	●	●	LC
			<i>C. punctata</i> (Bloch, 1793)	●	-	LC
			<i>C. stewartii</i> (Playfair, 1867)	●	●	LC
	Nandidae	<i>Nandus</i>	<i>N. nandus</i> (Hamilton, 1822)	●	●	LC
	Osphronemidae	<i>Trichogaster</i>	<i>T. fasciata</i> Bloch & Schneider, 1801	●	-	LC
Beloniformes	Belonidae	<i>Xenontodon</i>	<i>X. cancila</i> (Hamilton, 1822)	●	●	NA
Cypriniformes	Botiidae	<i>Botia</i>	<i>B. lohachata</i> Chaudhuri 1912	●	●	LC
	Cobitidae	<i>Lepidocephalichthys</i>	<i>L. guntea</i> (Hamilton, 1822)	●	●	LC
	Cyprinidae	<i>Pethia</i>	<i>P. conchoniuis</i> (Hamilton, 1822)	●	●	LC
			<i>P. phutunio</i> (Hamilton, 1822)	●	●	LC
			<i>P. ticto</i> (Hamilton, 1822)	●	●	LC
		<i>Puntius</i>	<i>P. chola</i> (Hamilton, 1822)	●	●	LC
			<i>P. sophore</i> (Hamilton, 1822)	●	●	LC
	Danionidae	<i>Salmostoma</i>	<i>S. bacaila</i> (Hamilton, 1822)	●	●	LC
		<i>Danio</i>	<i>D. rerio</i> (Hamilton, 1822)	●	●	LC
		<i>Devario</i>	<i>D. aequipinnatus</i> (McClelland, 1839)	●	●	LC
			<i>D. devario</i> (Hamilton, 1822)	-	●	LC
		<i>Laubuka</i>	<i>L. laubuca</i> (Hamilton, 1822)	●	●	LC
		<i>Esomus</i>	<i>E. danrica</i> (Hamilton, 1822)	●	●	LC
		<i>Amblypharyngodon</i>	<i>A. mola</i> (Hamilton, 1822)	●	●	LC
		<i>Rasbora</i>	<i>R. daniconius</i> (Hamilton, 1822)	●	●	LC
	Nemacheilidae	<i>Acanthocobitis</i>	<i>A. botia</i> (Hamilton, 1822)	●	●	LC
Gobiiformes	Gobiidae	<i>Glossogobius</i>	<i>G. giuris</i> (Hamilton, 1822)	●	●	NA
Osteoglossiformes	Notopteridae	<i>Notopterus</i>	<i>N. notopterus</i> (Pallas, 1769)	●	-	LC
Mugiliformes	Mugilidae	<i>Minimugil</i>	<i>M. cascasia</i> (Hamilton, 1822)	-	●	LC
Perciformes	Ambassidae	<i>Chanda</i>	<i>C. nama</i> (Hamilton, 1822)	●	-	LC
		<i>Parambassis</i>	<i>P. baculis</i> (Hamilton, 1822)	●	●	LC
Siluriformes	Bargidae	<i>Mystus</i>	<i>M. bleekeri</i> (Day, 1877)	●	●	LC
	Bargidae	<i>Mystus</i>	<i>M. tengara</i> (Hamilton, 1822)	●	●	LC
	Clariidae	<i>Clarias</i>	<i>C. batrachus</i> (Linnaeus, 1758)	●	●	LC
	Heteropneustidae	<i>Heteropneustes</i>	<i>H. fossilis</i> (Bloch, 1794)	●	-	LC
Synbranchiformes	Mastacembelidae	<i>Mastacembelus</i>	<i>M. armatus</i> (Lacepede, 1800)	●	-	LC
		<i>Macrognathus</i>	<i>M. aral</i> (Bloch & Schneider, 1801)	●	●	LC
			<i>M. pancalus</i> Hamilton, 1822	●	●	LC
			<i>M. lineatamaculatus</i> (Britz, 2010)	●	●	DD

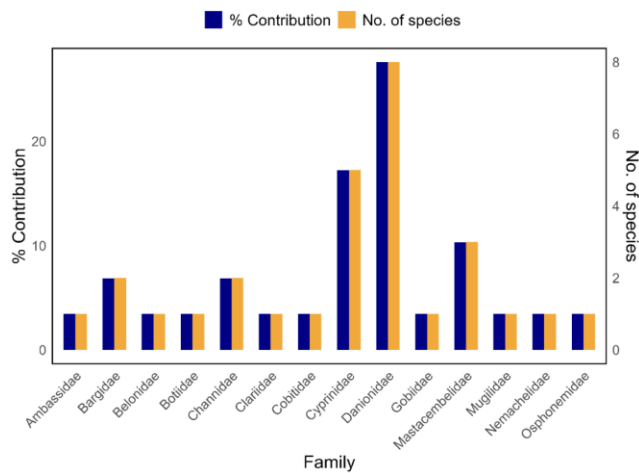
Note: -: Absence, ●: Presence, DD: Data Deficient, LC: Least Concern, NA: Not Evaluated



**Figure 2.** Main commodity fish of study area. A. *Trichogaster fasciata*, B. *Nandus nandus*, C. *Badis badis*, D. *Botia lohachata*, E. *Pethia conchoniuis*, F. *Pethia ticto*, G. *Acanthocobitis botia*, H. *Heteropneustus fossilis*, I. *Mastacembelus armatus*



**Figure 3.** Percentage (%) contribution of different families with the number of species in Jagadishpur Reservoir, Lumbini Province, Nepal



**Figure 4.** Percentage (%) contribution of different families with the number of species in Gajedi Lake, Lumbini Province, Nepal

In the Jagadishpur Reservoir, the number of individuals per catch ranged from 1 to 457, with an average of 93.47. In contrast, Gajedi Lake showed a catch range of 1 to 566 individuals, averaging 78.76, indicating a relatively average haul. The most abundant species were *R. daniconius*, followed by *P. sophore* in the Jagadishpur Reservoir, whereas in Gajedi Lake, *A. mola* was most abundant, followed by *T. fasciata*. Gautam et al. (2010) reported 28 fish species from Jagadishpur Reservoir. Of which Indigenous species such as *Myxus cavasius*, *M. vittatus*, *Osteobarma cotio*, *Cabdio morar*, *Opsarius bendelisis*, *Channa orientalis*, *C. striata*, *Parambassis ranga* were not reported during present study. Moreover, exotic major carps Bighead carp, Grass carp, Common carp and Silver carp were also not recorded during present study as these species typically found during monsoon due to introduction from nearby culture ponds through flooding (Gautam et al. 2010). The presence of species with single

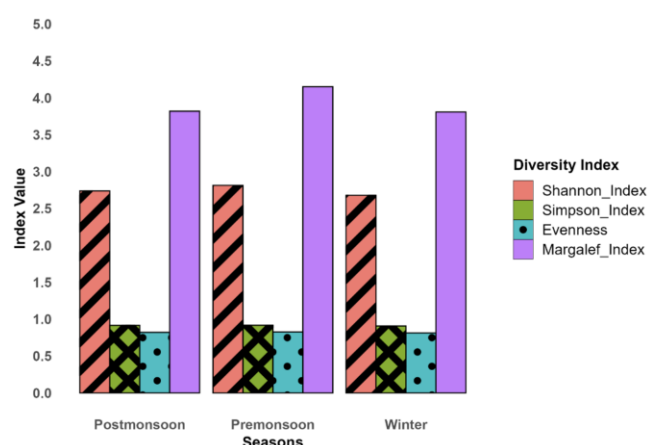
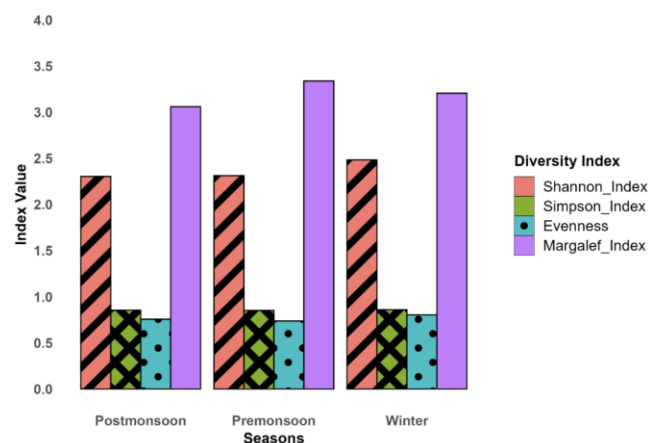
occurrences indicates a decline in their natural populations, likely due to anthropogenic stressors (Besson et al. 2020; Aziz et al. 2021; Barman et al. 2021). Additionally, the relatively low Catch Per Unit Effort (CPUE) values observed suggest a moderate average haul, reflecting a decline in natural fish populations when compared to the higher CPUE values reported by Jha et al. (2006) from several rivers in Nepal.

The seasonal values of species richness and various species diversity indices, including the Shannon-Wiener diversity index ( $H'$ ), Simpson's index of diversity (1-D), Pielou's evenness ( $J$ ), and Margalef's diversity index ( $D_{Mg}$ ) are presented in Figures 4 and 5. In Jagadishpur Reservoir, the Shannon-Wiener index ( $H'$ ) ranged from 2.06 to 2.77, with a mean value of  $2.45 \pm 0.21$ . Simpson's index of diversity (1-D) ranged from 0.86 to 0.92 (mean:  $0.89 \pm 0.02$ ), while the Pielou's evenness ( $J$ ) varied between 0.83 and 0.91, with a mean of  $0.87 \pm 0.02$ , and lastly Margalef's diversity index ( $D_{Mg}$ ) ranged from 1.71 to 4.11, with a mean of  $3.01 \pm 0.68$  (Figure 5). In Gajedi Lake, the Shannon-Wiener index ( $H'$ ) ranged from 1.54 to 2.57, with a mean value of  $1.98 \pm 0.26$ . Simpson's index of diversity (1-D) ranged from 0.73 to 0.88 (mean:  $0.81 \pm 0.05$ ), Pielou's evenness ( $J$ ) ranged from 0.72 to 0.93, with a mean of  $0.82 \pm 0.05$ , while Margalef's diversity index ( $D_{Mg}$ ) varied from 1.21 to 3.32, with a mean of  $2.15 \pm 0.53$  (Figure 6). The Mann-Whitney U test indicated significant variation between the seasons in Shannon-Wiener index ( $H'$ ) (U: 205, Z: 3.81, P: 0.000), Simpson's index of diversity (1-D) (U: 213, Z: 4.15, P: 0.000), Pielou's evenness ( $J$ ) (U: 192, Z: 3.28, P: 0.001) and Margalef's diversity index ( $D_{Mg}$ ) (U: 186, Z: 3.03, P: 0.002). However, the Kruskal-Wallis test revealed no significant differences ( $P > 0.05$ ) in abundance patterns and diversity indices among the three seasons. Dunn's post-hoc test, however, identified significant variation in species-specific composition during the study period, as shown in Table 2. The Shannon Wiener Diversity index was lower in the winter due to lower productivity and less favorable condition as the water level goes down during autumn-winter period, fish move to the deep sections of watercourses, whereas higher value during pre-monsoon may be due to high productivity (Westrelin et al. 2018; Withers et al. 2021). A well-balanced community is described through a high evenness index indicating no single species is significantly more abundant than others; in contrast, the lower the uniformity index number, the less homogeneous the fish population (Paul et al. 2021; Wahyuningsih et al. 2022). Many studies indicated that the diversity of fish species in the pre-monsoon is higher than in the winter (Jha et al. 2018; Lai et al. 2022; Laba et al. 2023).

On the other hand, some studies report the diversity of fish species in the dry season to be higher than in the rainy season (Oli et al. 2013; Cottet et al. 2016; Mekonen and Hailu 2021; Suriya et al. 2022). Seasons induce change in different environmental regimes of the lentic systems such as discharge, temperature, dissolved oxygen, and availability of food affect biotic assemblages which in turn affect the assemblages in aquatic ecosystem (Adrian et al. 2016; Espinosa-Mendoza et al. 2025).

**Table 2.** Fish species showing significant variation during different seasons

Water bodies	Species name	H	DF	P value	Dunn's test
Jagadishpur Reservoir	<i>Pethia phutunio</i>	7.53	2	0.023	Pre-monsoon-Winter
	<i>Pethia ticto</i>	6.5	2	0.039	Post monsoon-Winter
	<i>Danio rerio</i>	7.93	2	0.019	Pre-monsoon-Winter
	<i>Glossogobius guiris</i>	6.43	2	0.040	Post monsoon-Winter, Pre-monsoon-Winter
	<i>Macrornathus pancalus</i>	6.43	2	0.040	Post monsoon-Pre monsoon, Pre-monsoon-Winter
Gajedi Lake	<i>Trichogaster fasciata</i>	7.77	2	0.021	Pre-monsoon-Winter
	<i>Laubuka laubuca</i>	14.29	2	0.001	Post monsoon-Pre monsoon, Pre-monsoon-Winter
	<i>Esomus danrica</i>	7.86	2	0.020	Post monsoon-Pre monsoon, Pre-monsoon-Winter

**Figure 5.** Diversity indices during different seasons in Jagadishpur Reservoir, Lumbini Province, Nepal**Figure 6.** Diversity indices during different seasons in Gajedi Lake, Lumbini Province, Nepal

SIMPER analysis revealed an overall average dissimilarity of 43.69% among seasons in the Jagadishpur Reservoir and 50.86% in Gajedi Lake. In Jagadishpur Reservoir, the main contributors to the observed dissimilarity were *P. ticto*, *R. daniconius*, *P. chola*, and *P. baculis* whereas *A. mola*, *T. fasciata*, and *D. rerio* were the key contributing species of seasonal variation in Gajedi Lake.

### Environmental variables

The mean concentrations of various environmental variables during the study period are presented in Table 3. In Jagadishpur Reservoir, the pH ranged from 7.7 to 9.8, with a mean value of  $8.41 \pm 0.41$ , indicating slightly alkaline conditions. DO levels ranged from 6.1 to 9.7 mg/L (mean:  $8.01 \pm 0.98$  mg/L), while temperature varied between 18.0 and 33.0°C (mean:  $26.78 \pm 5.48$ °C). Water transparency ranged from 23.9 to 93.3 cm, with a mean of  $59.81 \pm 21.52$  cm. Carbon dioxide (CO<sub>2</sub>) concentrations ranged from 1.70 to 8.80 mg/L (mean:  $5.48 \pm 2.15$  mg/L). Alkalinity ranged from 53.00 to 373.00 mg/L (mean:  $269.63 \pm 91.69$  mg/L), and total hardness ranged from 67.00 to 175.00 mg/L (mean:  $124.47 \pm 29.64$  mg/L). In Gajedi Lake, the pH ranged from 7.6 to 8.7 (mean:  $8.30 \pm 0.26$ ), also indicating slightly alkaline conditions. DO ranged from 7.3 to 9.7 mg/L (mean:  $8.08 \pm 0.53$  mg/L), while temperature ranged from 17.5 to 34.8°C (mean:  $27.37 \pm 5.84$ °C). Transparency ranged from 19.3 to 55.0 cm (mean:  $35.81 \pm 10.85$  cm). CO<sub>2</sub> concentrations ranged from 4.10 to 9.30 mg/L (mean:  $5.69 \pm 1.49$  mg/L). Alkalinity ranged from 206.00 to 313.00 mg/L (mean:  $259.21 \pm 24.34$  mg/L), while total hardness varied between 99.00 and 205.00 mg/L (mean:  $119.14 \pm 21.54$  mg/L). The Mann-Whitney U test indicated significant seasonal variation in transparency (U: 732.5, Z: 4.17, P: 0.000) and alkalinity (U: 614.5, Z: 2.43, P: 0.015) between two water bodies.

Both the reservoir and lake exhibit slightly alkaline conditions, which are typical of freshwater systems with high bicarbonate concentrations, often influenced by bedrock geology and biological activity (Gurung et al. 2018). The reservoir's slightly higher pH may have resulted from the enhanced photosynthetic activity or lower CO<sub>2</sub> concentrations due to greater water transparency (Ignatius and Rasmussen 2016). DO levels in both systems are high (>6 mg/L), indicating good oxygenation and suggesting healthy aquatic conditions with comparable aeration and biological productivity (Boyd 2017). Temperature variation is slightly greater in the lake due to its shallower depth and increased exposure to atmospheric conditions, which promote thermal fluctuations (Meerhoff et al. 2012; Goetz et al. 2015). Transparency, as measured by Secchi depth, was significantly higher in the reservoir ( $P < 0.001$ ), indicating greater light penetration. This may be attributed to lower phytoplankton biomass or turbidity, possibly due to better watershed management or deeper waters limiting sediment suspension (Dantas et al. 2019).

**Table 3.** Physio chemical parameters of water bodies

Parameters	Jagadishpur Reservoir			Gajedi Lake		
	Pre-monsoon	Winter	Post-monsoon	Pre-monsoon	Winter	Post-monsoon
pH	8.58±0.59	8.46±0.10	8.19±0.30	8.26±0.11	8.42±0.24	8.16±0.4
DO (mg/L)	8.10±0.29	7.58±1.46	8.36±0.72	8.12±0.36	8.02±0.46	8.14±0.74
Temperature (°C)	32.07±1.22	19.59±0.55	28.69±1.53	33.24±0.93	20.04±2.10	28.87±0.65
Transparency (cm)	83.76±8.24	39.7±13.91	55.97±11.33	32.23±8.71	39.09±12.88	38.83±13.06
Carbon dioxide (ppm)	3.31±1.65	7.22±1.42	5.91±1.17	4.63±0.45	6.00±1.76	6.87±1.63
Alkalinity (mg/L)	172.30±95.45	315.70±36.41	319.10±32.41	276.30±13.73	255.00±27.52	241.00±22.35
Total hardness (mg/L)	102.80±19.99	115.50±19.83	155.10±19.62	112.60±6.70	127.30±28.87	117.00±21.02

In contrast, the lake may experience more surface runoff or eutrophication, increasing turbidity and reducing clarity (Schallenberg 2021). Alkalinity, which reflects the buffering capacity of water through the presence of bicarbonate, carbonate, and hydroxide ions, was also significantly higher in the reservoir. The greater variability and mean alkalinity observed may reflect differences in geology, inflow from streams, or anthropogenic influences such as agricultural runoff contributing additional bicarbonates (Boyd 2015). The result was also supported by the geographic location of two lentic systems and its geological structure (Dhital 2015).

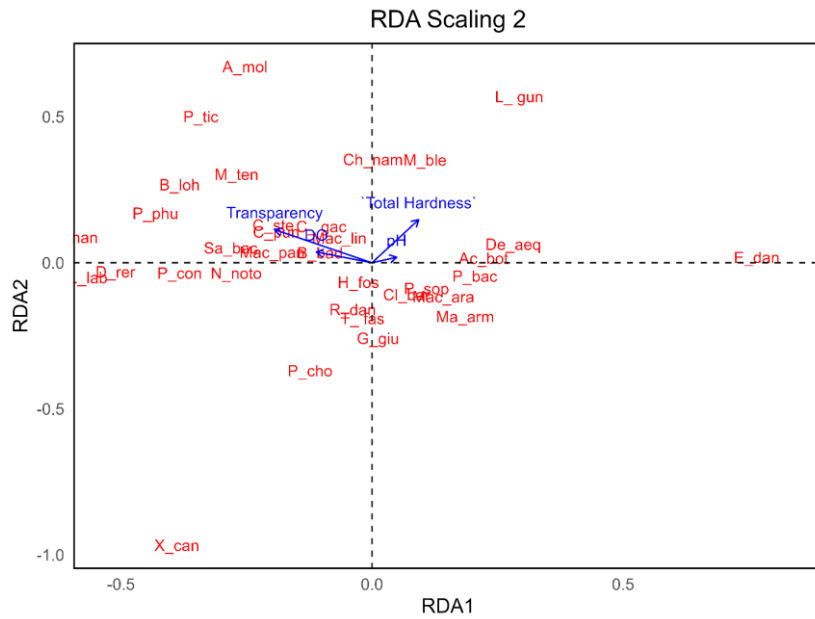
#### Relationship between environmental parameters and fish species abundance

In Jagadishpur Reservoir, the RDA model showed only 1.14% of the variation in fish community composition was based on the environmental variables (adjusted  $R^2$ : 0.0114). The first axis accounted for 26.49% of the explained variation (eigenvalue: 0.018), while the second axis explained 25.54% (eigenvalue: 0.017) (Figure 7). A permutation test indicate that the RDA model was not statistically significant at the 0.001 level. Despite the lack of overall significance, species-environment correlation revealed certain trends. *Lepidocephalichthys guntea* was positively correlated with axis 1 (0.3611) and axis 2 (0.5693) and was associated with total hardness and pH. *Devario aequipinnatus* exhibited a positive correlation with axis 1 (0.3591) and axis 2 (0.0636) but was negatively associated with DO. *Esomus danrica* showed a strong positive correlation with axis 1 (0.8303) and a weaker correlation with axis 2 (0.0185), while being negatively associated with transparency. *A. botia* was positively correlated with axis 1 (0.2914) and axis 2 (0.1578) but negatively associated with DO. Lastly, *P. baculis* was positively correlated with axis 1 (0.2676), negatively correlated with axis 2 (-0.0458), and was negatively associated with transparency (Figure 7).

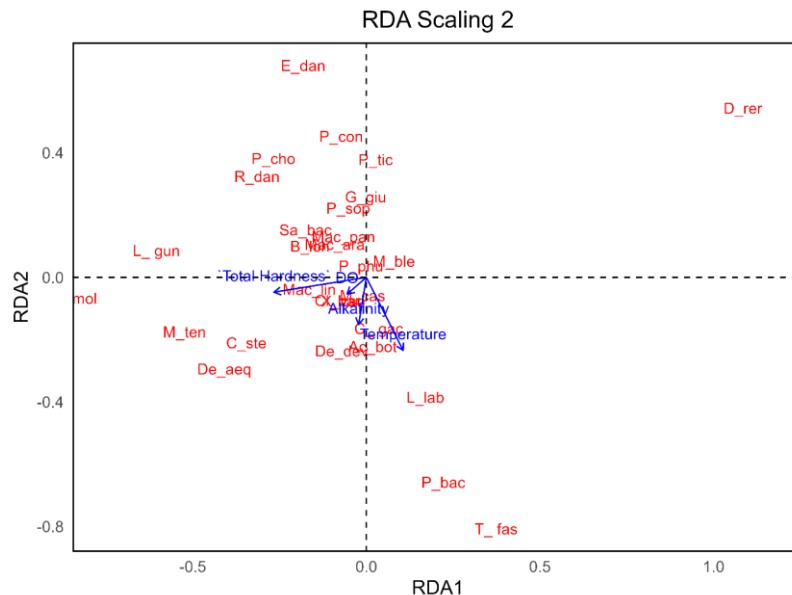
In Gajedi Lake, the RDA showed 1.56% of the variation in fish community composition was based on the environmental variables (adjusted  $R^2$ : 0.0156). The first axis accounts for 31.87% of this variation (eigenvalue: 0.026), while the second axis represents 30.71% (eigenvalue: 0.025) (Figure 8). The permutation test indicated that the overall RDA model was not significant at the 0.05 confidence level. However, when considering the selected environmental variables (DO, temperature, alkalinity, and total hardness) the RDA model became

significant at the 0.001 level, explaining 5.57% of the variance (adjusted  $R^2$ : 0.0557). Among these, temperature and total hardness showed significant variation. Species-environment correlation highlighted distinct patterns. *Danio rerio* was positively correlated with axis 1 (1.1627) and axis 2 (0.5432) but negatively associated with the total hardness. *M. bleekeri* exhibited positive correlations with axis 1 (0.1647) and axis 2 (0.05162) and was positively associated with temperature. *Channa gachua* showed a positive correlation with axis 1 (0.1349), a negative correlation with axis 2 (-0.1643), and a strong association with alkalinity. *Trichogaster fasciata* was positively correlated with axis 1 (0.4607) and temperature but negatively correlated with axis 2 (-0.8072). *Laubuka laubuka* displayed a positive correlation with axis 1 (0.2466), a negative correlation with axis 2 (-0.3853), and a strong association with temperature. Lastly, *P. baculis* was positively correlated with axis 1 (0.3102) and temperature but negatively correlated with axis 2 (-0.6580) and the total hardness (Figure 8).

However, a low adjusted  $R^2$  is not uncommon in ecological community data, especially in complex systems like freshwater ecosystems where biotic interactions, historical events, and unmeasured habitat variables (e.g., vegetation cover, microhabitat, and predation) also play significant roles (Mehner et al. 2021), still the RDA can reveal meaningful species-environment relationships. Many studies revealed that the changes of environmental factors viz, DO, pH, water depth, and turbidity affect fish community structure (Goetz et al. 2015; Missaghi et al. 2017). For instance, in our study, *L. guntea* prefers alkaline waters likely due to the adapted vegetated, muddy habitat (Endruweit 2016). *Devario aequipinnatus* and *A. botia* are associated with low dissolved oxygen, suggesting the use of stagnant or organic-rich areas whereas *E. danrica* and *P. baculis* are linked to vegetated zones, possibly for predator avoidance or prey access (Jayaram 2012). *D. rerio* favors oxygen-rich and clean water (Parichy and Postlethwait 2020) whereas *M. bleekeri* thrives in warm, oxygenated benthic zones with abundant food (Jayaram 2022). *Channa gachua* shows tolerance to varied water quality, with alkalinity associations indicating physiological resilience (Mouludi-Saleh et al. 2019). *T. fasciata* is adapted to low DO, stagnant habitats via air-breathing, while *L. laubuka* prefers shallow, sunlight water, likely for feeding or reproduction (Epa and Narayana 2016). The Kruskal-Wallis (Dunn's test) and SIMPER analysis of seasons also validated the findings of environmental variables and RDA outputs.



**Figure 7.** Redundancy Analysis (RDA) showing the relationship between fish species and environmental variables in Jagadishpur Reservoir. Species are abbreviated using the first letter(s) of the genus and species names: *Acanthocobitis botia* (Ac\_bot), *Amblypharyngodon mola* (A\_mol), *Badis badis* (B\_bad), *Botia lohachata* (B\_loh), *Chanda nama* (Ch\_nam), *Channa gachua* (C\_gac), *Channa punctata* (C\_pun), *Channa stewartii* (C\_ste), *Clarias batrachus* (Cl\_bar), *Danio rerio* (D\_rer), *Devario aequipinnatus* (De\_aeq), *Esomus danrica* (E\_dan), *Glossogobius guiris* (G\_giu), *Heteropneustes fossilis* (H\_fos), *Laubuka laubuca* (L\_lab), *Lepidocephalichthys guntea* (L\_gun), *Macrognathus aral* (Mac\_ara), *Macrognathus lineatamaculatus* (Mac\_lin), *Macrognathus pancalus* (Mac\_pan), *Mastacembelus armatus* (Ma\_arm), *Mystus bleekeri* (M\_ble), *Mystus tengara* (M\_ten), *Nandus nandus* (N\_nan), *Notopterus notopterus* (N\_noto), *Parambassis baculis* (P\_bac), *Pethia conchoniensis* (P\_con), *Pethia phutunio* (P\_phu), *Pethia ticto* (P\_tic), *Puntius chola* (P\_cho), *Puntius sophore* (P\_sop), *Rasbora daniconius* (R\_dan), *Salmostoma bacaila* (Sa\_bac), *Trichogaster fasciata* (T\_fas) and *Xenontodon cancila* (X\_can)



**Figure 8.** Redundancy Analysis (RDA) showing the relationship between fish species and environmental variables in Gajedi Lake. Species are abbreviated using the first letter(s) of the genus and species names: *Acanthocobitis botia* (Ac\_bot), *Amblypharyngodon mola* (A\_mol), *Botia lohachata* (B\_loh), *Channa gachua* (C\_gac), *Channa stewartii* (C\_ste), *Clarias batrachus* (Cl\_bar), *Danio rerio* (D\_rer), *Devario aequipinnatus* (De\_aeq), *Devario devario* (De\_dev), *Esomus danrica* (E\_dan), *Glossogobius guiris* (G\_giu), *Laubuka laubuca* (L\_lab), *Lepidocephalichthys guntea* (L\_gun), *Macrognathus aral* (Mac\_ara), *Macrognathus lineatamaculatus* (Mac\_lin), *Macrognathus pancalus* (Mac\_pan), *Minimugil cascasia* (M\_cas), *Mystus bleekeri* (M\_ble), *Mystus tengara* (M\_ten), *Parambassis baculis* (P\_bac), *Pethia conchoniensis* (P\_con), *Pethia phutunio* (P\_phu), *Pethia ticto* (P\_tic), *Puntius chola* (P\_cho), *Puntius sophore* (P\_sop), *Rasbora daniconius* (R\_dan), *Salmostoma bacaila* (Sa\_bac), *Trichogaster fasciata* (T\_fas) and *Xenontodon cancila* (X\_can)

In conclusion, a total of ichthyofaunal species belonging to 9 Orders and 18 Families were recorded from Jagdishpur Reservoir and Gajedi Lake, both representing typical wetland ecosystems that support indigenous freshwater fish communities. Species such as *R. daniconius* and *P. sophore* were dominant in the Jagdishpur Reservoir, while *A. mola* was most abundant in Gajedi Lake. The Shannon-Wiener diversity index ( $H'$ ) ranged from 1.54 to 2.77, indicating moderate biodiversity, while Pielou's evenness index ( $J$ ), ranging from 0.72 to 0.93, suggested a relatively balanced distribution of species within these water bodies. It is determined that the environmental variables such as DO, temperature, alkalinity, total hardness, pH, and water transparency play a crucial role in shaping fish assemblages, and therefore it is essential to monitor and manage these factors carefully to prevent pollution and maintain ecological balance. These findings highlight that the lakes still support a rich diversity of fish species and emphasize the importance of conserving these ecosystems to protect their aquatic biodiversity for future. Moreover, further research is essential to better understand and existing management practices and their role in promoting both community wellbeing as well as the long-term sustainability of important indigenous wetland species.

#### ACKNOWLEDGMENTS

The first author, SS, gratefully acknowledges the Nepal Academy of Science and Technology (NAST) for providing the Ph.D. fellowship. The authors are grateful to the Jagdishpur Reservoir Management Multi-Stakeholder Forum, the Gajedi Lake Management Committee, and local fishermen for their support during the fieldwork. This research was conducted with permission from the Department of Forests and Soil Conservation (GoN/MoFE), Nepal.

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