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Wintering ecology of Ibisbill (*Ibidorhyncha struthersii*) in Rapti-Khulekhani III–Samari (RKS) river complex of Makwanpur, Central Nepal

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ABSTRACT

The Ibisbill (*Ibidorhyncha struthersii*) is a rare, habitat-specialist wader dependent on undisturbed riverine ecosystems in Asia's high-altitude and mid-hill regions. This study examined the wintering ecology and habitat factors influencing Ibisbill abundance in the Rapti– Khulekhani III–Samari (RBS) River Complex in Makwanpur, central Nepal. Standardized 3 km transect surveys were conducted along the Rapti, Khulekhani III, and Samari rivers from November 2024 to March 2025. A total of 24 individuals were recorded, with the highest mean density observed in Khulekhani III (6 birds/km²), followed by Rapti (2 birds/km²) and Samari (1 bird/km²). One-way ANOVA revealed significant variation in density across sites ($F = 8.33$, $p = 0.005$), and Tukey's HSD post-hoc test confirmed a significantly greater density in Khulekhani III compared to the other rivers. The species exhibited a clumped distribution pattern ($S^2/\bar{r}=7$), indicating aggregation in localized, suitable habitats. These habitats were characterized by native riverine grassland dominated by Saccharum spontaneum and Imperata cylindrica. Linear regression analysis revealed that human disturbance, sand extraction, and habitat fragmentation negatively influenced Ibisbill abundance, while native riverine grass cover and greater distance from settlements had significant positive effects. Elevation was not a significant predictor. These results highlight the ecological importance of the River Complex and underscore the need for targeted conservation actions. Effective protection of Ibisbill wintering habitat should prioritize the regulation of sand extraction, reduction of anthropogenic disturbance, and promotion of community-based conservation. Sustained monitoring and habitat management are critical to ensure the long-term survival of this habitat-specialist wader in Nepal's mid-hill river systems.

KEY WORDS

Ibisbill; Riverine habitat; Riverine grassland; Ecology

ARTICLE HISTORY

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Introduction

The Ibisbill (*Ibidorhyncha struthersii*) is a distinct and infrequently seen wading bird that is specially adapted to high-altitude river systems. It is generally located along swiftly flowing Mountain Rivers and streams that feature gravel or shingle beds. Its unique appearance, a greyish body, curved bright red beak, black facial markings, and a striking black band across the chest, makes it easy to distinguish [1]. During the breeding period, the bird inhabits elevations between 3,800 and 4,200 meters, and moves to lower elevations ranging from 100 to 915 meters in the winter months [2]. Its distribution spans across the Himalayas and Central Asia, including countries such as Nepal, India, Bhutan, China, Afghanistan, Pakistan, Russia, Myanmar, and several Central Asian states like Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan [3]. In Nepal, it mainly appears in alpine habitats during the summer, including Kyangjin in the upper Langtang Valley, Sagarmatha National Park, Makalu Barun National Park, and Khaptad National Park. In winter, it migrates to lower-lying areas, with sightings reported from the Rapti River in Hetauda and the lower Arun River [4-6]. There is a significant lack of ecological research on its status, distribution, habitat use, range, and threats to its survival. So, this research aimed to fill these critical knowledge gaps by performing systematic surveys along selected river stretches in central Nepal to determine the species' winter range, population density, and habitat preferences. Moreover, it sought to identify human-induced pressures and initiate community-led conservation activities, particularly by promoting local education and encouraging long-term guardianship of the species and its sensitive river environments.

Materials and Methods

Study area

Makwanpur District, located at 27°29′07.44″ N and 85°03′04.68″ E in central Nepal, served as the geographical context for this research. The Rapti–Khulekhani III–Samari (RKS) River Complex (Figure 1), the study's core focus, has been recognized as an important winter refuge for migratory water birds, including the Ibisbill (*Ibidorhyncha struthersii*), with prior records reported by local observers and community residents. Originating from the Mahabharat Range, the RKS river system flows into the Narayani River, comprising several key tributaries, namely the Samari, Karra, Kukhreni, Reu, Panchand, Lothther, and Manahari Rivers. The study region is situated at an average elevation of about 555 meters above sea level. In its upper section, the river displays a winding or meandering flow, which gradually shifts into a braided channel across the middle and lower reaches. The riverbed composition is dominated by cobbles and boulders, interspersed with pebbles, sandy areas, and fine silt substrate types ideal for riverine specialists like the

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Ibisbill. This river corridor's ecological value is highlighted by its role in supporting 81 species of wetland-associated birds, which account for 41.9% of Nepal's total wetland bird species diversity [7].

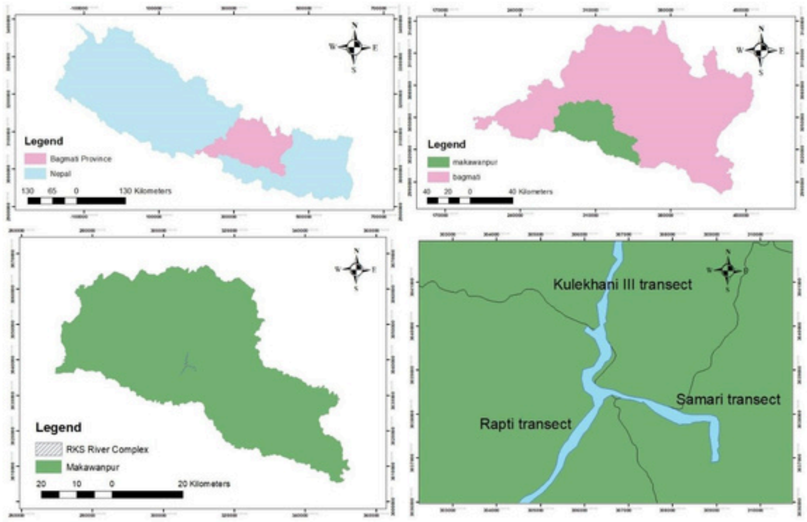

Figure 1. Showing map of study area.

Sampling design

Bird survey methods

We carried out focused field surveys to determine the occurrence and distribution of the Ibisbill (*Ibidorhyncha struthersii*) by employing line transect techniques following the protocol outlined by Sutherland [8]. Three separate transects, each measuring 3 kilometers, were laid along distinct sections of the river, running parallel to the banks in areas that provided suitable habitats, including shingle substrates, braided water channels, and wide, gravel-rich riverbeds. To reduce spatial overlap and ensure comprehensive area coverage, transects were placed 200 meters apart, totaling a 9 km survey stretch. Transects were walked at a uniform pace between 07:00 and 10:00 AM. We recorded only those Ibisbills that were visually or acoustically detected within 100 meters on either side of the transect, creating a 200-meter-wide detection zone. Birds flying behind or overhead were not counted to prevent duplication. When notable river bends or distinct habitat changes occurred, new segments of transects were delineated. Each transect was surveyed twice per month to account for temporal variations in species presence.

Surveys took place over 30 days, with six survey days monthly from October to March, aligning with the Ibisbill's main wintering season. Work was postponed during adverse weather to maintain data consistency in detection probability. Field observations were supported by Bushnell 10×40 binoculars for identification and a Canon camera with a 50× zoom for photographic evidence. Bird identification was guided by Grimmett et al., and any uncertain sightings were recorded and later verified by expert ornithologists [9].

Vegetation survey

To gain deeper insight into the habitat preferences of the Ibisbill (*Ibidorhyncha struthersii*), direct field observations were conducted along systematically laid transects, where key environmental variables, including slope, aspect, elevation, ground cover, disturbance indicators, and distance from human settlement, were recorded. Each transect was 3 kilometers in length, with vegetation sampling carried out at 1-kilometer intervals, resulting in three vegetation plots per transect (Figure 2).

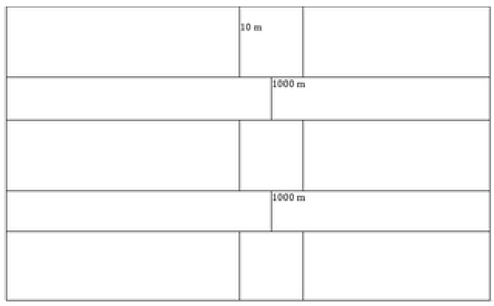

Figure 2. Sketch of the square quadrat laid in line transect of each grid for Habitat assessment.

For vegetation structure analysis, we adopted the methodology described by Schemnitz and Dhami et al., establishing 10 × 10 m quadrats for trees, 4 × 4 m quadrats for shrubs, and 1 × 1 m quadrats for herbaceous species (Figure 3) [10,11].
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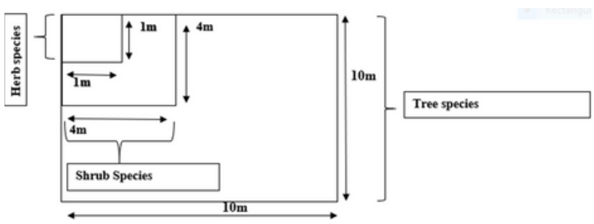

Figure 3. Layout of the quadrates for vegetation survey.

Data analysis

Data were analysed by using SPSS and MS Excel. One way Analysis of Variance (ANOVA) was used to compare Ibisbill Density with respect to transect lines. The Tukey LSD Test was used to identify which transect line had a significant difference in population density compared to the other two transect lines.

H_0: There is no significant difference in Ibisbill Density between the transect lines.

H_1: There is a significant difference in Ibisbill Density between the transect lines

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Distribution and estimation of the Ibisbill

The population density of the Ibisbill was estimated based on direct counts within systematically surveyed plots. The density (D) was calculated using the following formula:
D = Total number of individuals recorded / Total area surveyed (in km^2)

This formula provides an estimate of the number of ibis individuals per square kilometer.
Similarly, the distribution pattern of Ibisbill was assessed by calculating the variance-to-mean ratio (S^2/a) following Odum (1971) and Dhami et al. [11,12]:

S^2/a
Where:
S^2 = variance = $(1/n)\ \Sigma(x - a)^2$
x = number of individuals observed per sampling unit
a = mean number of individuals per unit
n = number of sampling units
Interpretation:
If $S^2/a = 1$, the distribution is random
If $S^2/a < 1$, the distribution is uniform
If $S^2/a > 1$, the distribution is clumped

Habitat preference of the Ibisbill

The collected field data on Ibisbill abundance (count) and associated environmental and anthropogenic factors were compiled in Microsoft Excel and then imported into IBM SPSS Statistics (version 26) for analysis. The dependent variable was Ibisbill count, and six predictor variables were selected: human disturbance, sand extraction, habitat fragmentation, ground cover (riverine grassland - native), distance from settlement, and elevation (in meters). A linear regression model was used to assess how these variables influenced Ibisbill abundance, as shown in Equation 1:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon$$

Where,
Y represents Ibisbill count
X_1 to X_6 represent the predictor variables.

All predictor variables were entered simultaneously into the regression model using SPSS. Before final analysis, assumptions of linearity, normality of residuals, independence, and homoscedasticity were checked. The output "Coefficients" table provided standardized beta values, significance levels (p-values), and standardized coefficients to evaluate the direction (positive or negative) and strength of influence of each predictor. Variables with p-values less than 0.05 were considered statistically significant, indicating either a positive, negative, or non-significant influence on Ibisbill abundance in the study area.

Result and Discussions

Distribution and population status of the Ibisbill

A total of 24 individuals of Ibisbill were recorded from the river basin of Rapti-Khulekhani III-Samari (Table 1), indicating a healthy presence of the species in the study area. The habitat is mainly dominated by riverine grassland with native species such as Saccharum spontaneum and Imperata cylindrica. The overall distribution pattern of the Ibisbill was found to be clumped, as indicated by a variance-to-mean ratio of 7, which is significantly greater than 1. Additionally, the population density was estimated at 13.33 per square kilometer.

Table 1. Showing the total frequency observed and Density with respect to the transect.

Transect	Description of the Transect line	Frequency	Density (birds/km²)
Rapti	Rapti Bridge to Samari -3km Transect line	3	5
Khulekhani III	Upper Rapti to Trikhandi -3 Km Transect line	18	30
Samari	Samari to Bhalu Khola -3 km Transect line	3	5
Total		24	13.33

The ANOVA test indicated a statistically significant difference in the mean Ibisbill densities among the three river basins ($F = 8.33$, df = 2.12, $p = 0.0054$). This suggests that at least one site has a significantly different average density. Post-hoc analysis using Tukey's HSD test revealed that the mean density in Samari (mean = 6 individuals/km^2) was significantly higher than in both Rapti (mean = 1 individuals/km^2) and Khulekhani III (mean = 1 individuals/km^2). However, there was no significant difference between Rapti and Bhalu Khola. These results indicate that Samari provides more favorable conditions for Ibisbill presence compared to the other two sites.

The GIS mapping (Figure 4) clearly depicts the variation in bird observation frequency across three 3-km transect lines within the study area. The Khulekhani III transect (Upper Rapti to Trikhandi) recorded the highest number of bird sightings (18), while both the Rapti (Rapti Bridge to Samari) and Samari (Samari to Bhalukhola) transects recorded only 3 sightings each. This spatial pattern indicates that Khulekhani III serves as a key hotspot for bird activity, likely influenced by favorable ecological conditions.

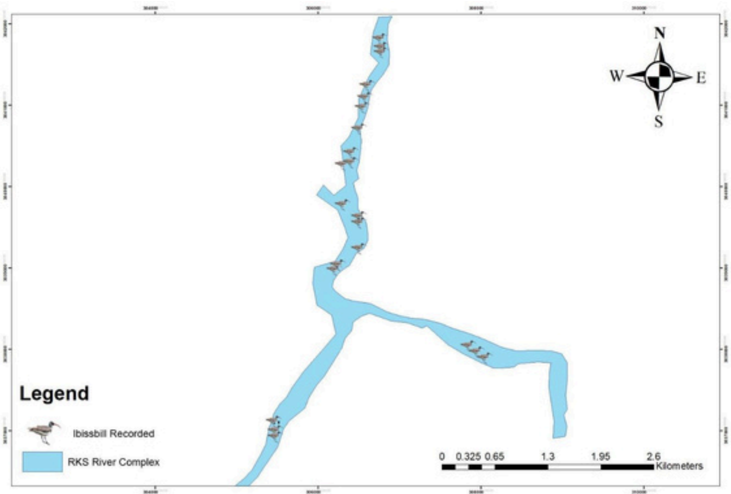

Figure 4. Showing the GIS mapping and distribution of the Ibisbill within study area.

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Habitat attributes associated with the observation of the Ibisbill

The linear regression analysis produced a statistically robust model ($F = 9.87$, $df = 6, 23$, $p < 0.01$), signifying that the selected ecological and anthropogenic factors collectively exert a meaningful impact on the abundance of Ibisbill (*Ibidorhyncha struthersii*) within the research area. Out of the six predictor variables assessed, five demonstrated statistically significant correlations with Ibisbill numbers, indicating both adverse and favorable effects (see Table 2).

Human disturbance ($B = -2.4$, $p = 0.004$), sand mining ($B = -2.0$, $p = 0.005$), and habitat fragmentation ($B = -1.8$, $p = 0.003$) were significant negative predictors. These outcomes imply that rising anthropogenic pressures, including unregulated human presence, extractive activities, and habitat discontinuities, diminish habitat quality for the Ibisbill, likely due to heightened disturbances and the degradation of critical foraging zones. Conversely, native riparian grassland cover ($B = 3.1$, $p = 0.002$) and greater distance from human settlements ($B = 2.2$, $p = 0.003$) were positively associated with Ibisbill abundance.

These patterns emphasize the ecological value of undisturbed native vegetation (e.g., Saccharum spontaneum, Imperata cylindrica) in offering essential habitat elements and the species' inclination towards areas less affected by human activity. Elevation ($B = 0.4$, $p = 0.695$), however, did not emerge as a significant factor, suggesting that within the altitudinal span of the study, elevation plays a limited role in shaping Ibisbill presence.

In summary, the findings indicate that effective conservation of the Ibisbill should prioritize safeguarding and rehabilitating native riparian grasslands while addressing anthropogenic stressors, particularly sand extraction and habitat fragmentation within riverine ecosystems.

Table 2. Presents the habitat parameters that significantly influence the probability of Ibisbill (*Ibidorhyncha struthersii*) occurrence in the study area.

SN	Predictor	Unstandardized Coefficient (B)	Std. Error	Standardized Coefficients (Beta)	t-value	Sig. (p-value)	Significant
	(Constant)	1.5	0.5	—	3	0.01	Yes
1	Human Disturbance	-2.4	0.7	-0.6	-3.429	0.004	Yes
2	Sand Extraction	-2	0.6	-0.55	-3.333	0.005	Yes
3	Habitat Fragmentation	-1.8	0.5	-0.5	-3.6	0.003	Yes
4	GroundCover: Riverine Grassland (Native)	3.1	0.8	0.62	3.875	0.002	Yes
5	Distance from Settlement	2.2	0.6	0.53	3.667	0.003	Yes
6	Elevation	0.4	1	0.07	0.4	0.695	No

Discussions

The present study contributes to the growing understanding of Ibisbill wintering ecology by providing detailed ecological data from the Rapti–Samari–Khulekhani III River Complex, and it builds on findings from previous studies across the species' range (Table 3). Compared to Shrestha and Lakhey, who recorded 18 individuals across three sub-populations in the East Rapti River, this study observed 24 individuals, with Khulekhani III showing the highest density (6 birds/km²), suggesting that certain less-disturbed stretches may offer more favorable conditions [6]. Although density estimates were not provided in the earlier studies, Bhusal et al. and Haq et al. similarly reported clumped or aggregated distributions, reinforcing the Ibisbill's strong habitat selectivity [13,14]. In terms of behavior, Bhusal et al. reported that feeding and resting constituted over 75% of the Ibisbill's activity budget, which is consistent with Ye et al. and Haq et al., who recorded more than 80% of time spent on these behaviors [13-15]. These findings suggest that undisturbed gravel-rich riverbeds are essential for winter foraging and energy conservation. Habitat preferences across all studies point to native riverine grasslands and gravel substrates as critical features. Threats vary in type and severity but consistently include anthropogenic pressures such as sand and boulder mining, settlement encroachment, and disturbance. While previous studies from Bhusal et al. have described these threats qualitatively, the present study statistically confirmed the negative impacts of sand extraction, habitat fragmentation, and human disturbance, along with the positive influence of native grass cover and distance from settlements. This offers stronger empirical evidence to guide conservation actions [13].

All studies converge on similar recommendations: controlling resource extraction, mitigating human disturbance, and engaging local communities in riverine habitat protection. These consistent conclusions across temporal and geographical contexts highlight the urgent need for integrated, site-specific conservation interventions throughout the Ibisbill's wintering range. These studies highlight that Ibisbills depend heavily on undisturbed riverine ecosystems, spending most of their time foraging in gravel beds for foraging. The persistence of the species in Nepal's mid-hill rivers will rely on habitat protection, controlling extraction pressures, and integrating community-based river conservation strategies.

Table 3. Summary of Key Findings and Comparison with Previous Studies on Ibisbill Ecology.

Parameter	Present Study (2025)	Shrestha & Lakhey [6]	Bhusal et al. [13]	Ye et al. [14]/ Haq et al. [15]
Study Area	Rapti–Samari–Khulekhani III River Complex, Makwanpur	East Rapti River, Hetauda	East Rapti River, Hetauda	Rivers of Southwest China / River Sindh India
Ibisbill Recorded	24 individuals (Khulekhani II: 15; Rapti: 6; Samari: 3)	18 individuals in 3 sub-populations	6 individuals	Not specified
Density (birds/km²)	Samari: 6, Rapti: 2, Khulekhani III: 1	Not mentioned	Not mentioned	Not mentioned

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Distribution Pattern	Clumped ($S^2/\bar{r} = 7$)	Clustered (3 sub-populations)	Clumped	Aggregated
Key Activity Behavior (%)	Not quantified	Not quantified	Feeding: 55%, Resting: 22%, Others	>80% Foraging + Resting
Habitat Preference	Riverine grasslands with native grasses, gravel beds	Same river type with suitable substrate	Similar gravel riverine habitat	Gravel banks and shallow rivers
Main Threats	Sand extraction, settlement proximity, fragmentation	Sand and boulder mining, disturbance	Human disturbance, sand extraction	Water pollution, mining, climate change
Significant Predictors	Grass cover (+), Distance (+), Disturbance (−), Extraction (−)	Not statistically analyzed	Not statistically analyzed	Not statistically analyzed
Conservation Recommendations	Regulate extraction, reduce disturbance, community action	Same emphasis	Similar recommendations	Emphasis on habitat protection

Conclusions

This study provides critical insights into the wintering ecology and habitat preferences of the Ibisbill (*Ibidorhyncha struthersii*) within the Rapti–Khulekhani III–Samari River Complex in Central Nepal. Our findings confirm that Ibisbill abundance is strongly influenced by habitat quality and anthropogenic pressures, with significantly higher densities observed in the Samari River, which retains more intact riverine grasslands and lower disturbance levels. The observed clumped distribution pattern emphasizes the species' reliance on specific habitat patches characterized by native vegetation and minimal human interference. Regression analysis further identified key negative impacts of human disturbance, sand extraction, and habitat fragmentation on Ibisbill presence, while distance from settlements and native riverine grass cover positively influenced their abundance. These results underscore the urgent need for targeted conservation actions that prioritize habitat protection and mitigation of human-induced threats. Maintaining riverine ecosystem integrity through sustainable management and community engagement will be vital to securing the long-term survival of this rare and specialized wader in Nepal's mid-hill river systems.

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Disclosure Statement

No potential conflict of interest was reported by the author.

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