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Habitat Preference and Foraging Technique of River Lapwing (*Vanellus duvaucelii* Lesson, 1826) in Punatsangchhu River, Bhutan

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Abstract

The River Lapwing is experiencing population decline and has recently been categorised under near threatened. This study examined the habitat preferences and foraging patterns of River Lapwing in the Punatsangchhu River in Bhutan. A systematic line transect method covering 123 km, incorporating 42 sampling stations, was deployed to observe foraging technique and foraging success of River Lapwing. In addition, habitat parameters, water parameters and macroinvertebrate were recorded to observe their relationship to River Lapwing occurrence. The present study results indicated that the River Lapwing occurrence correlated with higher macroinvertebrate diversity (H' = 1.93) compared to those where the River Lapwing did not occur. Sandbars were the primary foraging ground for River Lapwings, and a moderate positive relationship was observed between the sandbar used by the River Lapwing and the occurrence of the River Lapwing (r = 0.44, p = 0.00). However, human disturbance along the river and the occurrence of River Lapwing (r = -0.34, p = 0.00) had a moderate negative relationship. Among the five foraging techniques used by River Lapwing across the study area, walk-halt-peck (37.96%) was the highest, followed by walk-halt-probe (30.56%). Moreover, the River Lapwing foraging success was more than half (62.96 ± 9.53%) of the total attempts. Thus, River Lapwing occurrence was positively associated with higher macroinvertebrate diversity and the availability of sandbars along the river, while human disturbance negatively impacted their occurrence.

Keywords: Foraging technique, foraging behavior, habitat preference, River Lapwing, sandbar

Introduction

River Lapwing (*Vanellus duvaucelii* Lesson, 1826) is a medium-sized shorebird with black, grey and brown plumage (Dykstra, 2023). The bird appears entirely sedentary and does not make long-distance migrations from the sandbar (Wiersma & Kirwan, 2020). However, River Lapwangexhibits local seasonal movements (1 to 3 km) between nesting and foraging sites (Thompson *et al*., 1994; Mishra *et al*., 2018). River lapwings' presence reflects the health of river ecosystems, as they rely on undisturbed sandbanks and wetlands for nesting and feeding (Mishra *et al*., 2018; Mishra *et al*., 2024). Thus, they help to regulate insect populations by feeding on various macroinvertebrates, contributing to natural pest management (Ausden *et al*., 2003; McKeever, 2003; Mishra *et al*., 2018). They nest on exposed riverbanks and contribute to the dynamics of sediment stabilisation and vegetation growth (Ausden *et al*., 2003; McKeever, 2003). Protecting river lapwing habitats ensures survival of other species that share the same ecosystem

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(Mason, 2019). Although River Lapwing is found in southern China, Southeast Asia and Northern India (Chandler, 2009), this bird is listed as one of the most threatened river bird species (Arya *et al*., 2020). Ahmed *et al*. (2018) claimed that Bangladesh has the highest density of River Lapwing in the world. Due to the lack of protection for the River Lapwing Habitat, concerns have been raised about the population and habitat of the River Lapwing in Bangladesh (Ahmed *et al*., 2018). However, the factor which is a serious threat to River Lapwing is mainly due to human disturbance affecting the habitat preferences of the River Lapwing (Thewlis *et al*., 1998; Ahmed *et al*., 2018; Hassan *et al*., 2019; Arjun *et al*., 2023).

Foraging by birds is a complex series of behavioural movements consisting of searching, assessing, chasing and handling, which ultimately leads to food consumption (Stephens *et al*., 2008). Generally, prey availability and accessibility influence birds' habitat preference (Cody, 1985; Haas *et al*., 2007; Cresswell *et al*., 2010). Although River Lapwing is an obligate visual forager and prefers habitats with abundant prey, it shows several techniques such as presents wavering flight, transitional techniques and forward ground-picking patterns during foraging (Kumar *et al*., 2021). They typically attempt to capture their prey at substrate boundaries, mostly pecking on small invertebrates from the surface or low vegetation cover and probing near water (Mishra *et al*., 2018). However, factors such as size of sandbar, depth of water body and prey abundance would impact foraging techniques of River Lapwing (Faheem, 2017; Mishra *et al*., 2018).

River Lapwing population around the world is expected to decline rapidly over the years (Mishra *et al*., 2014). Although Bhutan provides an ideal habitat for River Lapwing and many other bird species (Norbu *et al*., 2021; Dorji, 2022; Nidup & Dorji, 2024), there is little information on prey, foraging techniques and factors affecting the selection of habitat of River Lapwing. Information on habitat and foraging potentially increase conservation efforts of River Lapwing (Mishra *et al*., 2018). Additionally, prey availability may influence River Lapwing density, which could be beneficial for their management and conservation. Given the importance of this species to the environment, the study was conducted to investigate the habitat preference and foraging technique of River Lapwing in the Punatsangchhu River.

Materials and Methods

Study area

The Punatshangchhu river was chosen for the study due to its diverse altitudinal range and for its macroinvertebrate diversity (Dorji, 2022). The river presents altitudinal changes and forms sandbars along its course (Rahman *et al*., 2024). The river is the longest and widest, extending from the extreme north of Gasa to the extreme south of Dagana (Dorji, 2022; Lungten *et al*., 2023). The fieldwork was conducted along the Punatsangchhu River (27°52'43.28"–27°0'5.96" N and 89° 43'56.23"–90°4'7.52" E) at an altitude of 316-2,148 masl, and sharing boundary of five districts (Gasa, Punakha, Wangdue Phodrang, Dagana and Tsirang) (Figure 1).

Sampling design

A systematic line transect method was used covering 123 km of river length from Gasa to Dagana along Punatsangchhu River. The sampling stations and points were generated using ArcGIS. In addition, the starting and the endpoint of the 123 km sampling length were included as sampling stations. Thus, a total of 42 sampling stations were deployed, with a 3 km distance between stations. The sampling intensity of the study was calculated as 0.34 samples/km.

Data collection

Habitat parameters and water parameters

The altitude was recorded from each sampling using a GPS handset. The width and slope of the river bank were measured using a range finder (Martin, 2022). Water surface elevation and depth of the river were extracted from a global database of (HydroSHEDS) bank full widths and depths (Giachetta & Willett, 2018). The area of the sandbar across the sampling river length and the distance of the sampling station from the road were extracted using Google Earth Pro to investigate the relationship with the occurrence of River Lapwing along Punatsangchhu River.

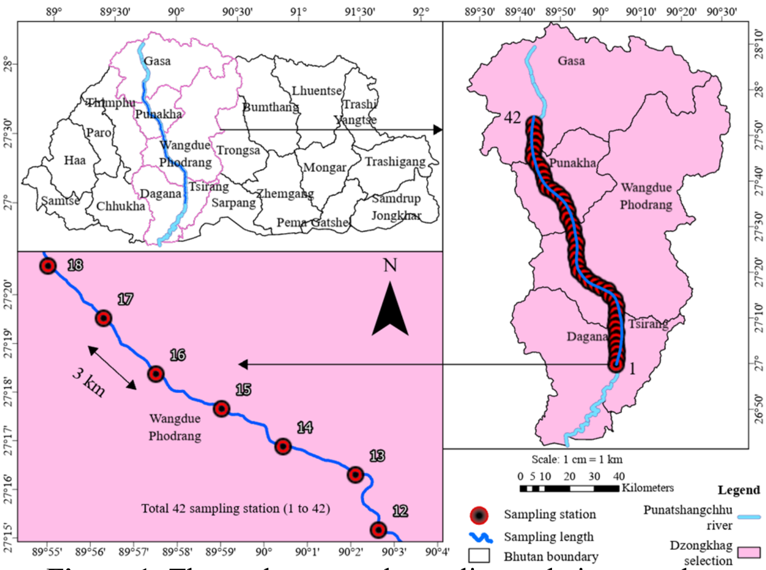

Figure 1: The study area and sampling technique used along the Punatsangchhu River

The water parameters were recorded from each sampling station in the study area. The pH, total dissolved solids (TDS), conductivity, and temperature of water were measured using a portable multimeter. The velocity was measured using a digital handheld water velocity meter by averaging three observations at different river depths (1 m distance from shore, with three separate readings taken at a 5 m interval). The average of water parameters (Table 1) was recorded using the Biodiversity Monitoring and Social Survey Protocol of Bhutan (Department of Forest and Park Services [DoFPS], 2020).

Macroinvertebrate record

For the collection of macroinvertebrates using a D-frame net with a mesh size of 250 µm, approximately 1 m of water depth was sampled at each sampling site using the 3-minute kick sweep method (Armitage & Hogger, 1994; Lungten *et al.*, 2023; Ntislidou *et al.*, 2023). The samples collected were rinsed with water into the end of the net and were sorted using sieve and forceps. The macroinvertebrates samples from each sampling station were sent for identification to the College of Natural Resources, Lobesa laboratory after being preserved in a 95% ethanol solution (Simmons, 1995; Moreau *et al.*, 2013). The macroinvertebrates were identified at family level using taxonomic keys and morphological descriptions provided by Klemm *et al.* (2002). The Shannon Diversity Index (*H'*) and Shannon Evenness Index (E_H) were used for the assessment and comparison of potential macroinvertebrate communities.

River Lapwing observation

To ensure a maximum number of counts, a combination of fixed-point counts and a non-random opportunistic technique with a 50 ob-

Table 1: Descriptive statistics of water parameters from 42 sampling stations along the Punatsangchhu River

Water parameter	Mean ± SD
pH	7.82 ± 0.18
Velocity (m/s)	0.71 ± 0.12
Total dissolved solids (mg/l)	53.84 ± 6.28
Conductivity (µS/cm)	107.68 ± 12.55
Temperature (°C)	16.89 ± 1.39

servable radius was applied (Bibby, 2000). Adult River Lapwing was identified by their colour ring combination (Thompson *et al*., 1994; Mishra *et al*., 2018). The adult River Lapwing observations were made using a Canon EOS 2000D camera and an Ultimaxx 840-1600 mm telephoto zoom lens during the study. River Lapwing adults return to their foraging and nesting grounds within 3 to 5 minutes, and males remain approximately 50 m away guarding the territory (Mishra *et al*., 2016; Mishra *et al*., 2018). This study observed adult River Lapwings in every sampling station continuously for 30 minutes to avoid possible double-counting.

The foraging patterns of River Lapwing were observed from 4 February 2024 to 18 March 2024, which is the breeding season for River Lapwing (Mishra *et al*., 2016; Mishra *et al*., 2018). The foraging pattern was recorded using binoculars (12 × 42 magnification), and actively foraging individuals were videotaped for 5 minutes at every sampling station (Altmann, 1974; Mishra *et al*., 2018). The foraging techniques were classified as walk-halt, walk-halt-peck, walk-halt-multiple pecks, walk-halt-probe, and walk-halt-multiple probes (Kumar *et al.,* 2021). In addition, foraging behaviours of the River Lapwing were categorised into four components, walking rate, feeding rate, foraging success rate, and attempt success percentage (Kumar *et al.,* 2021).

Data processing and statistical analysis
The data collected from the sampling stations were entered, sorted and cleaned using MS Excel. The video recordings from the sampling stations were transcribed and analysed using a VideoLAN Client encoder (Kumar *et al*., 2021). The statistical analysis was done using R Studio. The permutational multivariate analysis of variance was used to test the effects of River Lapwing occurrence and macroinvertebrate community. A Spearman correlation was used to examine the relationship between habitat parameters, water parameters and River Lapwing occurrence. In addition, a Spearman correlation test was used to find the relationship between sandbar, distance from the road, other human disturbances and the occurrence of River Lapwing.

Results and Discussion

Habitat characteristics of River Lapwing along the Punatsangchhu River
The habitat used by the River Lapwings showed significant variation and the River Lapwings were observed in 15 of the 42 sampling stations along the Punatsangchhu River. Table 2 summarises the key characteristics of the habitat of the River Lapwing along the river. The habitat of River Lapwing in the study area falls under 1,161 to 1,518 masl. Elsewhere, the River Lapwings were mainly found in an altitudinal range between 0 and 100 masl (Faheem, 2017; Mishra *et al*., 2020). However, the observation made in this study proves higher altitudinal habitat range variation of River Lapwings. Thus, the occurrence of River Lapwings in the mountainous

Table 2: Descriptive statistics of physical habitat parameters from 42 sampling stations along the

Habitat parameter	Mean ± SD
Altitude (m)	1030.21 ± 506.67
Width (m)	66.75 ± 36.03
Depth (m)	1.46 ± 0.31
Water surface elevation (m)	1028.53 ± 509.42
Slope of river bank (°)	15.79 ± 5.48

mid-altitude range of Bhutan showed a notable adaptation capacity.

River Lapwing occurrence and density along the Punatsangchhu River

The apparent occupancy of River Lapwing in the study area was approximately 35.71%. The highest count (7 pairs) of River Lapwing was recorded from Lakhu, Punakha, where there were open-unvegetated sandbars. However, the habitat where River Lapwings were present along the Punatsangchhu River had 94 sandbars with an average area of 14,955.1 m^2. It has been reported that River Lapwing prefers sandbars as its habitat (Thewlis *et al*., 1998; Faheem, 2017; Mishra *et al*., 2018). The density of River Lapwing was 3 birds/ha, which was close to that reported by Kumar *et al*. (2021) in India.

There were no River Lapwing above 1,653 masl and below 1,142 masl in the study area. Moreover, where River Lapwings were not present, the average width of the river (21.62 m) was recorded. The fact that River Lapwing was not found in high-altitude areas may have been due to the fact that the river was narrow and slow-flowing (Kumar *et al*., 2021). The high-altitude sampling stations, where the River Lapwing was not present, had an average river width of 21.62 m and fewer and smaller sandbars (average area of 287.6 $m^{2)}$. In addition, the low-altitude sampling stations, where the River Lapwings did not occur, had an average river width of 63.49 m and an average sand -bar area of 6,758.9 m^2.

Macroinvertebrate abundance in the study area

A total of 386 individuals of macroinvertebrates belonging to eight orders were recorded from 42 sampling stations (Table 3). The highest recorded macroinvertebrates belonged to the order Ephemeroptera (48%), followed by Plecoptera (16%), Trichoptera (13%), Hemiptera (10%), Diptera (7%), Coleoptera (3%), Odonata (2%), and Megaloptera (1%). Moreover, macroinvertebrate counts from the family Heptageniidae (126) were the highest, followed by Baetidae (91), Perlidae (32), and Ephemerellidae (30). There were also fewer macroinvertebrate counts belonging to Blephariceridae (1), Chironomidae (1), Chrysomelidae (1), Coleoptera (1), Gomphidae (1), Limoniidae (1), Siphlonuridae (1), and Tabanidae (1) families.

The macroinvertebrates recorded from the study area were further categorised into two communities: macroinvertebrate community where River Lapwings occurred, and macroinvertebrate community where River Lapwings did not occur. The diversity indices are given in Table 4, where the macroinvertebrate community with the occurrence of River Lapwing showed a higher diversity (H' = 1.93) compared to the community without River Lapwing (H' = 1.78). A study conducted by Patra *et al*. (2010) in India found a positive relationship between macroinvertebrate abundance and water bird species diversity. These results suggest that the River Lapwings prefers areas along the Punatsangchhu River where there are more macroinvertebrates.

The proportion of macroinvertebrates was slightly higher (E_H = 0.74) in the absence of River Lapwings than in the presence of River Lapwings (E_H = 0.7). The total abundance of the macroinvertebrate community in which the River Lapwings occurred was 231, and in the community where the River Lapwing did not occur, it was 155. There was a significant difference ($F_{(1, 39)}$ = 6.66, p = 0.00) in the macroinvertebrate communities (Table 5). Getachew *et al*. (2012) reported on birds in Ethiopia, where a positive relationship between bird diversity and abundance of macroinvertebrates was observed, which is consistent with the current study on River Lapwing in the Punatsangchhu River.

Correlation between habitat parameters, water parameters and River Lapwing occurrence

Altitude had a strong positive relationship with TDS and conductivity of water (r = 0.85, p = 0.00). This suggests that TDS and conductivity

Table 3: Taxonomic composition and relative abundance of collected macroinvertebrates from 42 sampling stations along the Punatsangchhu River

Order	Family	No. of individuals	Relative abundance (Order)	Relative abundance (Family)
Coleoptera	Chrysomelidae	1	2.33	0.26
	Coleoptera	1		0.26
	Elmidae	7		1.81
Diptera	Blephariceridae	1	5.96	0.26
	Chironomidae	1		0.26
	Limoniidae	1		0.26
	Limoniidae	6		1.55
	Simuliidae	13		3.37
	Tabanidae	1		0.26
Ephemeroptera	Baetidae	91	64.25	23.58
	Ephemerellidae	30		7.77
	Heptageniidae	126		32.64
	Siphlonuridae	1		0.26
Hemiptera	Aphelocheiridae	18	9.59	4.66
	Notonectidae	19		4.92
Megaloptera	Corydalidae	2	0.52	0.52
Odonata	Euphaeidae	5	1.55	1.3
	Gomphidae	1		0.26
Plecoptera	Peltoperlidae	2	8.81	0.52
	Perlidae	32		8.29
Trichoptera	Brachycentridae	27	6.99	6.99

in the study area increased with increase in altitude. This could be due to factors such as increased mineral content in soils at higher elevations (Ali *et al*., 2019). Altitude also presented a strong negative relationship with depth (r = -1.0, p = 0.00) and a moderate negative relationship with the width of the river (r = -0.37, p = 0.02). In addition, altitude and pH (r = -0.52, p = 0.00), altitude and temperature (r = -0.86, p = 0.00) showed a negative relationship in the study area. This negative relationship between altitude and water parameters was also stated in the studies of Jacobsen *et al*. (1997) and Mersel *et al*. (2013).

There was a strong negative relationship between depth of river and water surface elevation of river (r = -1.0, p = 0.00), suggesting that deeper water bodies generally have lower water surface elevation (Chen *et al*., 2022). Also, there was a strong negative relationship (r = -0.85, p = 0.00) between the depth of river and TDS, suggesting that deeper water bodies tend to have lower TDS (Adjovu *et al*., 2023). A moderate positive relationship between

Table 4: Diversity indices of the macroinvertebrate communities in the study area

Macroinvertebrate Community	**Diversity Indices**		**Abundance (no.)**
	H'	***E_H***	
River Lapwing occurred	1.93	0.7	231
River Lapwing did not occur	1.78	0.74	155

Table 5: PERMANOVA test on macroinvertebrate communities in the study area

Components of variance	***df***	**Sum of Squares**	***pseudo-R-squared***	***F***	***p***
Model	1	1.51	0.15	6.66	0
Residual	39	8.83	0.85		
Total	40	10.34	1		

water velocity of river and the slope of the river bank was observed (r = 0.54, p = 0.00), which indicates the slope of the bank stimulates the river flow (Li *et al*., 2024). A moderate negative relationship was also found between the width and slope of the river bank (r = -0.60, p = 0.00), suggesting that wider water bodies tend to have gentler slopes (Mentes, 2019).

The occurrence of River Lapwings and river width showed a slightly positive relationship (r = 0.38, p = 0.01) in the study area, suggesting that River Lapwings prefer habitats with a wider river gradient. Although the occurrence of River Lapwing had a moderate positive relationship with altitude and water surface elevation (r = 0.40, p = 0.00), there was a strong negative relationship between altitude and water depth (Table 6). In addition, River Lapwing occurrence and depth of river showed a moderate negative relationship (r = -0.40, p = 0.00). This suggests that with the increase in depth of the river, the River Lapwings occurrence decreased. Due to prey availability and food consumption, River Lapwings prefers shallow water bodies (Bancroft *et al*., 2002; Kumar *et al*., 2021).

Conductivity and TDS of water had a moderate positive relationship (r = 0.44, p = 0.00) with River Lapwing occurrence. Although temperature and River Lapwing occurrence showed a slightly negative relationship (r = -0.35, p = 0.02), altitude and temperature of water had a strong negative relationship (r = -0.86, p = 0.00). This suggests that River Lapwing occurrence is higher with the increase in conductivity and TDS. However, with the increase in water temperature occurrence of River Lapwing decreases (Faheem, 2017; Mishra *et al*., 2018). Overall, the correlation matrix reveals several relationships between habitat and water parameters, highlighting the complex interplay of factors in the study area. Moreover, occurrence of River Lapwing in relation to habitat and water parameters is valuable for understanding River Lapwing habitat along Punatsangchhu River.

Correlation between sandbar, human disturbance and River Lapwing occurrence along Punatsangchhu River

A moderate positive relationship (r = 0.44, p = 0.00) between the sandbar and occurrence of River Lapwing was observed (Table 7). This suggests that River Lapwings are more likely to be found on larger sandbars than on smaller ones because the larger sandbars probably offer increased foraging opportunities and better nesting sites for River Lapwing (Claassen, 2004; Habel, 2018). A moderate negative relationship (r = -0.34, p = 0.00) between human disturbance and the occurrence of River Lapwing was also found, suggesting that River Lapwings are less likely to be found in areas where there is human disturbance (Bötsch *et al*., 2017; Hevia *et al*., 2023). Distance from the road and occurrence of River Lapwing showed a weak negative relationship (r = -0.05, p = 0.00), which suggests that roads do not influence the occurrence of River Lapwing along Punatsangchhu River (Keithmaleesatti *et al*., 2022).

Table 6: Correlation between habitat parameters [1] altitude (m), [2] width of river (m), [3] depth of river (m), [4] water surface elevation (m), [5] slope of river bank (°); water parameters [6] pH of water, [7] velocity of river (m/s), [8] total dissolved solids in water (mg/l), [9] conductivity of water (µS/cm), [10] temperature of water (°C) and [11] occurrence of River Lapwing in the study area

	1	2	3	4	5	6	7	8	9	10	11
1	1										
2	-0.37*	1									
3	-1.00**	0.37*	1								
4	1.00**	-0.37*	-1.00**	1							
5	0.2	-0.60**	-0.19	0.2	1						
6	-0.52**	0.16	0.54**	-0.52**	-0.08	1					
7	0.22	-0.56**	-0.22	0.22	0.54**	-0.16	1				
8	0.85**	-0.03	-0.85**	0.85**	-0.01	-0.51**	-0.02	1			
9	0.85**	-0.03	-0.85**	0.85**	-0.01	-0.51**	-0.02	1.00**	1		
10	-0.86**	0.25	0.87**	-0.86**	-0.21	0.60**	-0.08	-0.81**	-0.81**	1	
11	0.40**	0.38*	-0.40**	0.40**	-0.49**	-0.12	-0.28	0.44**	0.44**	-0.35*	1

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Table 7: Spearman correlation between River Lapwing occurrence, sandbar area, distance from road, and human disturbance in the study area

Parameter	Occurrence of River Lapwing	Sandbar	Distance from road	Human disturbance
Occurrence of River Lapwing				
Sandbar	.44**	1		
Distance from road	-0.05	-0.21	1	
Human disturbance	-0.34*	-0.3	-0.12	1

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Foraging techniques and foraging success of River Lapwing along Punatsangchhu River

River Lapwings exhibited a diverse range of foraging techniques but walk-halt-peck (37.96%) was the frequently used technique in the present study (Figure 2), which was also reported in Northern India (Kumar *et al*., 2021). Mishra *et al*. (2021) reported that River Lapwing preferentially captures tiger beetle, earwig, caddis fly, black fly, and ants, as these preys were abundantly present, indicating that they are visual surface foragers. However, the second frequent technique was the walk-halt-multiple probes (30.56%) in the study area. The current study showed that River Lapwings primarily uses pecking techniques for prey consumption, while probing was also adopted. The shorebirds mostly forage where there is a high rate of food abundance in the shortest period (Custard, 1970; Dann, 1987). A positive relationship between prey abundance and wading bird foraging rates was also reported by Erwin (1985) and Draulans (1987).

The key foraging behaviour of River Lapwings observed along Punatsangchhu River is shown in Table 8. Although the percentage of successful attempts of River Lapwing was 62.96 ± 9.53%, Kumar *et al*. (2021) reported 72.4% successful attempts of River Lapwing during summer along the river Ganges in India. Thus, foraging success of the River Lapwing along Punatsangchhu River is low compared to the River Lapwing foraging success in India. The rate of foraging varies depending on the type of prey and environmental factors such as temperature, rainfall, water level, and the smoothness of the sediment (Mouritsen & Jensen, 1992; Mishra *et al*., 2021).

Conclusion

The present study found that larger sandbars are prominent habitats for the River Lapwing along the Punatsangchhu River. The study demonstrated a notable positive relation between river lapwing occurrence and the sandbar area, underlying the importance of these geomorphological features. The findings of the study not only indicated that the macroinvertebrate community where River Lapwings were found was diverse, but also that it supported a large number of macroinvertebrates. The study showed that River Lapwings used walk-halt-peck followed by walk-halt-probe foraging techniques in their habitat during the study, with a notable prey consumption success rate. The study revealed that several factors played a vital role in the distribution of River Lapwings in the Punatsangchu River. River Lapw-Ings were observed within an altitudinal range of 1.161 to 1,518 masl along the Punatsangchu River. However, human disturbance, such as hydropower projects, sand dredging, and agricultural activities, had a negative relationship to the occurrence of River Lapwing in the study area, indicating sensitively to antrhropogenic pressures.

Table 8: Foraging behaviour and success of River Lapwing in the study area

Foraging behaviour	Mean ± SD
Movement rate (steps/minute)	25 ± 1.37
Feeding rate (peck or probe/minute)	3.98 ± 1.27
Foraging success rate (prey consumed/minute)	2.51 ± 0.82
Percentage of successful attempts	62.96 ± 9.53

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relation that could have appeared to influence the work reported in this article.

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