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Habitat Utilization, Time Budget and Daily Rhythm of Ibisbill (*Ibidorhyncha struthersii*) in Daocheng County, Southwest China

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Abstract.—The Ibisbill (*Ibidorhyncha struthersii*) is a rare shorebird uniquely adapted to high-altitude river rapids. Ibisbill has received little study as a result of its isolation and the inaccessibility of its habitat. The habitat utilization, time budgets and daily rhythm of Ibisbill were studied in the southwestern part of Sichuan Province, China, in July to August 2008 and January to February 2010. A total of 55 Ibisbills were recorded in summer and 87 in winter. Encounter rates and group size were similar in summer and winter, but habitat selection differed. In summer, most Ibisbills chose central islands in rivers that had many large stones offering opportunities for both camouflage and physical concealment, and riverside pasture covered by weedy growth with abundant insects making them suitable for foraging. In winter, when water levels are low and many stony beaches are exposed, Ibisbills were more often encountered on riverbanks. Foraging (48.9%) and resting (32.3%) were the most commonly observed behaviors, and the time that Ibisbills spent on foraging (t_{19} = -4.0, P = 0.001) in winter was significantly higher than in summer. In winter, Ibisbills spent less time engaged in locomotion (t_{19} = 5.1, P = 0.001) and resting (t_{19} = -2.8, P = 0.012). Alertness increased toward sunset in summer but not in winter. *Received 28 November 2011, accepted 20 December 2012.*

Key words.—daily rhythm, Daocheng, habitat utilization, *Ibidorhyncha struthersii*, Ibisbill, time budget.

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The Ibisbill (*Ibidorhyncha struthersii*) is a wader uniquely adapted to high altitudes and river rapids and is morphologically unmistakable, the adult being gray with a long, down-curved crimson bill, a black face, and a black breast band (Pierce 1986; Knystautas 1996). Recent studies have confirmed that the Ibisbill is sufficiently distinctive to merit its own family, Ibidorhynchidae, a sister group to the stilt and avocet family Recurvirostridae (Baker *et al.* 2007; Livezey 2010). There are no morphologically recognized subspecies (Dickinson 2003; Zheng 2011). Its range is centered on the Pamirs, Himalayas and Tibetan Plateau, but peripheral populations occur west to Turkestan and east to northern Burma (Baker 1929; Vaurie 1965; Pierce 1986; Knystautas 1996; Zheng 2011). The Himalayas and the Tibetan Plateau are the global center of diversity for birds specializing in high altitude riverine landscapes (Buckton and Ormerod 2002), and there the Ibisbill inhabits broad stony rivers at altitudes typically between 1,700 and 4,400 m. The Ibisbill feeds by probing under rocks or gravel on stream beds (Pierce 1986; Knystautas 1996). In China, some Ibisbills occur on the Qinghai-Tibetan Plateau and Yunnan-Guizhou Plateau, but they can also be found at lower altitudes eastward as far as the suburbs of Beijing city, Henan Province and Hebei Province (Zheng 2011).

The Ibisbill, an anomalous shorebird, has received little field study as a result of its isolation and the inaccessibility of its habitat (Baker 1935; Livezey 2010). A small number of short historical contributions provide information about morphology (Baker 1929), nesting (Bailey 1909; Baker 1929, 1935), foraging (Hingston 1927; Pierce 1986), and classification (Simmons 1986). However, there have been no accounts of habitat utilization by Ibisbills or of their time and energy budgets during summer and winter.

The objectives of our research were to: (1) study habitat utilization, time allocation and adaptive strategies of this rare and under-studied species; (2) study the Ibisbill's behavioral ecology, particularly how it allocates time and effort differently between winter and summer; and (3) compare the birds' daily rhythm between summer and winter. We expect our results to help us better understand how Ibisbills are adapted to their harsh environment.

METHODS

Study Area

The study was conducted in Daocheng County (27° 58' to 29° 30' N, 99° 56' to 100° 36' E), Sichuan Province, China (Fig. 1). The site, located on the eastern edge of the Tibetan Plateau, is surrounded by high mountains and experiences a continental monsoon climate. Mean annual precipitation is 636 mm and most rain falls between June and September. Mean monthly temperature is 4.1 °C, monthly mean maximum temperature is 11.9 °C in July, but only -5.9 °C in January. The extremes of temperature during our study were -27.6 °C in January and 27.1 °C in July. The annual mean frostless season is 32 days from May to July. There are three rivers in Daocheng County. Our study focused on the Daocheng River, which has a catchment area of 1,844 km^2 and mean flow of 15 m^3/s. The elevations covered by this study area ranged from 3,712 to 4,055 m above sea level. The river starts to freeze in October, but some sections (34 ± 19.4%, n = 74 points sampled) remained unfrozen throughout the winter and were accessible to foraging Ibisbills. In winter, river width averaged 15 ± 13 m (n = 74) and the depth about 18 ± 12 cm (n = 74). The width of bank defined as the immediate cobbled floodplain is 30 ± 18 m (n = 74), and the current velocity is about 0.4 ± 0.2 m/s (n = 74). The beds of the river channels consisted mainly of cobbles (50-300 mm diameter) and boulders (greater than 300 mm diameter), with some underlying pebbles (5-50 mm diameter) and sometimes sand and silt. The river has much higher flows in summer (24 m^3/s) than in winter (6 m^3/s), due to snowmelt and slightly increased rainfall. In our study area, the river ran through alpine meadow and shrubby woodland dominated by *Quercus aquifolioides* and *Picea likiangensis*.

Bird Surveys

We initially surveyed most types of wetland habitat, such as rivers, lakes, marshes and reservoirs, in Daocheng County, both in summer and in winter. Ibisbills were only detected on gray riverine beach habitats with rocky beds and were absent from all others, so subsequent surveys were concentrated on this habitat. The gray riverine beach habitats were classified into three types: Riverbanks (the river floodplain and bank

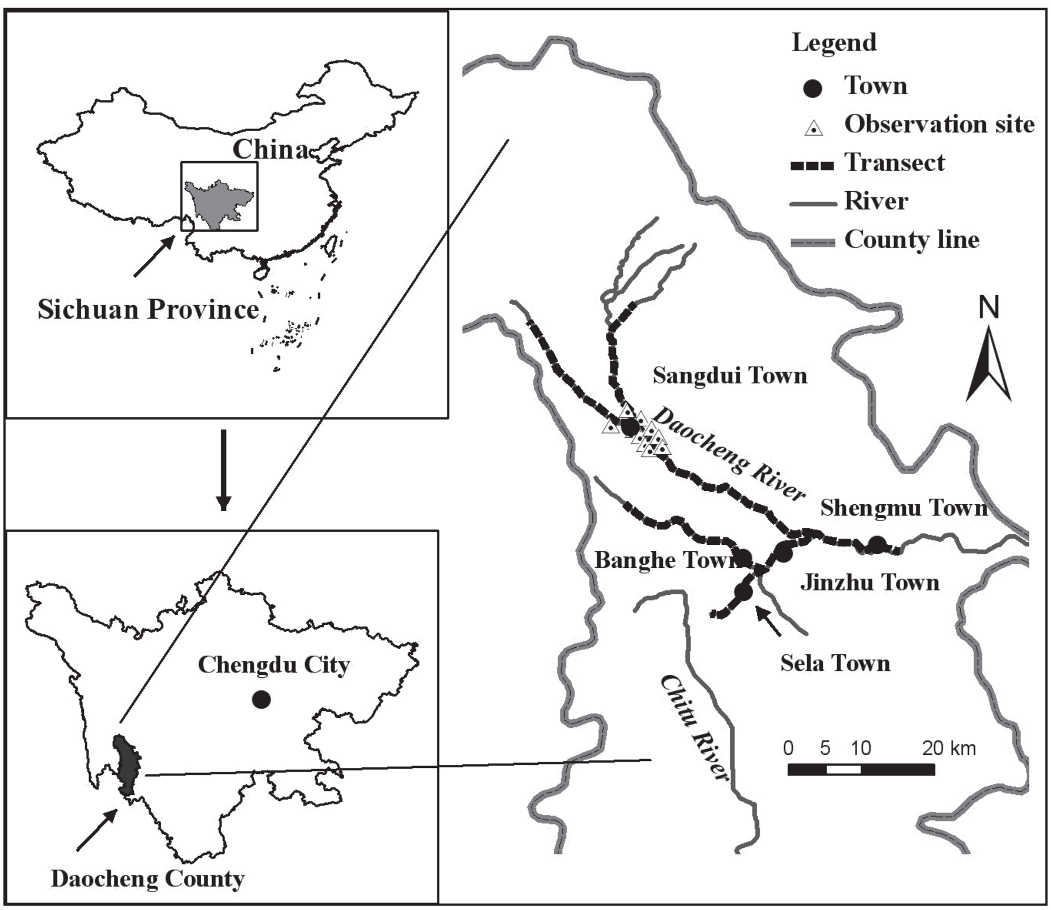

Figure 1. Location of the study area, Daocheng River, Daocheng Country, Sichuan Province, China.

consisting of cobbles and boulders); Central Islands (island in the middle of the river, covered with sparse herbs and shrubs) and Riverside Pasture (plateau marshes and flats with weedy growth). Eight transects were conducted of riverbanks along the Daocheng River within the study area (Fig. 1) and each transect covered major habitat types of gray riverine beach. Four investigators were split into two pairs, with each pair walking along the transect at a speed of 2-3 km h^{-1} and counting birds using 10×42 binoculars. All the surveys were conducted from 07:00 to 11:00 (4 hrs). The length of each transect was between 8 and 15 km (total 108 km), with the "detection width" of 200 m (100 m on each side of the transect); the transect lengths were measured using a GPS. The area surveyed was calculated by multiplying width by length of each transect. We conducted one survey of all eight transects both in summer and winter. The abundance of Ibisbills seen and heard, as well as their habitat types within the transects, were recorded, but birds that simply flew over the area were excluded. Behavioral observations (other than recording the habitat type) were not taken during these surveys.

Observations of Behavior

Observations on behavior were made at a cluster of sites on the Daocheng River (29° 11' 42" N, 100° 06' 39" E). Before collecting definitive data, we spent 3 days on pilot investigations, confirming that the site was suitable for behavioral observations and was used by more than 10 birds living along a 10-km river stretch, flying daily from roost sites to that area for activity. We positioned ourselves on the high banks on the side of the river (mostly at 10 sites indicated in Fig. 1) that gave an unobstructed view of the river-bed, but which, more importantly, did not disturb the closest birds (approximately 50 m away). Observations were made with a 20-60 magnification spotting scope. Behavior of Ibisbills was divided into five categories (Nicolaas 1972; Yang *et al.* 2007):

1) Foraging: including seeking (finding or obtaining food apparently by visual means, aided by altering the angle of view with head movements), pecking (tapping or snapping with the bill), probing (head stretched forward and down amongst cobbles or boulders and the bill used to probe between rocks) and swallowing (consumption of food aided by raising head).

2) Resting: including sleeping (standing or sitting with the head turned over the back and bill tucked amongst the dorsal plumage) and maintenance (making comfort movements including preening, head shaking, lateral stretching of wing and fluttering).

3) Locomotion: including walking (change of spatial position by moving on foot), running (moving on foot rapidly), flying (moving position by wing, clear of the ground) and swimming (typically travelling across the water surface using legs aided by flapping of the wings).

4) Alert: including scream (bobbing the head and calling loudly) and gazing (stopping foraging to scan the surroundings).

5) Others: including excretion (elimination of waste products of metabolism from cloaca), display (bobbing the head and body up and down or in circular fashion), mating (the male approaches rapidly and mounts directly onto female's back and remains mounted, cloaca in contact for 3-4 sec, followed by dismounting, after which both birds stretch their necks, ruffling their feathers and walking) and antagonism (the initiator moves toward an intruder, calling, and would then extend its neck, fluff its feathers and bob its head).

The instantaneous scanning sampling method (Altmann 1974; Martin and Bateson 2007) was employed. We scanned all individuals within our field of view every minute and recorded the behavior of each individual in views. Behavioral data were collected throughout the day (from dawn to dusk) totaling 122 hr of data on daily activity in summer (from July to August 2008, 16 survey days) and 218 hr of data in winter (from January to February 2010, 20 survey days). Observations were not made on days with rain, snow or strong winds so as to lessen bias caused by the effects of extreme weather.

Data Analysis

We used Kolmogorov-Smirnov Test to check whether the data was normally distributed (SPSS, Inc. 2009). In all tests, $P = 0.05$ or less was accepted as significant and two-tail probability values are given for all analyses. The form of data presentation was mean ± SD, except for percentage data where it was given as mean ± SE. An independent-sample t-test was used to test different encounter rates between summer and winter because the data were normally distributed, whereas Mann-Whitney U test was used to test for differences in average group size between the summer and winter since these data were not normally distributed (SPSS, Inc. 2009).

Chi-squared goodness-of-fit was used to compare habitat use (percentage of Ibisbills observed in each habitat) and habitat availability (percentage of area of each habitat) in summer and winter among the three types of habitat. If habitat use did not match habitat availability, Bonferroni analyses were used to test for positive, nil, or negative selection by the birds (Byers *et al.* 1984; Gan *et al.* 2009).

To analyze the activity budgets, we calculated proportions based on the number of time-points records (20,400 behavioral records) for each activity (foraging, resting, locomotion, alert and others). A chi-squared contingency test was employed to test the independence of behaviors and season (SPSS, Inc. 2009). For analysis of daily activity rhythms, the data were further subdivided into a 1-hr time block. The use of a large block of time (1 hr) to divide the day provides a suitable separation for statistical comparison (Natalie 2005; Zhou *et al.* 2010). Independent-sample t-tests were used to compare the percentages of each activity between the summer and winter seasons for all activity data that met the conditions of independence and normality (SPSS, Inc. 2009). A one-way ANOVA was used to test whether the differences in the percentage of time spent performing the various behaviors were significantly different, because all normality and independence assumptions were met except for "other" behaviors which were not tested for significance of the differences (SPSS, Inc. 2009). We investigated whether there was a diurnal rhythm in alertness (percentages of time devoted to alert behavior were arcsine-square root transformed) by using linear regression.

RESULTS

Abundance

A total of 55 Ibisbills (including three downy chicks) were recorded in summer and 87 Ibisbills in winter. The encounter rate of Ibisbill was not significantly different between summer and winter (t_{14} = -0.90, P = 0.38; Table 1) and group size did not differ significantly between summer and winter (t_{69} = 1.2, P = 0.091; Table 1).

Habitat

Habitat use by Ibisbills did not match habitat availability either during the summer or during the winter (χ^2 = 11.2, P = 0.004). Among the three habitat types, central riverine islands and riverside pasture were used most often in summer and Ibisbills were encountered more often on riverbanks in winter (Table 2).

Time Budgets

During the year, foraging was the most prevalent activity of Ibisbills, accounting for nearly half of the total activity budget (48.9 ± 2.7%, n = 18). This was followed by resting (32.3 ± 2.2%), locomotion (9.4 ± 1.0%), alert (6.2 ± 0.5%), and other behaviors (3.2 ± 0.4%).

An independent-sample t-test showed that there were significant differences in the percentage of time Ibisbills spent foraging in summer and winter (t_{19} = -4.0, P = 0.001), and also in the amount of time spent resting (t_{19} = 2.8, P = 0.012), in locomotion (t_{19} = 5.1, P = 0.000), and other behaviors (t_{19} = -4.7, P = 0.000). There was no significant difference in alert behavior (t_{19} = 0.87, P = 0.402) between summer and winter (Table 3).

Diurnal Rhythm

There were obvious diurnal rhythms in foraging ($F_{12, 144}$ = 2.5, P = 0.006) and resting ($F_{12, 144}$ = 3.2, P = 0.001) in summer, and resting ($F_{10, 235}$ = 2.4, P = 0.012) in winter (Table 4). The proportion of time spent on each category of behavior varied throughout the day (Fig. 2). Foraging peaked early in the morning and showed a trough between 16:00 and 17:00 in summer yet was continuously high through the afternoon in winter. Ibisbills spend more time on foraging in the afternoon (13:00 to 17:00) than in the morning (08:00 to 12:00) in winter (t_9 = -3.4, P = 0.010) while the reverse is true during the summer (t_9 = 2.5, P = 0.048). The frequency of resting rose from 06:00 to 13:00, and peaked between 16:00 and 17:00 in summer, but showed two peaks, in the morning and between 16:00 to 17:00 in winter. Locomotion and alert behavior showed no obvious diurnal rhythm (Table 4). Alertness increased toward sunset in summer (R^2 = 0.078, P = 0.001) but not in winter (R^2 = 0.008, P = 0.016; Fig. 3).

DISCUSSION

Downy Ibisbills were found in summer, and Ibisbills were present in the study area in all months; the encounter rate of Ibisbill did not differ significantly between winter and summer (Table 1). Hence, the habitat was able to sustain a resident population year round. Group sizes were typically small

Table 1. Comparisons of encounter rate (mean ± SD) and group sizes (mean ± SD) of Ibisbill between summer and winter in Daocheng Country, Sichuan Province, China.

Class	Summer	Winter	t	P-value
Encounter rate (km^{-2})	2.6 ± 0.8 (n = 8)	4.2 ± 1.5 (n = 8)	-0.9[a]	0.38
Group sizes	1.8 ± 0.3 (n = 30)	2.1 ± 0.1 (n = 41)	1.2[b]	0.091

[a]Independent-samples t-test; [b]Mann Whitney U-test.

Table 2. Habitat use (%) and selection by Ibisbill between summer and winter in Daocheng Country, Sichuan Province, China. The "+" sign in parentheses indicate positive selection and "-" sign negative selection.

	Riverbanks	Central Islands	Riverside Pasture
Habitat availability			
Summer	56.3	28.2	15.5
Winter	65.5	24.2	10.3
Habitat use			
Summer	33.3 (-)	43.4 (+)	23.3 (+)
Winter	73.2 (+)	17.1 (-)	9.7 (-)

in both summer (1.8 ± 0.3) and winter (2.1 ± 0.1). This is an ecological strategy that appears to differ from the most closely related charadriiform waders such as Black-winged Stilt (*Himantopus himantopus*) and Pied Avocet (*Recurvirostra avosetta*), that are often observed in large flocks (Yang and Liu 1991; Zhang 1994). We surveyed most types of wetlands and found that in both summer and winter Ibisbills used gray beach (stony) habitats along rivers and were absent from all others. The patterns of habitat selection by many birds are dependent on the scale of the analysis (Gibbs and Kinkel 1997), and more prolonged observations might have revealed individuals in other habitats. However, our observations showed that the habitat of Ibisbills is quite different from that of broadly sympatric populations of Black-winged Stilt (Yang and Liu 1991), which in China occupies inland plains with reedy marshes, rivers, rice fields and the edges of lakes. The habitat use of Ibisbills also differs from the Pied Avocet, which in China inhabits shallow desert lakes, wetlands, rice paddies, fish ponds, and coastal and estuarine habitats (Zhang 1994).

In our results, gray stony beach habitats were divided into riverbanks, central riverine islands and riverside pasture (Table 2). In summer, Ibisbills were more often encountered on islands in the river, which may

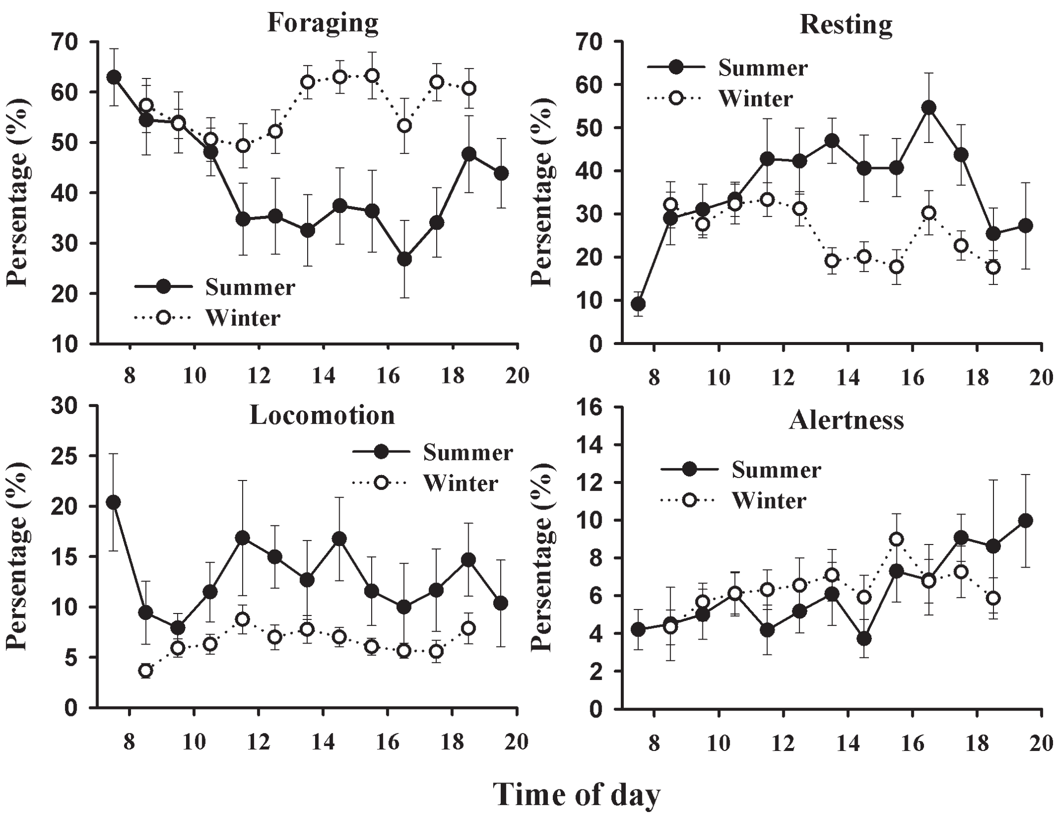

Figure 2. Diurnal behavioral rhythm according to season (summer versus winter) of Ibisbill in Daocheng Country, Sichuan Province, China (with standard error shown by vertical bar).

Table 3. Comparison of time budget (percentages of each activity, mean ± SE) of various behavioral types of Ibisbill between summer and winter in Daocheng Country, Sichuan Province, China. Independent-samples t-test: **P < 0.01, df = 19.

	Time Budget (%)		
Behavioral Types	Summer (n = 9)	Winter (n = 12)	T-test
Foraging	41.1 ± 3.1	56.7 ± 2.3	-4.0**
Resting	37.6 ± 2.8	27.0 ± 2.5	2.8**
Locomotion	12.7 ± 1.1	6.2 ± 0.7	5.1**
Alert	6.5 ± 0.8	5.8 ± 0.5	0.87
Others	2.1 ± 0.3	4.3 ± 0.3	-4.7**

be more secure during the breeding season when the summer water levels are high. On the islands, there are many large stones offering opportunities both for camouflage and physical concealment (Pierce 1986). This observation is based on a combination of measurements that found the Ibisbill to have a body length of 39.4 ± 1.8 cm, tarsus length of 4.4 ± 0.2 cm and bill length of 7.3 ± 0.4 cm (n = 28). Water depth is an important variable affecting the use of wetland habitats of Ibisbills, which chose feeding sites with a water depth of 12.5 ± 7.2 cm (Ye *et al.* 2012). When water levels are low in winter, many stony beaches are exposed (Ye *et al.* 2012). This increased availability of sites with stony beaches could increase the Ibisbill's selection of riverbanks as the primary winter habitat (Table 2). Hingston (1927) identified the Ibisbill's prey as insects, and Pierce (1986) later refined this to include aquatic invertebrates, especially stoneflies (Plecop-

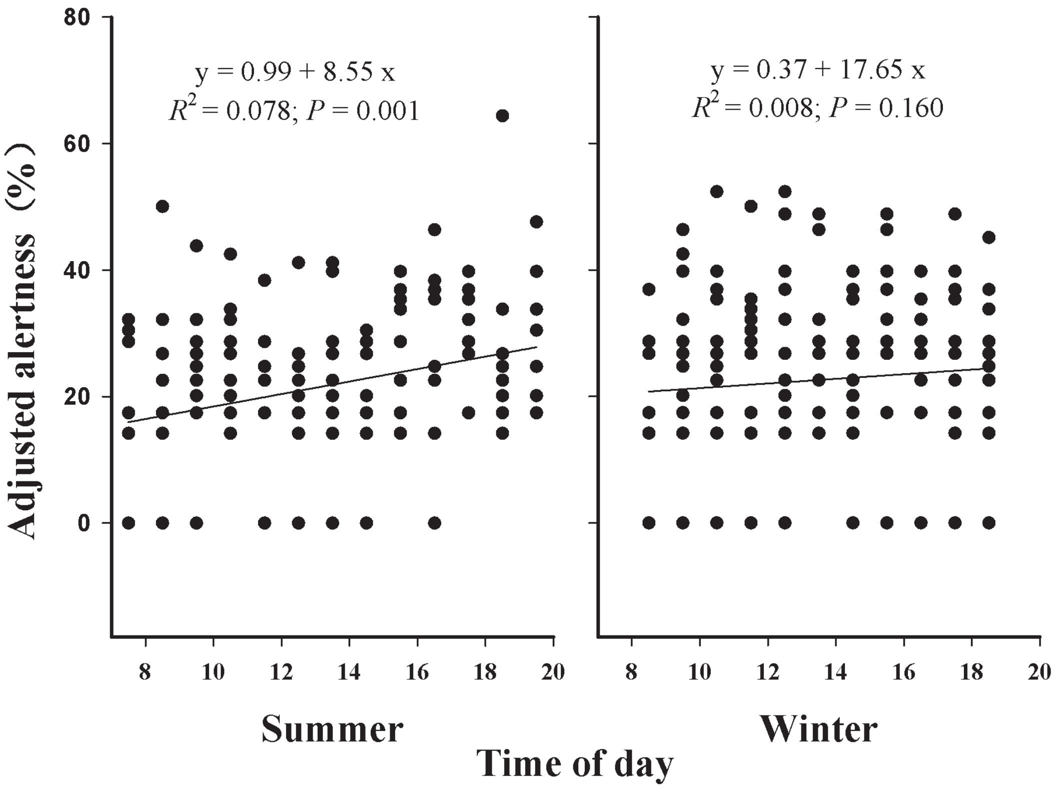

Figure 3. Relationship between adjusted alertness and time of day according to season (summer versus winter) of Ibisbill in Daocheng Country, Sichuan Province, China.

Table 4. One-way ANOVA test for diurnal behavioral rhythm of Ibisbill during summer and winter in Daocheng Country, Sichuan Province, China. One-way ANOVA test, $^{**}P < 0.01$, $^{*}P < 0.05$.

	Summer		Winter	
Behavior	df	F	df	F
Foraging	12	2.5**	10	1.6
Resting	12	3.2**	10	2.4*
Locomotion	12	0.92	10	1.5
Alert	12	1.2	10	0.85

tera), mayflies (Ephemeroptera) and caddisflies (Trichoptera). In summer, during our study, Ibisbills appeared to select riverside pasture that was covered by weedy growth with abundant insects for foraging.

Our study is the first to describe the detailed activity budget and diurnal rhythm of Ibisbills. The percentage of foraging and resting behavior of Ibisbills combined was over 80%; therefore, other behaviors occupied less than 20% of the day. The allocation of time by birds is not only an adaptation to local environmental conditions, but affects overall performance of all activities (Nicolaas 1972; Yang and Yang 1996).

Behavior of Ibisbills differed between summer and winter where the species spent more time on feeding in winter (Table 3). In winter, two thirds of our survey points along the river were frozen and many aquatic organisms were presumably inactive at low temperatures, probably making successful foraging difficult. In addition, we observed some intraspecific kleptoparasitism in Ibisbills in winter, suggesting the birds were competing for food resources. Moreover, cold winter conditions in Daocheng County, with mean temperatures below freezing, suggest energetic demands may be higher in winter, increasing the need to forage throughout the day. To avoid excessive physical exertion, Ibisbills often walked more slowly (8.9 ± 1.6 steps per 30 sec, $n = 30$) in winter than in summer (33.8 ± 5.5 steps per 30 sec, $n = 24$). In addition, the time spent in locomotion was less in winter than in summer (Table 3). They stood at one unfrozen section of river for 3-4 hr foraging (Pierce 1986). In a novel finding, alertness increased as night-time approached in summer, but not in winter when alertness declined after 16:00 hr (Fig. 3). This may have been a by-product of higher feeding requirements in winter compared to summer.

Fewer food resources, harsher weather conditions, and shorter day length should work in concert to influence the time allocation between resting, locomotion and foraging, as shown in other low temperate or arctic zone birds (Evers 1994; Jónsson and Afton 2006). Within high altitude wetland habitats in China, studies of Black-necked Crane (*Grus nigricollis*) (Yang *et al.* 2007; Kong *et al.* 2008) have shown that foraging and resting differ significantly between summer and winter. Early morning activity is essential to replace reserves expended during long, cold nights, and only after adequate food resources have been accumulated will other behavior occur. Hence, peaks of activity after dawn and before dark are typical in all of these species. However, the details of time allocation and its distribution throughout the day differ for each species, presumably optimized through natural selection according to altitude, latitude, weather conditions and species-specific physiological requirements (Nicolaas 1972).

Ibisbill foraging behavior in winter was distinctive in that it occurred throughout the day (Fig. 2), unlike species such as Red-crowned Crane (*Grus japonensis*) (Zhou *et al.* 2002), Hooded Crane (*G. monacha*) (Xu *et al.* 2006; Zhou *el al.* 2010) and Great Bustard (*Otis tarda*) (Sun *et al.* 2006). We suggest that Ibisbills need to forage throughout the day (including the afternoon and early evening) because of constraints caused by low winter temperatures, foraging grounds that are often covered by snow and ice in the morning, and running water becoming more accessible in the afternoon following the melting of the river ice. Increased feeding in the afternoon apparently anticipates the long cold night.

Although the Ibisbill has a reasonably large range in central Asia, numbers are low and birds occur only locally as they are very specialized in their habitat requirements. There are many imponderables about the effects of climate change, geographical and altitudinal shifts in habitat suitability, and pressures on riverine habitat from tourism, grazing, infrastructure development and waste disposal, all of which could affect this riverine specialist (Buckton and Ormerod 2002). Further details of habitat requirements, dispersion and time and energy budgets will be required to answer the protection and conservation needs of this species.

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