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Habitat and diet of Bhutan takin *Budorcas taxicolor whitei* during summer in Jigme Dorji National Park, Bhutan

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ABSTRACT

Little is known about the ecology of the rare and vulnerable Bhutan takin *Budorcas taxicolor whitei*, a large and basically forest-dwelling goat-antelope inhabiting mountain valleys in northern Bhutan. In Tsharijathang valley (3800 m asl) in Jigme Dorji National Park, we described the summer habitat of this takin subspecies through vegetation transects and by studying diet via microhistological analysis of faeces supplemented by examination of feeding sites. The habitats utilized by the *c.*250 animals occupying the valley consisted of six main vegetation types with roughly equal coverages, viz. three forest types (dominated by *Juniperus*, *Betula* or *Abies*), alpine scrub (mainly low *Rhododendron* shrubs), open alpine meadow (mainly graminoids and forbs) and semi-open willow shrub (mainly *Salix* and forbs). Sixty-eight food species were identified in the feeding sites, but the bulk of the diet consisted of ≈10 species, the same species that also dominated the faecal material. With >50% of the diet consisting of shrubs, mainly *Salix myrtillacea*, the takins were mainly browsers. When foraging, they exhibited a weak form of selection by choosing sites with a slightly higher coverage of the most important food species and, while at these, proportionally more feeding signs were recorded. Domestic yak *Bos grunniens* are allowed to graze in the study area during winter when the takins have descended to lower elevation. At the present grazing pressure, the wintering yaks probably benefit the takin by maintaining the open vegetation structure, but their numbers and impact on the habitat should be monitored to prevent adverse effects.

Introduction

Categorized as Vulnerable (Song et al. 2008), takin *Budorcas taxicolor* are large-bodied (>300 kg live weight), stocky goat-antelopes inhabiting steep forests extending into the timberline and mountain valleys in the Eastern Himalayas and adjoining mountain ranges of Bhutan, India, Myanmar and China (Sharma et al. 2015). Four subspecies are recognized, all considered rare and vulnerable. In spite of their relatively large geographical distribution, little is known about their life history, as very little research has yet been conducted due to the remoteness and rather inaccessible terrain of their habitat. Over the years some scientific

information has become available through studies of the golden takin *B. t. bedfordii* (Song et al. 1995; Zeng et al. 2003) and the Sichuan takin *B. t. tibetana* (Schaller et al. 1986) in China, and the Bhutan takin *B. t. whitei* in India (Sharma et al. 1995). No scientific study has yet been published on the Bhutan takin subspecies in Bhutan.

The subspecies *B. taxicolor whitei* is the national animal of Bhutan. According to Bhutanese legend, the takin was created by adjoining the head of a goat to the body of a cow by Drukpa Kuenleg, the Divine Madman, a Buddhist teacher of crazy wisdom (Japhu 1966). It is a totally protected species under the Forest and Nature Conservation Act of 1995. Like takin in China (Zeng et al. 2008), Bhutan takin migrate seasonally from alpine valleys to lower forests in late summer and back up again in early spring (Wollenhaupt 1991; Wangchuk 1999), the movement presumably an adaptation to spatial patterns of plant phenology and solar radiation (Zeng et al. 2010). In Bhutan, the migratory routes follow steep river courses and traverse ridges; the summer and winter ranges are often >1000 m apart in altitude across a horizontal distance of less than 15–20 km. Spring migration is slow, starting in April to early May, and consists of movement by separate, small groups, with animals then arriving and congregating in large groups in the summer mountain valleys in June. Takin have an atypical breeding phenology: mating takes place in midsummer and animals give birth on the wintering range in March after a long gestation (210 to 240 days). Hence, the calves are about three months old when they arrive on the summer pastures in June.

Except for general observational studies, no systematic study has yet been conducted on the habitat and food ecology of the *whitei* subspecies in Bhutan. Owing to quite different habitat, information generated from research conducted on other takin subspecies in China has limited usefulness for management in Bhutan. From a general observational study of the Sichuan takin in China, Schaller et al. (1986) concluded that takin are mainly browsers, with pronounced seasonal shifts in diet composition.

The objective of this study is to describe the summer habitat and diet of this rare bovid in Bhutan, as such basic information is lacking but is a prerequisite for formulating appropriate conservation measures for this vulnerable species.

Study area

The study was conducted during June and July of 1998 in Tsharijathang valley (27°58′ N and 89°31′ E) within Jigme Dorji National Park in north-west Bhutan (Figure 1). At 3800 m elevation, the flat mountain valley is located just below the treeline, dissected by the south-flowing Tsharijathang Chu river and its Thankana Chu tributary. The area occupied by takin in this area in summer is approximately 6 km^2; at the southern end it drops steeply into narrow conifer and mixed hardwood forests. The main valley is broad, consisting mainly of open meadows along the meandering streams, surrounded by moderately steep, forested slopes. The valley experiences cold winters and wet and warm summers; average minimum/maximum temperatures in January and July are −7/+10°C and +7/+16°C, respectively (Gyamtsho 1996).

Tsharijathang valley is considered to be home to the main summer concentration of takin in the country. Other ungulates in the valley are musk deer *Moschus chrysogastor*, blue sheep *Pseudois nayaur*, barking deer *Muntiacus muntjak* and serow *Capricornis sumatraensis*. None of these are abundant, although they spatially
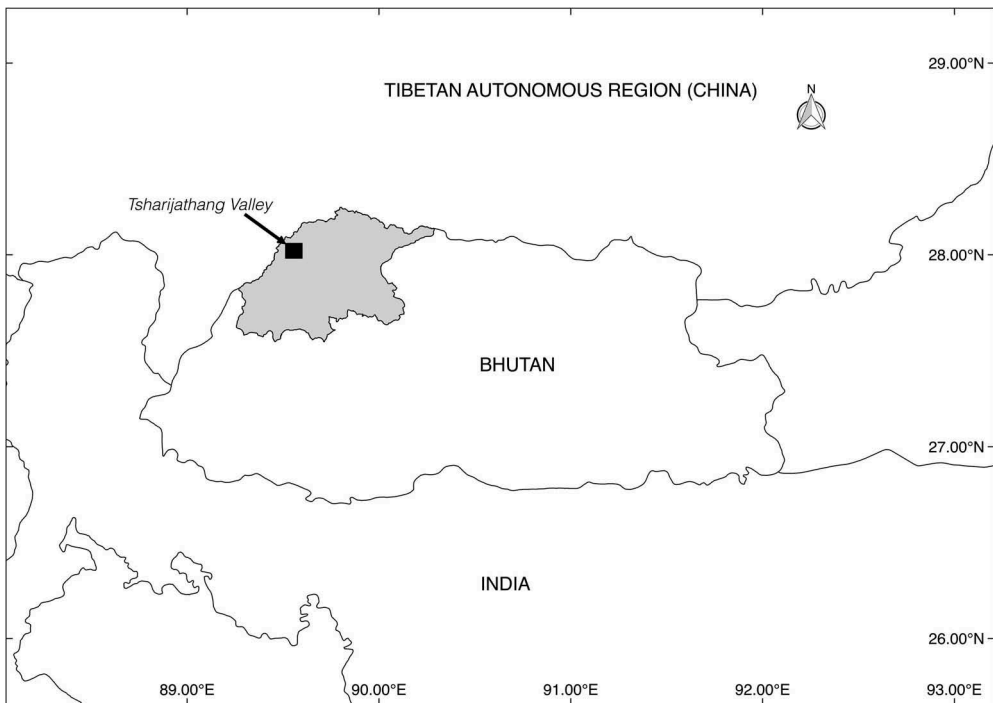
Figure 1. Location of study area, Tsharijathang valley (black box), within Jigme Dorji National Park (shaded grey), north-western Bhutan.

overlap a little with takin. From oral accounts of the history of the area, some 200 years ago the area was occupied by a small community who grazed domestic yak *Bos grunniens* in the valley year-round; present day ruins allude to the presence of a small garrison, a monastery, and a few settlements. Following a disease outbreak the community was abandoned (K. Phub, personal communication, 24 August 1998). Meyer et al. (2009) suggest possible inhabitation of a similar valley, Lunana, in the north-eastern part of the park some 4500–6700 years bp. When the national park was established in 1974, four families were permitted to graze their yaks in pastures on nearby slopes. Later, in 1992, an agreement was reached with 13 herding families that they could graze their yaks in the central valley (takin habitat) during the winter months. In the 1950s, juniper forests adjoining the river bottom were set on fire to clear the land for grazing. Potential predators of takin are tiger *Panthera tigris*, Himalayan black bear *Selenarctos thibetanus*, snow leopard *Panthera uncia*, leopard *Panthera pardus* and transient dhole *Cuon alpinus*; wolf *Canis lupus* has been reported from nearby areas, but at elevations above 5000 m. Besides tiger and dhole packs, the others are most likely to only be able to attack juvenile, old, or sick takin. In 2012 we observed a snow leopard approach a small group of takin with two calves, but the adults successfully deterred advances by the cat. Predation pressure could influence diet selection in takin, but nothing is known about predation rates.

Material and methods

Types and composition of habitats

Based on life-form categories and dominant plant species, we first identified and mapped six habitat types. Within these major types, we surveyed seven line transects along the contours, spaced 100 m elevational distance apart, and estimated cover values of plant species in nested quadrats spaced at 100 m intervals. We started each transect at the south end of the valley and selected the first station after 100 m. At each station ($n = 197$), we measured forest composition (>3 m height) in 10 m × 10 m quadrat plots, shrubs in 5 m × 5 m plots, and graminoids and forbs in two 1 m × 1 m plots. Our transects allowed us to measure 55 plots in alpine scrub, 30 plots in alpine meadow, 42 in *Salix* shrub, 31 in juniper forest, and 12 in fir forest. Species-area curves showed that the number of sample plots was sufficient for enumerating species abundances in all types, except in one type (fir forest) where an asymptote was not yet reached at 12 plots.

In order to assess the relative importance of the six habitat types as provider of takin forage, we calculated prominence values (Dinerstein 1979) of the three most abundant shrubs, forbs and graminoids in each habitat:

$$PVx = Cx\sqrt{Fx}$$

where PV_x = prominence value of species x

$\quad C_x$ = mean percentage cover of species x

$\quad F_x$ = frequency of occurrence of species x

Diet composition

We used two different methods to estimate the diet of takin – feeding site examination and faecal analysis.

Feeding sites

After an animal had left the feeding site, we laid out nested sample plots across the site and examined them thoroughly. Similar to habitat description plots, plot sizes varied between forest trees, shrubs and ground vegetation. In each plot, we estimated the cover of all species present and recorded those with fresh signs of being eaten. Older incidences of use could be deduced from dried-up scars and discoloration at the break-off points on twigs and leaves, and were not recorded. Compared to those on shrubs and larger forbs, incidences of use on graminoids and small forbs were difficult to tally. We attempted to estimate consistently what was considered an approximate bite incidence on those species. A total of 81 feeding sites were examined, 15 in alpine meadow, 15 in alpine scrub, 15 in birch forest, 10 in fir forest, 11 in Juniper forest, and 15 in *Salix* shrub habitat.

Faecal analysis

We collected 16 fresh faecal samples for microhistological analysis. Samples were collected over a six-week period and distributed among adults and subadults of both sexes. Samples were pooled into groups of five, five, and six samples, thoroughly mixed, and air-dried before

laboratory analysis. For reference material, we collected 23 plant species in the field, and after air-drying we prepared slides of these and the three air-dried, pooled faecal samples. Slide preparation and reading of the slides followed the general methodology of Holechek et al. (1982), as modified by Jnawali (1995) and Shrestha and Wegge (2006). We prepared and examined 10 slides of each of the three pooled samples. Each slide consisted of two transects. Diet composition has been reported to stabilize at approximately 200 identifications (Takatsuki 1978). We recorded 25 successive identifications along the transects on each slide, thus giving a total of 250 identifications/pooled sample or 750 identifications of the whole faecal material.

In order to assess the importance of the various species in the diet, we calculated their relative importance values (RIV) according to the equation given by Jnawali (1995):

$$RIVx = Dx\sqrt{Fx},$$

where RIV = relative importance value of species x

D_x = mean percentage of species x in faecal sample

F_x = frequency of species x in faecal sample

Food plant preferences

The feeding site examinations and the faecal analysis provided information about the relative importance of various plant species in the diet. Comparing the frequency distribution of incidences of use per species in the feeding sites with the abundances of the same use species in the same vegetation plots enabled us to make inferences about diet preferences. Lastly, by comparing the abundances of the selected food species in the feeding site plots with the abundances of the same species in the general habitat plots we make inferences about the extent to which takins make selection within habitat types when foraging.

Based on the composition of the habitat types and the selection of dietary species we also make inferences on the quality of the various types as food habitat for takin.

Results

Habitat composition

Within the area occupied by takin, we identified and mapped six broad vegetation types:

Fir forest, consisting of *Abies densa* in almost pure stands on moist, northern and north-eastern aspects, with mosses and lichens and litter covering >50% of the ground. Graminoids virtually absent, a few forbs and shrubs in openings, together covering <10%. Estimated cover in study area was *c*.15% (Figure 2).

Juniper forest, covering *c*.20% of the study area on drier sites on south and south-western aspects, consisting of *Juniperus pseudosabina* and *J. squamata* with forbs, grasses and shrubs in clearings, covering >50% of the understory vegetation.

Birch forest, covering <10% in narrow belts near the flat valley bottom, next to the fir and juniper forests above. Tree layer consisting of *Betula utilis* interspersed with *Rhododendron wightii*, with less than 20% shrubs, forbs and graminoids along the ground.
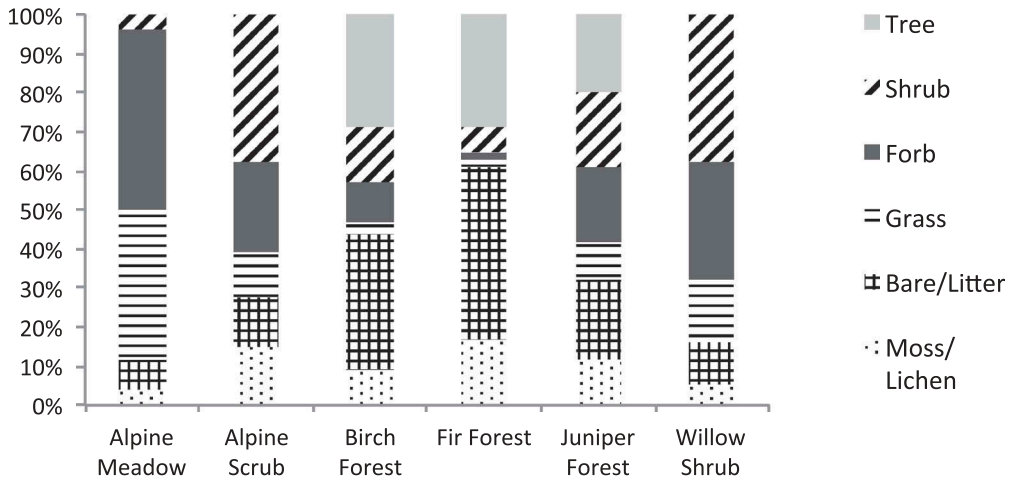
Figure 2. Spatial composition of habitat types in Tsharijathang occupied by takin during summer. Six main habitat types have been classified and the proportion of dominant ground cover described here based on habitat surveys.

Willow shrub, covering 20–25% of study area, growing in the valley bottom mainly along the meandering streams mixed with the shrub *Hippophae rhamnoides*, bordering the birch forest belt further away from the river. *Salix* and *Hippophae* shrubs, forbs and graminoids cover *c*.70% of the ground.

Alpine scrub, *c*.20% coverage, dominated by *Rhododendron* spp. mainly at higher elevations above the forests, forbs and graminoids covering *c*.20% of the ground.

Alpine meadow, 10–15% coverage, in moist depressions at higher elevations, almost devoid of shrubs and dominated by graminoids and forbs with *c*.40% each.

As seen from Figure 2, graminoids were relatively scarce in all habitats, except for Alpine meadows where the three most common grasses covered an estimated 16.5%. This habitat was also rich in forbs. Willow dominated the Willow shrub habitat, with an average coverage of *c*.33%.

Diet composition

Faecal analysis

Shrubs dominated the faecal material with >50%, followed by forbs; the proportion of graminoids was low, only about 13%. Altogether, 28 different food species were recorded, distributed rather evenly among the three lifeform categories. Among the shrubs, *Potentilla fruticosa, Spirea arcuata,* and *Salix* spp. were most commonly encountered, all with high RIV values (Table 1). *Erigeron multiradiatus* and *Nardostachys jatamansis* made up half of the forbs. No specific species of graminoids appeared frequently in the samples.

Feeding sites

The results from the feeding site examinations compared closely with those from the faecal analysis; 67% of the use incidences were on shrubs, 22% on forbs and 11% on

Table 1. The most frequently recorded species in each life form category in the faecal sample material, expressed by relative importance values (see text).

Species	RIV	SD[1]
Shrubs		
Potentilla fruticosa	15.2	1.8
Spirea arcuata	11.9	1.8
Salix spp.	9.9	2.6
Forbs		
Erigeron multiradiatus	8.4	0.7
Nardostachys jatamansi	6.8	4.3
Acanthocalyx nepalensis	3.6	2.4
Graminoids		
Festuca stafii	3.5	1.2
Unidentified grass spp.	2.7	0.5

[1]SD = standard deviation across pooled samples

Table 2. Comparison of the relative importance of various species in the diet derived from faecal analysis and from feeding site examination, expressed by ranking, and comparison of the frequency of usage and the availability of food species at feeding sites.

	Faecal analysis	Feeding sites		Availability[3]	Selection[4]
	Rank	Rank	% Use[2]		
Shrubs					
Potentilla fruticosa	1	3	11.6	3.4	3.4
Spiraea arcuata	2		1.0	1.2	0.8
Salix spp.	3	1	16.5	7.9	2.1
Unidentified shrub	5		n/a	–	–
Ribes orientale	8	2	12.8	3.8	3.4
Betula utilis[1]	13	5	5.5	0.6	9.2
Forbs					
Erigeron multiradiatus	4	6	4.0	2.3	1.7
Nardostachys jatamansi	6	10	1.7	0.4	4.3
Aster himalaica	7	11	1.6	0.2	8.0
Acanthocalyx nepalensis	8	7	2.8	0.7	4.0
Anemone rivularis	11	8	2.6	1.1	2.4
Bistorta macrophylla	n/a	9	1.9	0.7	2.7
Graminoids					
Festuca stafii	10		0.3		
Unidentified grass A	12	4	7.3		

[1]Only saplings <3 m height.
[2]Use is measured as average bite incidences for specific plants in the feeding sites.
[3]Availability is average percentage coverage for each species.
[4]Selection is the ratio of use to availability within feeding sites.

graminoids. In total, 68 different species were recorded to be ingested, 13 shrubs, 39 forbs and 16 graminoids. The relative proportions of individual species, however, differed somewhat from what was found in the faecal material. This is illustrated in Table 2, which compares the ranking of the species based on proportion of incidences of use with the ranking of the same species according to the faecal analysis.

When considering the six habitat types separately, the Wilcoxon sign rank test disclosed statistical preferences for 11 species (Table 3).

Table 3. Species preferentially ingested in different habitat types in Tsharijathang valley during summer.

Alpine meadow	Alpine scrub	Willow shrub
Acanthocalyx nepalensis F	*Ribes orientale* S	*Salix myrtillacea* S
Bistorta macrophylla F	*Anemone rivularis* F	
Erigeron multiradiatus F	*Bistorta macrophylla* F	
Carex parva G		
Juniper forest	**Birch forest**	**Fir forest**
Potentilla fruticosa S	*Betula utilis* S	*Betula utilis* S
Unidentified grass G	*Ribes orientale* S	

F = forb, G = graminoid, S = shrub.
Significance level $p < 0.05$ for all except *Salix myrtillacea* in Willow shrub at $p < 0.001$.

Habitat and diet

Feeding sites were distributed in all six habitat types. The composition of life form categories at these sites and in the randomly distributed sampling plots for habitat mapping was not different (chi square tests for homogeneity = 2.72–5.52, $p > 0.24$, df = 5 each). However, the composition of plant species within the two series of plots varied markedly, but not in the same direction: among the three most frequently eaten species in each life form category across all habitat types (12 species), only four had higher cover values in the feeding sites than in the general habitat plots, and for only two species (*Potentilla fruticosa* and *Salix myrtillacea*) was this difference significant ($p < 0.05$, Wilcoxon two-sample tests). Food species tended to be less abundant in the feeding plots, and in two cases (*Agrostis parva* and *Ribes orientale)* significantly so ($p < 0.05$). It is interesting to note that plants with tough leathery leaves such as *Rhododendron* and *Cotoneaster* species were not eaten even though they were present in the feeding sites.

Discussion

The summer habitat consisted of a mixture of forested slopes, with alpine rhododendron-dominated scrubs and meadows above, and a flat and wide willow-dominated bottomland with forb and gaminoid-rich clearings below. The takin foraged in all habitat types. While the study was not designed to investigate habitat preferences, non-systematic observations indicated that the animals spent most of their time in the willow-dominated habitat. Besides foraging and engaging in pre-rutting activities, the animals regularly visited two mud flats (salt licks) located in this habitat. Indirect evidence from the diet composition also indicated that the open, flat valley bottom was the most used habitat, as willow was the single or second most important species in the diet. However, the forests, in spite of their much lower abundance of forage plants, were also used regularly both during the day and especially during night-time, then mainly for bedding and rumination.

As noted by Schaller et al. (1986) and Zeng et al. (2001) in their observational studies of the Sichuan and golden takins, respectively, the Bhutan takin fed on a very large number of different plants. However, only seven out of 68 species accounted for >60% of the incidences of use recorded in the feeding sites. Fewer species were identified in the faecal material, but the results were comparable to those recorded

from the examination at feeding sites, with roughly the same ranking of the most frequently encountered species. Discrepancies in ranking might be due to the distribution patterns and niche specificities of individual species. For instance, *Spiraea arcuata* was frequently encountered in faecal material with the second highest RIV value, but based on feeding site examinations in all habitat types combined, it ranked relatively low, probably because it had a very patchy distribution mainly in the alpine scrub habitat.

Faecal analysis and feeding site examination are crude methods for estimating diets of herbivores, the former tending to underestimate proportion of succulent forbs (Shrestha and Wegge 2006). In our results, the tendency was the opposite: the forb component was ≈10% higher in the faecal material than recorded in feeding sites. The discrepancy was due to a lower proportion of shrubs rather than graminoids in the faecal analysis, as the latter proportions were similar from the two methods. Most probably, this difference stems partly from the sampling procedure; the feeding site method did not account for the time distribution of feeding in different habitats. If so, the takin probably foraged more in the forb-rich patches than on willows within feeding site plots.

Shrubs were the most important food category, with willow, *Potentilla fruticosa* and *Ribes orientale* alone making up for ≈40% of the total number of bites recorded in feeding sites. Thus, takins can properly be classified as a browser, as suggested by Schaller et al. (1986). Although the diet was quite wide in terms of number of species, the dominance of only a few suggests that it is not a generalist browser, but that it exerts a certain degree of selection when foraging. Within a habitat type, takin did not select feeding sites with different proportions of life form categories (shrubs, forbs and graminoids) than was typical for that habitat type. Furthermore, in general, selected food plants were not more abundant at feeding sites than at random sites. Important exceptions to this pattern, however, were noted for the two most important food plants – the shrubs *Potentilla fruticosa* and *Salix myrtillacaea*. Both of these species were significantly more abundant at feeding sites than at random sites. Thus, takin tended to be selective only when foraging on their most preferred species; when feeding on less preferred species, they fed randomly within the habitat. Among the food plants at feeding sites, some species were eaten preferentially. These were also the ones that made up the bulk of the diet. Hence, within habitat types, selection occurred at two spatial scales: first among sites when feeding on main food plants, secondly among plants at the feeding sites where the same most important ones were preferentially eaten.

Takin are among the largest ruminants in the world, and in Asia the largest (Figure 3). Among this group of herbivores, the ratio of rumen to body size increases with body size (Hofmann 1989). This physiological adaptation is linked to a longer digestion period, decreased time allocated for feeding, and more rapid ingestion of food in large-sized species (Owen-Smith 1988; Illius and Gordon 1992; Mysterud 1998). According to optimum foraging theory (Schoener 1971), they simply cannot afford to forage as selectively as the smaller-sized ruminants with more rapid throughput rate of ingested food. This general pattern is most pronounced when food quality is low, for instance during winter when available food is more fibrous and less digestible. During summer, takin exhibited a certain degree of

Figure 3. Large bull takin radio-collared for another study by Ugyen Wangchuck Institute for Conservation and Environment in Tsharijathang in 2012. Photo by Tshewang Wangchuk.

selectivity probably because food was then plentiful and of high quality, and could be digested rather quickly.

We observed roughly 250 different takin in the study area, equating to approximately 40 animals/km^2 during the summer. Presumably, this high density could have led to competition for food. However, the fact that the animals exhibited a certain degree of selection, and that we did not observe social interactions where individuals were being displaced from feeding sites, suggests that the habitats were not overcrowded. Also, although the willow was heavily browsed, this plant species is known to be well adapted to browsing; browsing might even stimulate regrowth of more available forage on the browsed shrubs.

During winter, a large number of domestic yak graze in the study area, with heavy use of the flat river bottom. These animals also forage on willows, which include bark stripping as evidenced by scars on twigs and stems. In spite of this foraging on shrubs – which might be an evidence of pasture overuse – yak are basically grazers, not browsers (Shrestha and Wegge 2008). Winter grazing by yaks probably benefits the takin by maintaining a rather open habitat. However, grazing pressure should be monitored, as excessive use might alter the floristic composition and in the long run degrade the habitat quality for the summer-visiting takins. The overlapping use of the valley by yak and takin calls for further investigation and surveillance of ungulate diseases that could be transmitted in both directions (yak to takin, or takin to yak) affecting their health and survival.

Acknowledgements

Disclosure statement

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