

Habitat selection by sympatric chiru and Tibetan gazelle in the Aru Basin, Chang Tang Nature Reserve, Tibet Autonomous Region, China

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Abstract: Habitat selection was examined between two sympatric ungulate species of the high Tibetan plateau, the chiru (Tibetan antelope) *Pantholops hodgsoni* and the Tibetan gazelle *Procapra picticaudata*. The study was conducted in a high elevation area of low human presence during the early part of two summers (2000 - 2001), within the Aru Basin, Tibet Autonomous Region, China. Potential niche divergence between chiru and Tibetan gazelle was assessed in relation to elevation, slope angle, distance to hills, aspect and vegetation type and resource selection functions were used to attempt to differentiate habitat selection between species. However, habitat selection by the two species was similar in most respects, with both selecting low elevation, relatively flat, northerly facing aspects in *Stipa*-forb vegetation. Both species strongly avoided *Carex* vegetation that was present in flat, low elevation sites. Differences between the two species were noted primarily in the gazelle's somewhat greater use of near-hill and hill habitats, possibly related to both food selection and predator avoidance. The results suggest that the scale on which habitat separation occurs between these two species is generally both larger and smaller than that measured here, with plant community patchiness, within the *Stipa*-forb vegetation type for example, probably a key factor in determining differential habitat selection within the study site.

Key words: Body size; Chiru (*Pantholops hodgsoni*); Habitat selection; Microhabitat; Tibetan gazelle (*Procapra picticaudata*)

西藏羌塘自然保护区藏羚和藏原羚的生境选择

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摘要: 2000年和2001年初夏, 在高海拔、低人口密度的阿鲁盆地内对同域分布的藏羚与藏原羚的生境选择进行了研究。以海拔高度、坡度、离山岗距离、坡向以及植被类型作为资源参数, 利用 Resource Selection Function 对藏羚与藏原羚的潜在生态位分化进行检验。研究表明: 藏羚和藏原羚对低海拔、相对平地、针茅-非禾本科群落以及北坡的资源选择具有相似性, 但对低海拔苔草平地具有强烈的避开; 藏原羚对山岗或斜坡生境的利用比藏羚大。以针茅-非禾本科群落为例研究, 结果显示斑块植物群落可能是决定生境选择的主要原因。

关键词: 藏羚; 藏原羚; 栖息地选择; 微生境; 身体大小

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Resource selection can be viewed in terms of optimal foraging theory associated with trade-offs between predator pressure and food requirements. Niche divergence is the basis for coexistence of similar sympatric species within natural communities (Rosenzweig, 1981; Townsend *et al.*, 2000). Morphological characteristics can affect the pattern of food selection by ungulates, and hence their selection of habitat on the Tibetan plateau (Harris and Miller, 1995; Schaller, 1998a), as with the coexistence of ungulates in the Serengeti (Jarman and Sinclair, 1979). Other fac-

tors, such as behavioural differences related to micro-habitat selection, can also be important causes of niche divergence. The distributional range of wild ungulate species is being changed by humans and their livestock, and the potential for displacement of wildlife from preferred habitats must be considered in their conservation. Habitat management is an important issue for conserving endangered species and sustaining other endemic species.

The Tibetan antelope or chiru (*Pantholops hodgsoni*) and the Tibetan gazelle (*Procapra picticaudata*)

are endemic members of the Bovidae family, with almost completely overlapping distributions on the Tibetan plateau. The Tibetan gazelle's distribution is somewhat broader, encompassing additional areas to the east on the plateau and to the south towards the Himalaya and trans-Himalaya ranges, including Ladakh and Sikkim in India and the Mustang region of Nepal (Schaller, 1998a). But the chiru does occur to the north of Tibetan gazelle range on the northwestern Tibetan plateau (Chang Tang region), where chiru females migrate north to calving grounds in summer. The sympatric distributions of chiru and Tibetan gazelle imply that the two species separate resource use or predator avoidance in some way to avoid strong competition. Both species avoid large predators by running, with their long slender legs providing speed for escape, and such behaviour is consistent with their known use of relatively flat and open terrain (Schaller, 1998a). In contrast to the chiru, the Tibetan gazelle is not a long-distance migratory species, and may therefore be more selective in its habitat choice. Where female chiru migrate long distances for calving, as in the northwest Chang Tang region, only male chiru remain in areas sympatric with gazelle in summer.

Even though resembling true antelopes in appearance, the chiru apparently has closer genetic affinities to sheep and goats (Schaller, 1998a). Although the chiru has a wide habitat distribution, increasing human activities such as hunting, grazing and mining are threatening the chiru population, which has seen a decrease from over 1 million to less than 100 000 over the past century (Schaller, 1998b), and the chiru therefore falls within the declining population paradigm related to conservation (Caughley, 1994). The chiru has been designated a Class I (highest protection) endangered species in China (Qiu and Bleisch, 1996), and since 1975 has been a Schedule I species within the Convention on International Trade in Endangered Species of Flora and Fauna (CITES). The Tibetan gazelle is designated a class II (second highest protection level) threatened species in China (Qiu and Bleisch, 1996). Because of its endangered status, long distance migratory habits, and broad use of habitat types, the chiru can be considered a classic umbrella species for conservation.

Chiru males (36 – 55 kg) and females (25 – 30 kg) (Schaller and Junrang, 1988) are considerably larger than Tibetan gazelle (ca. 14 – 15 kg) (Schaller, 1998a), suggesting possible differences in diet selection related to nutritional requirements and bite size. Initial diet studies for both species show substantial overlap but suggest somewhat different food selection in summer, with chiru taking more grasses and

gazelle more forbs (Harris and Miller, 1995, Schaller, 1998a). With niche divergence as a key expectation, we have initiated an investigation of habitat use differences by male chiru and Tibetan gazelle (both sexes) that share summer range, through an assessment of their use of physical habitat characteristics such as elevation, aspect, distance to hills, slope angle and vegetation type.

The Aru Basin study area (33°45' – 34°25' N, 81°55' – 82°40' E) supports a high diversity of wildlife, with chiru and Tibetan gazelle being the most common wild ungulate species present in summer (Schaller and Gu, 1994; Fox *et al.*, 2004), although it is near the northern limit of Tibetan gazelle range. Because chiru tend to avoid human activity more than gazelle across the Chang Tang Nature Reserve (Fox and Bårdsen, 2005), assessing comparative habitat use without substantial effects of human activity is important. The human population in and around the Aru Basin is still low, such that wildlife habitat selection can be assessed without strong influence by anthropogenic activity. The present study encompasses an initial quantitative assessment of habitat selection, which was carried out in late spring and early summer of 2000 and 2001. Such work provides a background for future study, for once chiru and Tibetan gazelle habitat selection in the absence of strong human activity is determined, then one can look further at the details of areas where they differ under increased human pressure.

1 Methods

1.1 Study site

All data were collected from within the 2 300 km catchment of the Aru Basin in the northwest portion of the Chang Tang Nature Reserve, Tibet Autonomous Region (TAR), China. The Aru Basin is bounded in the west by high glaciated mountains with several peaks over 6 000 m, and rounded hills rise from 5 200 to 5 800 m to form the boundary in the east. There are two lakes, the fresh-water Aru Co (4 960 m), which flows into the brackish Memar Co (4 940 m). Even though the day-time temperature in summer may reach 15 – 20°C, there is no frost-free season and snow may occur in any month. Annual precipitation is apparently less than 100 mm in the region of the Aru Basin (Chinese Academy of Science maps), although around the Aru mountains it is certainly somewhat higher. The northwest Chang Tang is high, dry and cold, but the study area's proximity to moisture-trapping high mountains makes the basin a relatively productive area, explaining its support of a high diversity and richness of wild-

life. Six vegetation cover types are currently recognized in the Aru Basin; dry *Stipa*, *Stipa*-forb, dry hill-*Stipa*, *Carex*, *Ceratoides*, and Mountain Forb, (Schaller, 1998; Fox and Dorji, unpubl. data; see also Dorji, 2006).

1.2 Habitat availability and use

Data were collected by systematic searches for chiru and Tibetan gazelle throughout the Aru Basin, primarily from hilltop observation points, but also along vehicle transects between the areas covered from observation points. Observations were made with 8×40 binoculars and a 15×45 spotting scope. All observational data are of ungulate groups, the locations of which were placed on a space photography image of the basin and later transferred to topographic maps. Virtually all data are from either morning or late afternoon of mostly clear days when observational conditions were best. The male chiru population in summer was much more abundant than that for gazelle, so to achieve similar sample sizes, a systematic sample of chiru mapped locations, or every fifth group location, was used for analysis. For gazelle, the data were derived from one search of the basin in June 2000 and two searches of the basin, about 2 weeks apart, in late May and early June of 2001. For chiru the data were from a single June search each year.

The availability of elevation, slope angle, aspect and distance to hills in the Aru Basin was determined from maps or photographic sources, applying a systematic point grid and assessing habitat parameters from every point. No digital terrain models were available at the time of this study, so elevation, slope angle and slope aspect were estimated based on TPC 1:500 000 topographic maps and a vertical space photograph of the study area. Elevation was interpolated from the map contour lines, and slope angle was estimated based on field estimations and mapped locations. Terrain above 5 400 m elevation was generally barren or ice-covered, and was thus not considered as available habitat for chiru or gazelle.

Elevation categories defined within chiru and gazelle habitat were: 4 940 m (Memar lake level) – 5 000 m, > 5 000 – 5 200 m and > 5 200 – 5 400 m. Slope angle was categorized as follows: 0 – 15°, > 15 – 30° and > 30 – 45°. Slopes over 45° were not considered as potential habitat for these species, but such slopes were very rare at elevations below 5 400 m. Slope aspect was separated into the four cardinal directions, north, south, east and west. Distance from hills edge was determined by measurement on the study area map, and divided into the following categories: 0 or within hills, > 0 – 3 000 m, > 3 000 – 6 000 m, and 6 000 – 9 000 m. A total of 694 habitat

points were sampled within the 2 048 km² of land surface within the study area, although only 536 points (ca. 1 900 km²) were within what was considered available habitat, i. e. < 5 400 m elevation and < 45° slope. Vegetation type availability was determined from the same sample of points laid on an initial vegetation map of the study area.

1.3 Data Analysis

Resource utilization is defined as that quantity of resources used by an animal or a population of animals in a fixed period of time (Manly *et al.*, 2002), and it can be characterized by a resource selection function. It was impossible to identify individual animals; therefore, Design 1 with sampling protocol A, according to Manly *et al.* (2002), was used for a population level analysis. Although availability of habitat was sampled by intensive systematic sampling from a point grid, it is assumed that the results represent the population proportion. A habitat was “preferred” when its use is significantly greater than its availability in the environment (Johnson, 1980), the converse being the case for “avoidance”. That selection was taking place by a species was tested by the modified χ^2 : log-likelihood chi-square test. The Bonferroni adjustment 100 (1 – α)% of confidence intervals was applied for determining differences in each habitat category. If the lower confidence limit was greater than the population proportion, the habitat was selected, and if the upper confidence limit was less than the population proportion, the habitat was avoided.

2 Results

All observations of Tibetan gazelle (106 groups) during 2000 and 2001 and a sub-sample of chiru observations (140 groups) during 2000 provided the data base for analysis. There were no significant differences in group size or habitat use for gazelle between the two periods of observation in 2001, and these data were therefore combined. There were also no highly significant between-year differences in group size or habitat use characteristics for either chiru or Tibetan gazelle, thus the data sets from 2000 and 2001 were combined for analysis for each species.

Selection of elevation was apparent by both chiru ($\chi^2 = 68.216$, $df = 2$, $P < 0.001$) and Tibetan gazelle ($\chi^2 = 36.588$, $df = 2$, $P < 0.001$), although the two species did not differ much from each other in their respective selection (Table 1). Chiru selected both the middle elevation category ‘> 5 000 – 5 200 m’ and the low elevation category, whereas they avoided the higher elevations ‘> 5 200 – 5 400 m’ (Table 1). Tibetan gazelle also selected the middle elevations and

avoided the high elevations, but used the lower elevations in accordance with availability (Table 1). At this

season there were no significant differences in elevation between male and female gazelle.

Table 1 Estimated elevation use for chiru and Tibetan gazelle in the Aru Basin, Chang Tang Nature Reserve, TAR, China. π_i is the proportion of available elevation units in category i ; u_i the number of used elevation units in category i ; o_i the proportion of used units in category i , and s_i selection of elevation category i

Elevation (m)	Chiru				Tibetan gazelle			
	π_i	u_i	o_i	s_i	π_i	u_i	o_i	s_i
4 940 - 5000	0.332	63	0.450	+	0.332	38	0.358	0
> 5000 - 5200	0.377	73	0.521	+	0.337	61	0.575	+
> 5200 - 5400	0.291	4	0.029	-	0.291	7	0.066	-
Total	1.000	140	1.000		1.000	106	1.000	

+ represents selection, - is avoidance, and 0 is use in accordance with availability

Chiru showed selection in relation to distance from hills ($\chi^2 = 61.224$, $df = 2$, $P < 0.001$), exhibiting preference for areas within 3 000 m of hills, use of more distant areas in proportion to their availability, and avoiding areas within hills (Table 2). Tibetan ga-

zelle also exhibited selection relative to distance from hills ($\chi^2 = 32.238$, $df = 2$, $P < 0.001$), greatly preferring areas within 3 000 m of hills, while avoiding areas far from hills and using areas within hills in proportion to availability (Table 2).

Table 2 Selection of "distance from hills" by chiru and Tibetan gazelle in the Aru Basin, Chang Tang Nature Reserve, TAR, China. π_i is the proportion of available distance from hills (DFH) units in category i ; u_i the number of used DFH units in category i ; o_i the proportion of used units in category i , and s_i selection of DFH category i

Distance from hills (DFH)	Chiru				Tibetan gazelle			
	π_i	u_i	o_i	s_i	π_i	u_i	o_i	s_i
0	0.382	14	0.100	-	0.382	21	0.198	0
> 0 - 3000	0.445	102	0.729	+	0.445	77	0.726	+
> 3000 - 9000	0.162	24	0.171	0	0.162	8	0.075	0
Total	1.000	140	1.000		1.0000	106	1.000	

Both chiru ($\chi^2 = 190.56$, $df = 2$, $P < 0.001$) and Tibetan gazelle ($\chi^2 = 92.596$, $df = 2$, $P < 0.0001$) exhibited selection of slope angle within the Aru Basin, with both species showing preference for

slopes of less than 15° avoidance of steeper slopes up to 30°, and with no apparent use of slopes > 30° by either species in this sample (Table 3).

Table 3 Slope angle selection by chiru and Tibetan gazelle in the Aru Basin, Chang Tang Nature Reserve, TAR, China. π_i is the proportion of available slope angle units in category i ; u_i the number of used slope angle units in category i ; o_i the proportion of used units in category i , and s_i selection of slope angle category i

Slope angle	Chiru				Tibetan gazelle			
	π_i	u_i	o_i	s_i	π_i	u_i	o_i	s_i
0° - 15°	0.379	129	0.921	+	0.379	85	0.802	+
> 15° - 30°	0.453	11	0.079	-	0.453	21	0.198	-
> 30° - 45°	0.168	0	0.000	-	0.168	0	0.000	-
Total	1.000	140	1.000		1.000	106	1.000	

With regard to aspect, both species exhibited selection of north aspects, with other directions used in proportion to availability except for chiru avoidance of

east and west aspects, and gazelle avoidance of west aspects (Table 4).

Table 4 Selection of aspect by chiru and Tibetan gazelle in the Aru Basin, Chang Tang Nature Reserve, TAR, China. π_i is the proportion of available aspect units in category i ; u_i the number of used aspect units in category i ; o_i the proportion of used units in category i , and s_i selection of aspect category i

Aspect	Chiru				Tibetan gazelle			
	π_i	u_i	o_i	s_i	π_i	u_i	o_i	s_i
East	0.494	47	0.336	-	0.494	46	0.434	0
South	0.157	14	0.100	0	0.157	14	0.132	0
West	0.222	15	0.107	-	0.222	7	0.066	-
North	0.127	64	0.457	+	0.127	39	0.360	+
Total	1.000	140	1.000		1.000	106	1.000	

In terms of vegetation type use, chiru exhibited clear selection ($\chi^2 = 132.728$, $df = 5$, $P < 0.001$), with strong preference of the *Stipa*-forb type, use of the

Stipa type in accordance with its availability, and avoidance of other types (Table 5).

Table 5 Vegetation type selection by chiru and Tibetan gazelle in the Aru Basin, Chang Tang Nature Reserve, TAR, China. π_i is the proportion of available vegetation type units in category i ; u_i the number of used vegetation type units in category i ; o_i the proportion of used units in category i , and s_i selection of vegetation type category i

Vegetation type	Chiru				Tibetan gazelle			
	π_i	u_i	o_i	s_i	π_i	u_i	o_i	s_i
<i>Ceratoides</i>	0.146	10	0.071	-	0.146	0	0.000	-
Hill- <i>Stipa</i>	0.194	13	0.093	-	0.194	18	0.170	0
<i>Stipa</i>	0.239	27	0.193	0	0.239	12	0.113	-
Wet <i>Carex</i>	0.073	0	0.000	-	0.073	0	0.000	-
<i>Stipa</i> -forb	0.239	90	0.643	+	0.239	70	0.660	+
Mt-forb	0.112	0	0.000	-	0.112	6	0.057	0
Total	1.000	140	1.000		1.000	106	1.000	

Tibetan gazelle also exhibited selection of vegetation types ($\chi^2 = 52.12$, $df = 5$, $P < 0.001$), and again, as with chiru, showed preference for the *Stipa*-forb type while avoiding the *Ceratoides* and Wet *Carex* types, but in contrast to chiru, using Hill-*Stipa* and

Mountain forb in proportion to their availability (Table 5, Fig. 1). In this early summer sample, no observations for either species occurred in the Wet *Carex*, none for gazelle in *Ceratoides* and none for chiru in Mountain forb.

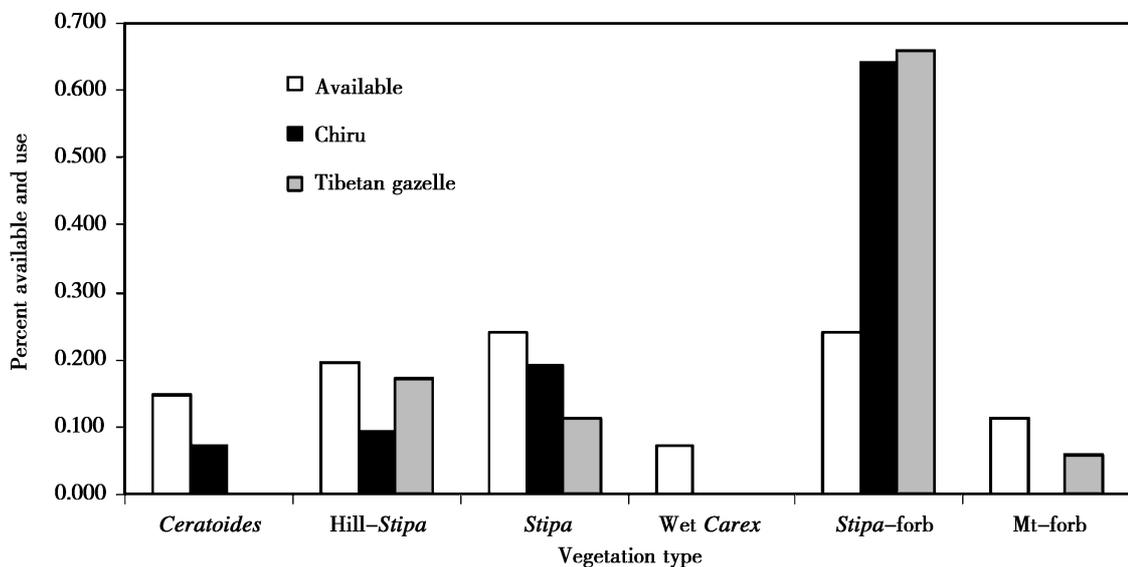


Fig. 1 Availability and percent use of vegetation types for chiru and Tibetan gazelle in the Aru Basin, Chang Tang Nature Reserve, TAR, China

3 Discussion

Chiru and Tibetan gazelle overlap almost completely in their overall distributions on the Tibetan plateau (Schaller, 1998). At a large scale, both temporally and spatially, chiru and gazelle separate habitat use primarily in terms of the female chiru's migration during summer to calving areas. Such migratory behaviour on the part of chiru acts to eliminate any potential food competition between the smaller female chiru and their young (both more similar in size to gazelle than the male chiru) for several months in summer. Whether such competition is significant, however, and whether it provided a selective pressure in the evolution of the chiru's migration is only speculative.

At the moderate landscape scale of the present study, where both male chiru and Tibetan gazelle occur in the same high plateau area in summer (all habitat >4 940 m elevation), it was found that both species selected similar lower basin, relatively flat terrain, on northerly aspects within the *Stipa*-forb vegetation type. Furthermore, when using this early summer data-set in an attempt to use resource selection function modeling of differential habitat selection by chiru and Tibetan gazelle, the result had very little explanatory power (x_1^2), indicating that the independent variables used in this study did not capture resource use differences between these species. Thus, at the scale dealt with here (ca. 2 000 km²), there was little difference in habitat selection by male chiru and Tibetan gazelle of both sexes. The only suggestion of a difference was the somewhat greater use of near and within hill habitats by Tibetan gazelles (Table 2).

Initial plant cover and biomass estimates indicate that *Stipa*-forb is the most productive vegetation type in the Aru Basin (Schaller, 1998; Dorji, 2006; Fox unpubl. data), and overall its plants are probably more nutritious and water-bearing than that in other communities. Thus, its selection in summer by both chiru and gazelle is reasonable. However, because the *Stipa*-forb vegetation type is comprised of a variety of plant associations (Dorji, 2006), it would also be reasonable to expect that a more intensive and smaller-scale study of feeding site selection would begin to show differences between forage selection by the relatively large male chiru and the smaller gazelle of both sexes. As indicated above, a suggestion of some niche divergence between the chiru and gazelle associated with the latter's greater affinity for sites close to and within hills may well reflect access there to moist forb-rich plant associations on the west side of the basin. And the gazelles' close association with the basin's western hills (north-

easterly aspects) is corroborated by additional data from other seasons, which is in contrast to the chiru's much more widespread use of the basin (Fox unpubl. data). This indicates that at a larger time scale, including the period when chiru females and young are also present, there is apparently some landscape use differentiation for these species within the basin, perhaps related to preference for certain plant associations within the *Stipa*-forb and Mountain forb vegetation types.

Both chiru and Tibetan gazelle avoid predators by running, and there are probably not great differences in the avoidance behavior advantages associated with terrain type, except that the smaller gazelle may more easily hide in very small breaks in terrain. If so, this may also influence the gazelle's greater affinity for hills and their vicinity than that of chiru. Still, as indicated above, not all hill vicinities in the basin are used by gazelle, only the moister western side of the basin. Morphological differences between chiru (especially the larger males) and Tibetan gazelle do suggest potential niche divergence in terms of food requirements, and diet studies do indicate that during summer gazelle forage selection is comprised of greater proportions of forbs than that for chiru (Schaller and Gu, 1994; Harris and Miller, 1995). Such a possibility lends further support to the idea that a smaller-scale feeding-site selection approach could be expected to demonstrate differential forage use by chiru and gazelle in the Aru Basin.

In terms of interaction with human activity such as livestock herding, both chiru and gazelle apparently select the same relatively productive vegetation types that are also preferred by herders for livestock grazing in the basin (Fox unpubl. data). Recent studies of the interaction between livestock and these wild species indicate that while chiru avoid the presence of herded livestock, gazelle are much more tolerant (Fox and Bårdsen, 2005), and comparative habitat preference studies for chiru and gazelle in areas of more intensive livestock herding will provide different results than those presented here. Such knowledge is important in assessing the overall effects of pastoralist activities in the Chang Tang on wildlife species such as the chiru and gazelle.

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