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# An assessment of endangered species habitat at large scale: chiru distribution across the Tibetan region of Chang Tang

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**Abstract.** Habitat degradation is a major threat to the survival of chiru (*Pantholops hodgsonii*). Detailed knowledge for habitat conservation in this steppe-dwelling ungulate is needed if effective conservation and management strategies are to be developed. The distribution of potential habitat and the relative value of habitat to chiru on a regional scale remains unknown, hindering landscape conservation planning. Our aim was to identify and rank chiru habitat across the Chang Tang region of the Tibetan Plateau. We assessed overall habitat suitability using geographical data, field surveys, and information contained within previous studies. We identified 10194 $km^2$ of optimal habitat (1.71 % of the region), 256816 $km^2$ of suitable habitat (43.17 % of the region), and 213799 $km^2$ of marginal habitat (35.94 % of the region). Our habitat model shows that suitable habitat is located primarily in the central (Nyingma county and Shuanghu county) and western (Geze county) regions of the study area. When we looked specifically at a chiru reserve (Chang Tang Nature Reserve) located within the study area, we found that over half of the reserve could be classified as suitable habitat. This highlights the regional importance of this reserve to chiru conservation. Our findings further indicate that the protection of suitable habitat and improvement of habitat linkages will be important features of any regional chiru conservation plan.

**Key words:** *Pantholops hodgsonii*, habitat assessment, species distribution, habitat suitability

## Introduction

The loss and fragmentation of habitat is a major threat to the continued survival of many species (Fahrig 1997, Huxel & Hastings 1999, Berggren et al. 2001). To manage endangered species effectively, conservation projects often require knowledge of a species' geographical distribution and patterns of habitat use (Pearce & Boyce 2006). Chiru or Tibetan antelope (*Pantholops hodgsonii*) are endemic to the Tibetan Plateau, and listed as endangered on the IUCN Red List (IUCN 2008) and Appendix I of CITES (CITES 2000). In China it has the highest level of protection possible, and is a Class I animal (State Forestry Administration of China 1998). Chiru once ranged across large tracts of the Tibetan Plateau and numbers approximating 1 million were estimated a century ago (Schaller 2000). The species now numbers less than 75000 (Schaller 1998) and habitat degradation continues to be the major threat to the survival of this species.

Habitat fragmentation involves the division of large, contiguous areas of habitat into smaller patches isolated from one another (Darren et al. 1998, Harrison & Bruna 1999, Ries et al. 2004, Sari et al. 2014). This process exacerbates the problem of habitat loss for grassland animals (Johnson 2001). Systematic research on chiru started during the late 1980s, and including studies on behaviour, foraging, and population status, among many other topics (Miller & Schaller 1996, Schaller 1998). Most of these studies were carried out at a small scale or within a local area and did not provide information at the scale of entire landscape ranges. While illegal hunting was once the primary concern for chiru conservation, particularly at some of the calving grounds, habitat competition with nomadic pastoralists and their livestock at the large scale is currently their greatest conservation threat (Shang et al. 2014). This is particularly true given the migratory behaviour of most chiru populations in the region (Schaller 1998), and the potential impacts

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of habitat fragmentation on their movement. Wild species generally depend on the same kinds of food sources as the domestic livestock herded on the plateau (Schaller 1998), and as a result the contest between livestock development and wildlife conservation has grown in the past two decades (Dorji et al. 2010). Furthermore, chiru habitat in southern Chang Tang is being converted to agricultural and grasslands for livestock at a rapid rate, creating isolated groups of chiru vulnerable to stochastic events such as extreme weather and disease (e.g. snowstorms, Schaller 1998, Liu 2006). In addition, the number of herders managing domestic animals is rising as the government creates economic policies that promote livestock production. As a consequence, human-wildlife conflict in this area is escalating (Schaller & Binyuan 1994, Miller & Schaller 1996). Additional pressures have arisen from increased infrastructure development, fencing and gold mining (Bleisch et al. 2009, Fox et al. 2009). Therefore, identifying the distribution of chiru habitat is now a high priority for conservationists as we attempt to ensure the long-term survival of this species.

The objectives of our study were to determine habitat distribution and delineate important habitat areas for chiru across Chang Tang. In combination with our analysis of the importance of several environmental parameters for chiru, we assess the amount of information that can be obtained for the steppe environment. We chose Chang Tang and the Chang Tang National Nature Reserve as our focal study areas. Habitat conditions and protection status varied substantially in this region, thus providing an ideal area to quantify chiru habitat assessment. The results of our investigation will directly inform management guidelines for this important species.

## Material and Methods

The region of Chang Tang (29°55′-36°30′ N, 83°55′-91°05′ E) is enclosed by the Kunlun, Nyainqentanglha, Tanggula, and Hoh Xil Mountains in the northwestern of Tibet, China. The area is an extremely broad alpine steppe, spans ten counties, and covers an area of almost 600000 km$^2$ (Fig. 1). Qiang Tang Nature Reserve is located in this region, accounting for more than 50 % of the area, and was created in 1993 (Fig. 1). The reserve includes one of the earth's last, largely undisturbed rangeland ecosystems and provides habitat for a unique assemblage of wildlife (Tibetan antelope *Pantholops hodgsonii*, Tibetan gazelle *Procapra picticaudata*, kiang *Equus kiang* and other species), several species of which are endangered and endemic to the Tibetan Plateau. The southern and westernmost parts of the reserve also support Tibetan pastoralists and their livestock (Miller & Schaller 1996).

Resource utilization is defined as the quantity of resources used by an animal or a population of animals in a fixed period of time (Manly et al. 2002). According to Schaller (1998) and Wangdwei & Fox (2008), both biotic and abiotic conditions are important for assessing the potential of an area to be suitable chiru habitat. We analyzed the suitability of chiru habitat by assessing these factors (Table 1) and the effects of humans (Table 2) on habitat. Vegetation type is a major biotic factor that defines habitat suitability because ruminants rely on high

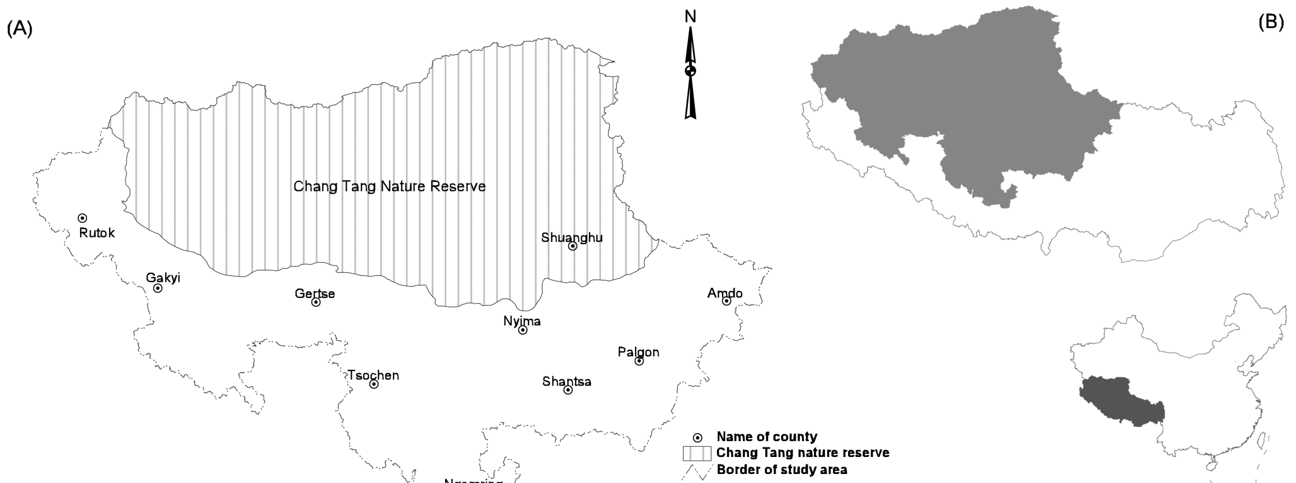


**Fig. 1.** Maps of study area and Chang Tang Nature Reserve (A), study area within Tibet (B), and Tibet within China (C).

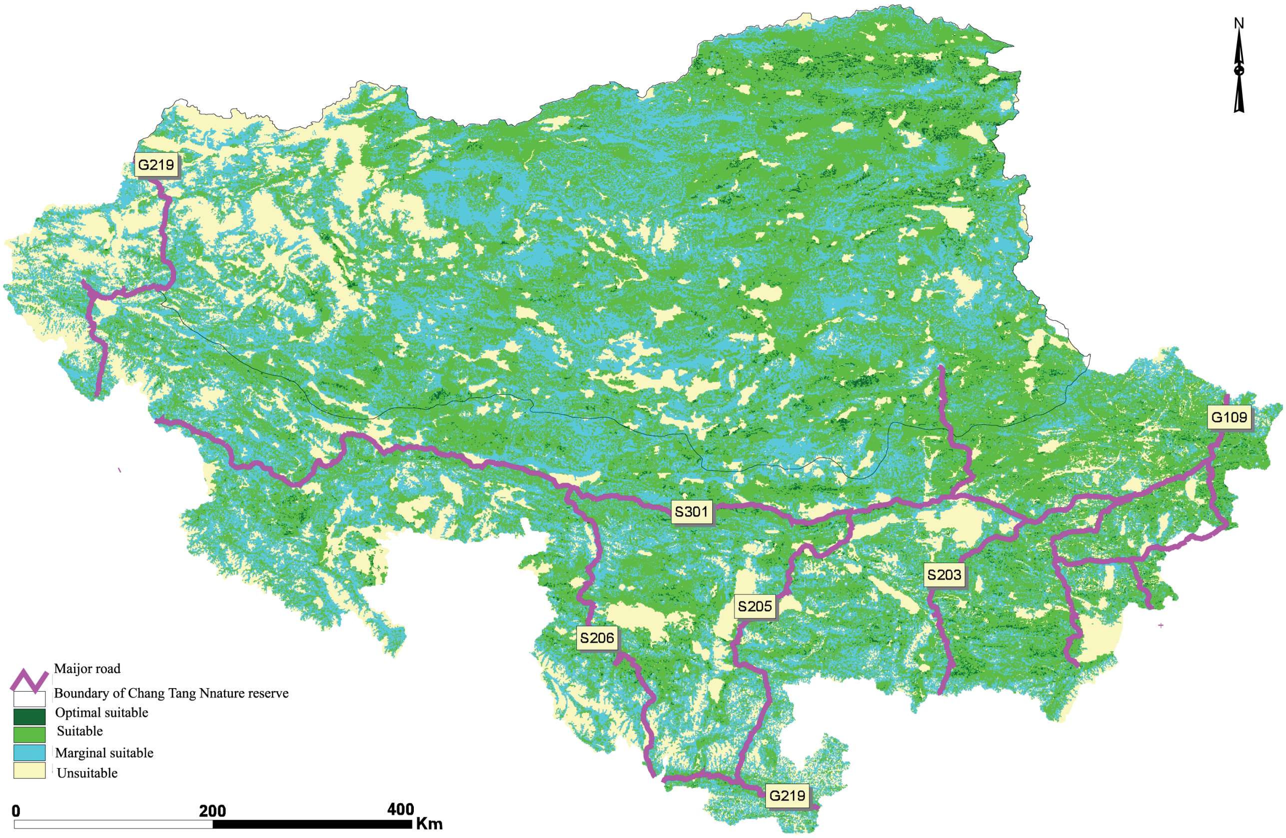


**Fig. 2.** Chiru habitat suitability map in Chang Tang range.

**Table 1.** Variables affecting chiru habitat suitability.

| Factor | Optimal | Suitable | Marginal | Unsuitable |
|---|---|---|---|---|
| Vegetation cover | > 50 % | 20-50 % | < 20 % | none |
| Elevation | 4600-5000 m | 4300-4600/5000-5200 m | 4000–4300/5200-500 m | < 4000/> 5500 m |
| Slope | 0-15° | 15-30° | 30-45° | > 45° |
| Aspect | north | south | east and west | NA |

**Table 2.** Assessment of the effect of humans on chiru habitat.

| Variable | Degree of effect | | | |
|---|---|---|---|---|
| | Strong | Moderate | Weak | None |
| Distance from road | < 0.2 km | 0.2-0.5 km | 0.5-1 km | +1 km |
| Distance from village | < 1 km | 1-2 km | 2-4 km | +4 km |
| Distance from town | < 3 km | 3-5 km | 5-8 km | +8 km |

**Table 3.** Final chiru habitat suitability scheme from the combination of a potential habitat and human impact maps.

| Habitat quality | Effect of humans | | | |
|---|---|---|---|---|
| | Strong | Moderate | Weak | None |
| Optimal habitat | 0 | 1 | 2 | 3 |
| Suitable | 0 | 0 | 1 | 2 |
| Marginal suitable | 0 | 0 | 0 | 1 |
| Unsuitable | 0 | 0 | 0 | 0 |

quality forage provided by natural grasslands and sufficient water (Wangdwei & Fox 2008). Vegetation characteristics at 1:10000 resolution were provided by the Center for Resources and Environmental Sciences, Chinese Academy of Sciences. Chiru are opportunistic, selecting both grasses and sedges and a variety of forbs in the grasslands. Consequently, we defined chiru habitat based on richness of grass and water availability (Table 1).

**Table 4.** Area of habitat of differing quality across the study area.

| Habitat suitability | Total | | Within Chang Tang Nature Reserve | | Outside Chang Tang Nature Reserve | |
|---|---|---|---|---|---|---|
| | Area ($km^2$) | Proportion of total (%) | Area ($km^2$) | Proportion of total (%) | Area ($km^2$) | Proportion of total (%) |
| Optimal | 10194 | 1.71 | 5377 | 1.78 | 4816 | 1.65 |
| Suitable | 256816 | 43.17 | 139233 | 46.06 | 117583 | 40.18 |
| Marginal | 213799 | 35.94 | 109912 | 36.36 | 103887 | 35.5 |
| Unsuitable | 114063 | 19.17 | 47731 | 15.79 | 66331 | 22.67 |
| Total | 594874 | 100 | 302254 | 100 | 292619 | 100 |

Elevation and slope can be significant abiotic factors (Wangdwei & Fox 2008). Chiru prefer flat to rolling terrain, often at elevations 3700-5500 m, although they readily ascend high rounded hills, penetrate mountain ranges and cross passes by following valleys (Schaller 1998). Chiru cannot tolerate the low temperatures and inadequate food and vegetative cover at extremely high elevations, and prefer low elevations (Liu 2006). With regard to slope aspects preferences, chiru exhibited selection of north aspects, with other directions used in proportion to availability for chiru avoidance of east and west aspect (Wangdwei & Fox 2008). A score of 0-3 was attributed to each habitat level (optimal, suitable, marginal, and unsuitable) for all factors (Table 1). These values were then multiplied, producing a potential habitat map for chiru with values ranging from 0 to 81. This analysis was done at the pixel scale and scores corresponded to habitat classification using the following: if a pixel scored a composite score of 0 it was deemed unsuitable habitat and attributed the overall rank of 0, a composite score of 0-16 was deemed marginal habitat and given the overall rank of 1, a composite score of 16-81 was deemed habitat and given the overall rank of 2, a composite score of 81 was deemed optimal habitat and given the highest rank of 3 (Xu et al. 2006).

Since human activities also cause habitat degradation, they need to be considered as well. Three measures of human impact were used (Table 2). We assumed that the impacts of human activities on chiru habitat decrease as a function of distance, and that the closer an area was to a road or settlement, the greater its negative influence on the value of that habitat (Cincotta et al. 1991). In support of these assumptions, when recording chiru in the field, we found that they had a faster and greater response to potential risks when within 200 m distance from a road (D. Qi, pers. observ. and Schaller 1998). Therefore, the impacts of roads and human settlements were identified using digital maps and classified into four different human impact classes based on distance. We attributed scores following the schema in Table 2, and for each cell used the lowest score (most negative influence) in the combination analysis that followed (Liu et al. 1999). A final habitat suitability map was produced by merging the habitat map and human impacts map (Table 3). All analyses were performed in Arc View GIS 3.3 (ESRI, Redlands, USA).

## Results

Our habitat model showed that suitable habitat for chiru is located primarily in the central (Nyingma and Shuanghu counties) and western (Geze county) regions of the study area. Very little suitable habitat was detected in the southernmost region (Ngamring county, Fig. 2). The total area of chiru habitat present across Chang Tang is 480810 $km^2$ (81 % of the region, Table 3). This area includes optimal habitat of 10194 $km^2$, suitable habitat of 256816 $km^2$ and marginal habitat of 213799 $km^2$.

Chang Tang Nature Reserve covers an area of 302254 $km^2$ and was found to encompass 51 % of all chiru habitat (594874 $km^2$). Deeper analysis showed that the reserve protects only 1.8 % (5377 $km^2$) of optimal habitat across the region, 46 % (139233 $km^2$) of suitable habitat, and 36 % (109912 $km^2$) of marginal habitat (Fig. 2). Analysis by administrative county revealed that 80 % of optimal and suitable habitat present in Shuanghu and Gertse counties is protected within the reserve, more than half in Rutok county, approximately 40 % in Amdo and Nyima counties, 20 % in Gakyi county, and no habitat is protected in Tsochen, Shantsa, Palgon, and Ngamring counties (Table 4).

## Discussion

The geographical range of chiru extends 1600 km across the Tibetan Plateau between Ngoring Hu, China and Ladakh, India. Chiru face extinction at the current rate of habitat loss, fragmentation and degradation. Although population patterns in chiru have been explained (Schaller 1998, Liu 2006), the distribution of chiru habitat at the landscape scale has not. Our models show that suitable habitat for chiru appears to be fragmented, especially in the southern areas of the reserve and outside their key reserve. Chiru in southern Chang Tang are likely to be confined to isolated patches of suitable habitat. The rather low number of chiru records to the south means that chiru here are isolated and vulnerable to local extinction. Accordingly, these populations are in need of immediate protection.

Large patches of habitat in landscapes will maintain viable populations of grassland animals (Winter et al. 2006). In general, chiru typically live in high density grassland habitat (Schaller 1998). Our resulting maps showed that many highly suitable habitats for chiru were in the north and west, areas within official reserves. High suitability habitat outside of the reserves in these regions appear to be poorly located or are too small to support chiru (Fig. 2). Suitable environmental conditions are restricted to a few mountain valleys in southern and western Chang Tang (Fox & Bādsen 2005). Traditionally, these valleys included relatively disturbed grassland where chiru occur in low population densities (Schaller et al. 2006). In our three field surveys this species was recorded mainly in low density grassland. The reason may be that high density grassland are rare in transects surveys except for a few areas near water. As previous research has suggested, anthropogenic threats such as road construction, tourist infrastructure, and livestock in these areas may reduce suitable areas for chiru, and increase vulnerability of local extinctions (Schaller 1998, Liu 2006). The most important of these factors are habitat loss and disturbance.

With the establishment of the Chang Tang Nature Reserve in 1993, approximately 300000 km$^2$ of Tibetan wilderness were brought under protection. The reserve, which is the second largest protected area in the world, includes one of Earth's last and largely undisturbed rangeland ecosystems and provides habitat for a unique assemblage of wildlife, several species of which are endangered and endemic to the Tibetan Plateau. On the basis of habitat evaluation, this reserve only protects half of the available suitable habitat found across Chang Tang. Further, while many of the protected areas of the Tibetan Plateau encompass high-altitude rangelands, protected areas at lower grassland elevations are scarce (Miller & Schaller 1997). In areas of unprotected habitat, isolated chiru populations are vulnerable to poaching and habitat encroachment. Furthermore, the nature reserves are mostly distributed in the northern and eastern parts of the study area, and no nature reserves are found in the south. The conservation of chiru in Chang Tang should maximize the area contained by current nature reserves and generate new nature reserves and corridors that facilitate the movement of chiru among different habitat patterns.

In this study, habitat assessment was carried out based on biotic, abiotic, and human impact factors that affect the distribution of chirus. Although information on elevation, slope, vegetation cover, roads, and human settlements were used in our assessment, our reliance on these as the primary factors influencing chiru habitat was mainly a function of data availability, and does not mean that other factors are not of importance. Other human factors including pastoralists, fencing, and livestock grazing should affect the distribution and quality of habitats.

Pastoralists affect the distribution of chiru habitat because of their proximity to this species (Schaller 1998). The pastoralist population is sparse but almost all available pasture is used for grazing (Fox et al. 2008). For example, some 30000 pastoralists in Chang Tang Nature Reserve utilize areas within the park and many are still dependent on hunting chiru for subsistence (Fox et al. 2004). Unfortunately detailed information on pastoralist distribution in Chang Tang is unavailable. The effect of fencing on wild herbivores, especially those with disappearing long-distance migratory routes, increases their vulnerability (Berger 2004). In other dry rangelands the effects of enclosures have been to reduce the capacity of the land to support large herbivores (Reid et al. 2004). A few small chiru populations are sedentary, but most animals are migratory. Schaller (1998) found four migratory populations (West Chang Tang, Central Chang Tang, East Chang Tang, and Qinghai) based on the movements of females, and indicated that the abundance and distribution of chiru in an area depend on the migratory patterns of a particular population.

Livestock grazing is an important conservation concern globally (Prins 1992, Fleischner 1994, Mishra et al. 2004). Increasing movement, resource extraction activities, rangeland use and settlement by pastoralists in chiru habitat present a variety of potential threats that will likely lead to the curtailment, adverse modification or destruction of chiru habitat (Fox & Bādsen 2005). Livestock production is already curtailing and modifying chiru habitat, and could eventually lead to the destruction of some portion of the species' range through competition, overgrazing and/or desertification (Miller & Schaller 1996).

Other human factors, including herb collection, mining, and tourism, would also affect the distribution and quality of habitat (Harris 2007); but such data were not available in our study. If these factors were considered, the accuracy of the analyses would potentially enhance. However, we have provided an overall coarse evaluation of the situation of chiru habitat in the study area, rather than a definite habitat suitability map. Our study suggests ecological modelling using large scale GIS is useful in assessing broad scale habitat suitability for chiru. All the southern Chang Tang localities with suitable chiru habitat should be completely protected. Finally, the conservation of chiru habitat in the Chang Tang needs to increase the area encompassed by the current reserve system.

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