

Migratory and calving behavior of Tibetan antelope population

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Abstract: A migratory population of female Tibetan antelope or chiru was studied on its calving ground in the western Kunlun Mountains, Xinjiang in June - July 2005. It was estimated that 4 000 - 4 500 females were in the 1 200 km² calving area but most births were concentrated in 350 km². The habitat at 4 500 - 5 000 m in elevation had vegetation coverage of less than 5%, principally the dwarf shrub *Ceratoides compacta*. Young were born 18 June - 7 July with a peak 24 June - 3 July. Only about 40% of adult females had young, a low fecundity possibly the result of heavy winter snows leading to poor physical condition. Wolf, red fox, and birds of prey killed a few chiru but predators were scarce; most mortality was unrelated to predation. Females arrived at the calving grounds in late May and early June from the west of Tibet, and by early July started their return migration. It remains unclear why chiru migrate to that site. Analysis of chiru food plants showed no marked difference in nutritive values at this season between the calving grounds and the southern range. Escape from predators, parasitic insects, and people with their livestock may all have a role. Based on the study, we suggest that the main calving ground requires strict protection from disturbance, and a large reserve in the region needs to be established.

Key words: Behavior; Calving; Conservation; Migration; Population dynamics; Tibetan antelope (chiru)

藏羚羊雌性种群的迁徙行为和产仔行为

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摘要: 2005年6~7月, 我们在新疆昆仑山西部的一处藏羚羊繁殖地, 对一个雌性藏羚羊的迁徙种群进行了研究。整个调查区域的海拔是4 500~5 000 m, 植被覆盖率小于5%, 主要植被是垫状驼绒藜 (*Ceratoides compacta*)。根据研究结果, 我们估计在本产仔季节, 共有4 000~4 500头雌性藏羚羊迁徙聚集到一个1 200 km²的区域内, 集中产仔地面积约为350 km²。产仔的高峰期是在6月18日~7月7日, 其间只有40%的成年雌性产仔, 这可能和2004年冬西藏阿鲁盆地的降雪量较大导致藏羚羊在交配期和怀孕期身体条件较弱有关。这个区域的雌性藏羚羊迁徙自西藏的西部, 在5月下旬至6月上旬之间到达该区域, 然后在7月上旬开始返回。研究区域内的狼、赤狐和大型猛禽是主要的捕食者, 但是出现的频次很少。研究区域内大部分藏羚羊成体和幼仔的死亡和天敌捕食没有关系。我们对藏羚羊主要采食的植物的营养成分进行分析, 没有发现这个区域和其南部其他区域的差异, 所以食物可能不是藏羚羊迁徙的主要原因。躲避捕食者、躲避传播寄生虫病的昆虫干扰、或者是避开牧民和家畜, 这些因素都有可能导致藏羚羊雌性迁徙到这个区域产仔。基于本次研究, 我们建议新疆和田地区能够对这个产仔地进行严格保护, 禁止产仔期的人类干扰, 同时有必要考虑建立一个大型保护区, 或者和相邻保护区联合起来进行管理。

关键词: 藏羚羊; 迁徙; 产仔地; 种群动态; 行为; 保护

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1 Introduction

The Tibetan antelope or chiru (*Pantholops hodgsoni*), the only genus of large mammal endemic to the

Tibetan Plateau, is found in the rolling, treeless terrain of the northwestern part, called the Chang Tang, usually at elevations of 4 000 - 5 000 m. It occurs only in

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China except for a few animals that stray seasonally into India. Once the chiru was abundant, but the international demand for its fine wool caused the animal to be killed illegally in large numbers, particularly in the late 1980s and 1990s. The wool was then smuggled to Kashmir in India where it is woven into high-priced shahtoosh shawls (Wright and Kumar, 1998; Zhen, 2000). Concerned about the plight of the chiru, a Class I protected animal, China initiated intensive anti-poaching efforts (Xi and Wang, 2004) and involved international conservation communities to reduce this illegal trade (Zhen, 2000). The species also has legal protection in several large, contiguous reserves, namely the Chang Tang Nature Reserve in Tibet, the Arjin Shan and Mid-Kunlun reserves in Xinjiang, and the Kekexili Reserve in Qinghai with a total area is over 400 000 km².

Knowledge of the natural history of a species is essential for effective long-term conservation and management. Although the chiru has been studied intermittently (Feng, 1991; Harris and Miller, 1995; Schaller, 1998; Fox and Bardsen, 2005; Schaller *et al.*, 2005), many aspects of its life remains little known; indeed its total number is still unclear. Research by Schaller (1998) and his coworkers revealed that chiru have a number of sedentary populations and 4 main migratory populations that travel north in spring and then return south by autumn. One of these migratory populations is in the western Chang Tang where it travels between Tibet and Xinjiang, and it is the focus of this study. Of note is that these migrations consist mainly of adult females and of yearling females born the previous year, and that movement is into remote, uninhabited terrain to traditional calving grounds. Males do not accompany the females. In this the chiru differs from other migratory ungulates such as saiga (*Saiga tatarica*), wildebeest (*Connochaetes taurinus*), and caribou (*Rangifer tarandus*) in which both sexes go to the calving grounds (Kelsall, 1968; Sokolov, 1974; Sinclair and Norton-Griffiths, 1979).

We were intrigued by the question of why only chiru females travel as much as 700 km roundtrip to and from a specific site to calve first when pregnant and then lactating. Both are costly periods for an animal in terms of expended energy, and migration adds a further stress. Detailed information on the behavior of chiru on the calving ground was not available. Calving is a critical time for a population; newborns are highly vulnerable to predators and inclement weather and poachers can easily decimate the population (Wong, 1998; Xi and Wang, 2004). We selected the western population for study because its main migratory route and calving site were known based on previous research in

1990, 1992, 2001, and 2002 (Schaller, 1998; Schaller *et al.*, 2002; Ridgeway, 2004). Information about chiru in Tibet in this report is mainly from Schaller (1998).

2 Study area

The western chiru population is in the southern part of its range from August to May. There the animals are scattered over about 200 km west to east (82° – 84°) and 100 km south to north (33° – 34°50'), an area of about 20 000 km², and there mating occurs in December. The terrain consists of a mosaic of broad valleys, plains, and steeply rolling hills, all above 4 300 m in elevation, and of the glaciated Aru Range between the lakes Lumajangdong Co in the west and the Aru Basin with its Aru Co and Memar Co in the east. The vegetation consists mostly of alpine steppe with a vegetation cover seldom exceeding 30% and sandy soils without sod layer. Species of feather grass (*Stipa*) are dominant and other graminoids and a variety of flowering plants are locally common. Alpine meadow vegetation, consisting of turf covered mainly with the sedge *Kobresia* occurs along streams.

In May and early June the females move north. The various travel routes join just north of the Aru Basin, and from there the animals take a well-defined route past the western base of 6 350 m Toze Kangri, across a wide plain, and into the lake basin of Heishi Beihu (Fig. 1). Satellite photos show that vegetation biomass drops sharply at about 35°N. Here the desert steppe is mostly bare of vegetation except for patches of coarse *Carex moorcrofti* and the dwarf shrubs *Ceratoides compacta*, only 10 – 15 cm tall. With the terrain too high and bleak to support livestock, nomads do not inhabit it. Chiru continue north and soon enter Xinjiang. After passing east of a lake at 35°41'N, 82°52'E the animals disperse. Some move north and northeast around a small, rugged range toward a lake basin, the Shar Kul, but most go west and northwest into hills, especially those bordering the Ser Kul Basin (Schaller *et al.*, 2002).

The calving area extends from 82°20'E eastward for about 60 km and 20 km south to north, or a total of 1 200 km; however most calving was concentrated in 350 km². A few chiru disperse farther, as into the Serak Tus valley that cuts through the Kunlun Mountains. The whole region is extremely bleak. The snow peaks of the Kunlun Mountains border the northern edge of the Ser and Shar Kul basins. Large expanses of these basins lack vegetation and sand storms blast across them. There are patches of *Carex moorcrofti* in the low parts of the basins and even a little *Kobresia* turf and

Myricaria shrub along Shar Kul's shoreline, but the dominant plant, thinly scattered, is *Ceratoides*. The hills south and west of the basins often have such barren and eroding slopes of sand, silt, clay, and rock debris that only the deep-rooted *Ceratoides* may find a foothold. A sparse scattering of graminoids occurs along streams and seepages. There are two broad outwash plains on the calving ground, covered sparsely with *Ceratoides* and rare patches of *Astragalus forb.* Different is a plateau of about 40 km² at 35°54'N, 82°26'E which has an extensive cover of cushion plants (*Oxytropis*, *Arenaria*) at an elevation of 4 800 – 5 000 m. But, in general, over 95% of the ground is bare.

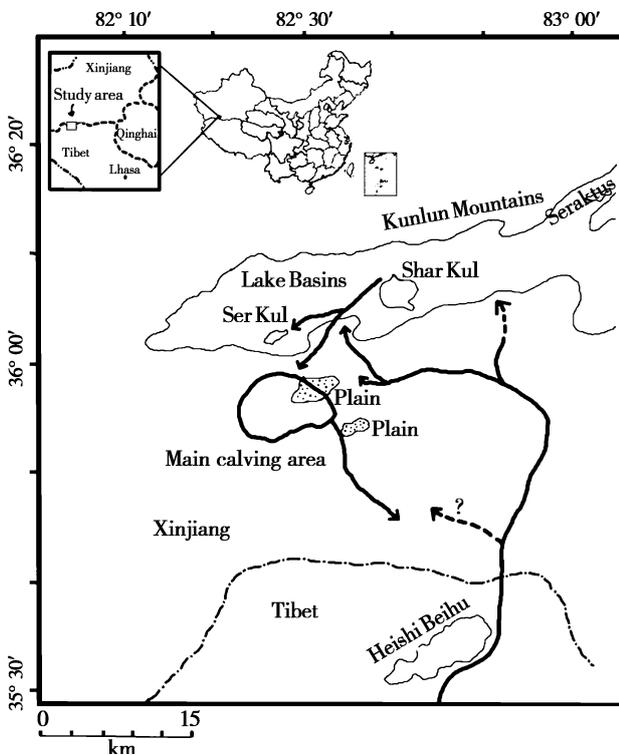


Fig. 1 Movements of female Tibetan antelope to and from the main calving area in Xinjiang

The climate is severe. Between June 10 and July 7, a period that includes calving, it snowed or hailed on 19 days, there were violent sandstorms on 6 days, and only 3 days were relatively benign. The weather improved between July 8 and 17 when it snowed on only 3 days. Temperatures were moderate, generally ranging from a low of -5°C to 1°C at night to a high of 10°C to 15°C in daytime.

3 Methods

From 10 June to 18 July 2005 we maintained a base camp ($36^{\circ}08'N$, $83^{\circ}40'E$) at an elevation of 4 530 m at the southern edge of the Ser Kul basin.

Chiru were located and observed with binoculars

and spotting scopes by teams of 2 – 3 persons on foot and occasionally by driving in a vehicle along the Ser and Shar Kul basins. Animals were extremely shy and we remained at a distance of several hundred meters to record group size and composition, noting adult females, yearling females, and newborns. Vegetation was sampled with circular 0.25 m² plots and the percent coverage of each species estimated. Each of 28 transects consisted of 25 plots about 3 m apart for a total of 700 plots.

To help determine chiru movements, we radio collared 12 newborns, most 1 – 2 days old, capturing them by hand as they crouched. Transmitter and collar weighed 100 g, and the latter was designed to expand as the young grew. A newborn was weighed, sexed, collared, and placed where it was found, a process that required only 1 – 1.5 minutes. A new pair of surgical gloves was put on before handling an animal and all equipment was rubbed with strong-smelling *Ceratoides* leaves to minimize human odor from adhering to the newborn. The chiru mother usually watched from a distance of 250 – 400 m and later retrieved and accepted her offspring, as direct observations and evidence from radio signals indicated. We attempted to monitor signals daily, but the mountainous terrain and extensive movement of animals made reception difficult.

4 Results

4.1 Migration to and from calving grounds

Chiru may appear on the calving ground in mid-May according to local informants. However, the timing of arrival varies between individuals and probably from year to year. On 10 – 11 June 2001 at least 900 chiru were already on the calving ground as well as in the Serak Tus valley at $36^{\circ}21'N$, $83^{\circ}12'E$. Yet on 9 June the following year a total of 215 chiru were seen at Heishi Beihu several days south of the calving ground (Schaller *et al.*, 2002). Even more lagging was the migration in 1992 when 2 200 – 2 400 chiru were counted as they passed Toze Kangri between 16 – 22 June.

When we arrived in the study area on 10 June 2005, chiru were scattered along the southern parts of the Ser and Shar Kul basins. Usually 150 – 300 chiru were there until 6 July after which most left. Over 100 chiru could usually be found in scattered herds in the adjoining hills to the south in a day's walk, but virtually all were gone by mid-July. Such constant movement was illustrated by minimum counts in one small basin ($35^{\circ}59'N$, $82^{\circ}27'E$): 13 June 143, 20 June 593, and 22 June 175. Movement was generally south-southeast toward a 5 000 m plateau and the western edge of a plain where many females calved (Fig. 1).

A southward shift of animals during the first week of July suggested the onset of the return migration, even before all calves had been born. Several days of snowstorms resulted in a concentration of animals. Both the inclement weather and the concentration as well as the basic forage shortage, perhaps stimulated animals to move south. By 13–14 July the main calving area was virtually deserted. The principal route south and southwest was from the plateau and plain across low hills to the west side of a small plain (35°54'N, 82°34'E), south up a valley over a pass, down another valley and onto a plateau (35°50'N, 82°37'E) where we ceased to follow the route. The animals continued toward Heishi Beihu and farther into Tibet (Fig. 1)

This southward shift was also evident in the radio-collared young. Although the signal of most young was received only on 1 or 2 days after collaring, two were found on 3 days, one on 4 days, and one for 6 days from 7–15 July.

On 21 July 1896, Deasy (1901) was camped on the plain north of Toze Kangri and noted “thousands of antelopes” migrating, and on 27 July 1903 Rawling (1905) saw there “thousands of doe antelope with their young.” In 1992, the first migrants, a herd of 69, reached the northern end of the Aru Basin on 28 July and between 30 July–3 August at least 7 350–7 750 animals passed, crossing the Aru Range westward over a pass. These observations suggest that the migratory route and its timing has persisted for over a century.

4.2 Population size

Numbers are difficult to determine because the females move constantly (we saw fewer than 10 males) and the area is large. We observed a total of 2 360 females in the main calving area between 25–27 June, and 2 130 between 2–7 July when animals concentrated after daily snow storms. But by July the migration had begun and one herd of 1 000 was already in the hills south of the calving area. Probably at least 3 000 females were in the main calving area. Chiru were also scattered elsewhere, with, for example, 246 still in the Ser and Shar Kul basins on 5 July. We estimate that 4 000–4 500 females came to the calving grounds in study period.

Rawling (1905) saw so many chiru that “there could not have been less than 15 000 or 20 000 visible at one time,” and many more were coming into view. In subsequent decades numbers decreased. In 1992, Schaller (1998) estimated that “over 10 000” females and young passed the Aru Basin toward the west-southwest of the Aru Basin and an unknown number to the east-southeast. About 40% of these or at least 4 000 were young of the year and 6 000 were females. These

figures do not include males, which generally are outnumbered by females. If we arbitrarily add 5 000 males, then the total population would have been at least 15 000, not counting animals that went other routes. Fox *et al.* (2004) noted 11 000 chiru of both sexes within the Aru Basin in autumn 2 000 – an area not much frequented a decade earlier. In autumn 2002, a total of 10 000 were in the basin and 2 000 west of it (J. Fox, pers. com.). These figures are perhaps somewhat lower than those we estimated for 1992.

As noted, about 4 000–4 500 females were presumed to be on the Kunlun calving grounds in 2005. What was the size of the total population migrating south? Females do not give birth until 2 years of age. A total of 16% of females were still yearlings or about 640–720, leaving 3 360–3 780 adult females of which 40% had newborns, or roughly 1 300–1 500. Thus, our calculated total was 5 300–6 000 female chiru and young, considerably fewer than we observed in 1992. Given the data provided by Fox *et al.* (2004) it is probable that some females of that population calved elsewhere, as reported in 1996 by the Tibet Forestry Department when animals gave birth near Gozha Co, southwest of Heishi Beihu in Tibet. If males are added to our numbers, the total approaches that noted by Fox *et al.* (2004). Long-term monitoring of the population is essential.

4.3 Food habits

The food available to chiru in May and June consisted mostly of *Ceratoides* and a few graminoids. *Ceratoides* already had new leaf buds in early June and was widespread. Of 23 transects in areas where *Ceratoides* was the only species present, average coverage was 2.5 (<0.1–7.0)%. Graminoids existed only in scattered patches. The graminoids were dormant until mid-June and later and then green leaves appeared among the yellow, dead ones. Between 20 June and 14 July, we examined the rumen contents of 11 females that had died and estimated the percent of each food type. *Ceratoides* averaged 57 (0–95)% and graminoids 43 (5–100)%, the latter with more dead than green leaves. Mixed with the grass of several rumens, were some thin roots. We had not anticipated so much grass and sedge. Chiru grazed on *Carex moorcroftii* in the Ser and Shar Kul basins, but elsewhere the amount of graminoid forage seemed negligible except around the plateau where most calving occurred. The top of the plateau had good vegetation coverage, in places as high as 75%, mostly cushion plants. One transect on 14 July at a site of moderate coverage (34%) showed *Oxytropis pauciflora* 19%, *Arenaria* sp. 8%, *Ceratoides* 3%, *Sinelowskia* 3%, and the remaining percent some

grass, *Leontopodium*, *Braya*, and others. These plants offered chiru relatively little forage, but they held moisture from melting snow with the result that the slopes of the plateau were in places noticeably damp and along the many seepages were graminoids.

Biomass productivity, as measured by satellite between 2000 and 2004 at calving time, was over twice as high on the chiru's winter range than the calving grounds or 400–600 versus 1 200–1 400 median NDVI. The main calving area has somewhat higher biomass than other parts.

Ruminants require 5%–9% of crude protein for maintenance in their diet (Fryxell, 1987; Sinclair and Arcese, 1995). Green leaves generally have high protein levels, as shown from samples collected in the Tibetan Chang Tang between June and August: various graminoids 13%–22%, *Oxytropis pauciflora* 18%, *Ceratoides* 13%–20%; green *Carex moorcrofti* leaves had 17% protein and dead ones from the same site 3%. We collected 3 *Ceratoides* samples within the calving area in early June 2001 and these averaged 27% crude protein. Three *Ceratoides* samples in green leaf, collected during our 2005 study, averaged 22.7%, and one sample with dead leaves was 7.0%. A graminoid sample of mixed green and dead leaves, collected on June 27, had 13.2% crude protein. It remains unclear why chiru ate so much grass, as shown by rumen contents, when protein values of *Ceratoides* were considerably higher.

4.4 Population composition

Most chiru groups (excluding calves) were small, numbering fewer than 30 individuals, and many females were alone (Table 1). Not included in the computations were occasional large aggregations such as when several hundred chiru were loosely spread out feeding or when over a thousand rested together at the base of hills after a snowstorm. Although we determined group composition and sampled aggregations, it was difficult to obtain an unbiased population composition. Many yearling females separate from their mothers on the calving ground. Several yearlings may form a group or may attach themselves to an adult without newborn and then frequent areas other than the main calving site. The percent of yearlings in an area thus varied between 10%–20% with an average of 16% ($n=2913$ animals). There were 27% yearlings in the same area in 2001, suggesting better recruitment that year but our sample was small ($n=356$).

Fewer adult females than expected were heavily pregnant in mid-June. Pregnancy rates of Mongolian gazelles (*Procapra gutturosa*), caribou, saiga, and other migrants generally exceed 85% (Olson *et al.*, 2005). We assumed that births were delayed or that

females ready to give birth had concentrated at a place we had not yet discovered. However, many females still lacked bulging abdomens after calving was well advanced. From 4–17 July, when the calving season was almost over, only 45% of adult females ($n=1 496$) were with newborns in and around the main calving area. A number of newborns had died, and females who lost offspring or did not have any tended to be peripheral, causing biases in our counts. Therefore, about 40% of adult females had newborns, totaling around 1 350–1 500, when the animals began to migrate south.

Table 1 Group sizes of female chiru on the calving ground (based on 468 groups and 3 986 animals; newborns are not included)

Group size	Percent of groups	Percent of females
1	21.6	2.5
2	13.0	3.1
3	8.8	3.1
4	8.8	4.1
5	4.5	2.7
6–10	16.0	14.5
11–15	10.0	15.2
16–20	6.0	12.7
21–25	4.1	10.7
26–30	3.2	10.8
31–75	4.1	20.7

The fact that at least half of the adult females did not appear to be pregnant requires explanation. After a heavy snowfall in October 1985 two chiru populations in Qinghai entered the rut in such poor condition, the result of malnutrition, that females either failed to come into estrus or to conceive, and fetal survival rates may also have been low. Few young were born in 1986. Between November 2004 and February 2005 heavy snows caused the death of much livestock on the winter range of the western chiru population in Tibet, and this may have had an impact on chiru fecundity.

4.5 Birth synchrony, body mass and newborn behavior

Rawling (1905) noted that chiru give birth during the last week of June and first week of July. We observed newborns from 18 June–7 July with a peak of 10 days during 24 June–3 July. Similarly, Olson *et al.* (2005) found that Mongolian gazelles gave birth from 23 June–4 July but that 90% occurred in 8 days between 25 June–2 July. About 75% of caribou in the Canadian Arctic are born within a period of 7–8 days in the second week of June (Kelsall, 1968; Miller and Broughton, 1974). In contrast to frequent twinning in saiga (Sokolov, 1974), chiru usually give birth to single young, although we noted one instance of two young suckling on the same female. Mean body

mass of 7 newborn males was 3.3 (3.1 – 3.8) kg and of 4 females 3.1 (2.9 – 3.7) kg. Excluding a dead newborn that weighed only 1.5 kg, mean body mass of 3 males found freshly dead was 3.0 (2.8 – 3.2) kg and of 4 females 3.0 (2.4 – 3.9) kg.

We observed a female for one hour as she gave birth at 1435 hours on 3 July. Only 15 minutes after birth the newborn stood up but stumbled backward and fell. One hour after its birth the female left the site closely followed by the young. The following day a birth occurred at 2149 hours, and the newborn first stood up 12 minutes later, again illustrating precocial behavior.

Females are flexible in sites they select for giving birth. Young were born on wide flats and moderate slopes, in ravines and narrow valleys, and on sand or rock debris. Newborns ungulates can broadly be categorized into those that hide and those that follow their mothers soon after birth (Walther, 1979). Many gazelles and antelopes are hidiers during the first days and even weeks while the mother returns only intermittently during the day. Among those are blackbuck (*Antilope cervicapra*), Tibetan gazelle (*Procapra picticaudata*), and pronghorn (*Antilocapra americana*) as described by Mungall (1991), Schaller (1998), and Autenrieth and Fichter (1975). Migratory Mongolian gazelles hide much of the time for 7 – 8 days (Odonkhuu, 2004), whereas migratory wildebeest may follow their mother within 10 minutes after birth (Estes, 1966).

Chiru newborn may rest while the mother feeds nearby, lying curled up with head resting by the flank. There appeared to be little effort to hide, other than to remain motionless. Most newborns were mere tan humps lying in the open, though occasionally one was by a *Ceratoides* or in a shallow gravel outwash. When disturbed by us, the young either kept its position, eyes open and ears sometimes alertly upright, or it lay with head and neck extended on the ground and ears retracted in a typical position of hidiers. Able to run fast within a day after birth, the young may dash off when approached to within 10 m or so, but after running 50 – 100 m it may recline again. With females much on the move in this severe environment, and the migration beginning even before the birth season is wholly over, the young has to remain with her; behaviorally chiru are followers. Proximity does not, however, imply physical closeness. When mother and newborn rested, they were typically 2 – 5 m apart.

Several radio transmitters could relay signals about whether the animal was moving (active) or at rest (inactive). On several occasions we monitored signals every 15 minutes for several continuous hours during the newborn's first week of life. Three newborns were active 15% – 45% of the time (Table 2). For comparison, Mongolian gazelles were active for 11% – 18% during a 24 – hour period when 2 – 3 days old and 29% when a week old (Odonkhuu, 2005).

Table 2 Percent activity of 3 chiru newborn during first week, based on monitoring radio signals every 15 minutes

Date radio collared	Date monitored	Time monitored	Percent active
25 June	26 June	1030 – 1645	38 %
29 June	4 July	1135 – 1710	45 %
	5 – 6 July	1040 – 0425	25 %
1 July	4 July	1130 – 1710	15 %
	5 – 6 July	1040 – 0425	33 %

4.6 Mortality

A total of 21 dead females were found including 4 yearlings and one two-year-old. Judging by wear on molars of the lower jaw, 6 of the 13 other females were in their prime (little tooth wear), 3 were somewhat past prime (1st molar worn smooth), and 4 were old (1st and 2nd molars worn smooth). To determine cause of death we examined the animal and surrounding site for evidence of predators such as tracks and feces. Sometimes it was unclear if a predator had killed or scavenged. Six females had died in childbirth, both mother and young dead, and 4 females were probable wolf (*Canis lupus*) kills and at least two of these were pregnant. The remaining females died of unknown causes but not predation. In most instances scavenging

birds had partly stripped the carcass. One adult female, freshly dead, had been neither pregnant nor had given birth and her viscera showed no pathology.

42 dead newborns were found. Two were killed by birds of prey, either golden eagle (*Aquila chrysaetos*) or cinereous vulture (*Aegypius monachus*), judging by deep talon punctures along the back and method of eating. (Not included in our tally is one young whose radio collar we found much frayed as if torn by a beak but no body was at the site). Five newborns were probable red fox (*Vulpes vulpes*) kills and one of these was radio collared. The cause of death of the remaining 35 young was unclear, most having been eaten by scavenging birds. A few young probably died at birth or soon after; some were visibly smaller than normal.

An occasional young wandered alone as if in search of its mother; lost or abandoned young are doomed. Chiru concentrated along the base of a plateau when it snowed for 6 days, and afterwards we found 9 dead newborns there, possibly the result of hypothermia or respiratory problems. In addition to these dead animals, we saw one with paralyzed hindquarters and one with a broken foreleg.

Mortality of newborns was high but probably not exceptionally so. There was little predation. Both old and fresh wolf and red fox feces showed that chiru were eaten (Table 3). However, chiru are available for at most 3 months, and predators must subsist on other prey or move away for the remaining year. Except for a few kiang (*Equus kiang*) that visit the area in summer, no other ungulates reside in the calving grounds.

Table 3 Frequency of occurrence (in percent) of food items in 20 wolf feces and 40 red fox feces

	Wolf	Red fox
Chiru	54 %	10 %
Hare (<i>Lepus oiostolus</i>)	18	7
Marmot (<i>Marmota himalayana</i>)	9	–
Pika (<i>Ochotona</i>) or rodent	14	78
Blue sheep (<i>Pseudois nayaur</i>)?	5	–
Bird	–	13
Lizard (<i>Phrynocephalus</i>)	–	3
Beetle	–	2
Soil	–	3

Note: Totals add up to more than 100% because some droppings contained more than one food item.

5 Discussion

Why do chiru migrate 700 km airline distance to and from a calving site, and why do only females make this trek? Migrants have greater access to abundant and nutritious food; they can make more efficient use of resources; and they are less vulnerable to predation because most predators cannot follow the moving animals (Fryxell *et al.*, 1988). Studies on species as diverse as white-eared kob (*Kobus kob*), wildebeest, and Mongolian gazelles have concluded that migrants move to areas with much available green digestible and nutritious vegetation, rich in crude protein and minerals (Fryxell, 1987; Sinclair and Arcese, 1995; Leimgruber *et al.*, 2001).

Since only female chiru migrate to calving grounds one could hypothesize that food quality there is exceptionally high, including phosphorus (P), calcium (Ca), and magnesium (Mg) levels needed for fetal growth and milk production as well as other ingredients, such as potassium (K), that males require in lesser amount. Crude protein levels in the southern

part of the chiru's range and the calving grounds showed no marked difference. One *Ceratoides* sample from the calving ground had 1.81% Ca, 0.30% P, 0.45% Mg, and 1.27% K. P and K appear low, as was also noted for graminoids in the southern part (see Schaller, 1998).

Bothersome insects could also contribute to migration. Two species of oestrid fly, the nostril and warble fly, parasitize chiru. The larvae of the former attach themselves around the throat and in the frontal sinuses, and the latter bury under the skin and move to the lower back where they cut breathing holes. Chiru modify their behavior to avoid the flies by, for example, standing with muzzle close to the ground, running wildly, or clustering on patches of snow. No such behavior was seen on the calving ground where cold weather deterred insects. Chiru would be exposed to the flies later in the summer but they escaped harassment in June and July. The larvae of warble flies are said to leave chiru in June. At that time the females are temporarily in the desolate north where the adult flies cannot find hosts later. Possibly the migration helps to reduce the number of these parasitic flies.

Synchrony in calving within a limited area by migrants is thought to be a strategy for reducing predation on young when they are most vulnerable to a variety of predators. The sheer number of young overwhelms predators with prey and relatively few are killed (Estes, 1976). The chiru migrated to an extremely desolate region with little wildlife. Predator density depends on prey density. Elsewhere newborn chiru are vulnerable to brown bear (*Ursus arctos*), lynx (*Lynx lynx*), snow leopard (*Panthera uncia*), sand fox (*Vulpes ferriata*), and dogs of nomads, but no evidence of these species was seen on the calving grounds. We noted occasional wolf tracks and discovered an unoccupied den. Red foxes were widespread but sparse and we found 3 active dens, each with 2–3 pups. Impact of these two predators seemed to be minor. Vultures (3 species) and golden eagle were scarce and ranged widely. The only conspicuous though not abundant avian scavenger was the raven (*Corvus corax*) which typically pecked the eyes out of dead chiru before feeding on other parts. On two occasions a raven approached a live newborn closely but was chased away by its mother. The paucity of predators lends support to the idea that migration and synchronous calving is an anti-predator strategy.

The calving grounds are notable for the absence of other wild ungulate herds, except kiang some of which occupy the area after chiru leave, and of nomads with their livestock. Chiru females possibly seek isolation from all such disturbances.

We are unable to provide any one reason to explain why the chiru females migrate to that particular site for calving; any simple answer would be wrong. Complex behavior may be based on a variety of factors and be additive. Escape from parasitic insects, predators, and people, as well as lack of competition with other ungulates may all contribute to the tranquility and solitude the species might require for calving.

6 Conservation

The calving ground we studied is in one of the most remote and desolate spots on the Tibetan Plateau, so remote that it was seldom visited before 2001. Now 3 roads built by mining concerns and geological survey teams provide access. A gold mine in the Serak Tus valley has not affected chiru directly, but its road enables gold and jade prospectors to travel by vehicle the 300 km from the nearest town to the Shar Kul basin with relative ease in 2–3 days. A guard post was established in the Serak Tus valley in 2004. On 20 November 2004 the Hetian Prefecture government designated the Shar Kul Tibet Antelope Nature Reserve, its 1 320 km² encompassing the whole calving ground. Both are important conservation initiatives.

Caribou females and calves are more sensitive to human intrusion and development than males (Nellemann and Cameron, 1998) and the same is probably true of chiru. Fox and Bardsen (2005) noted that in general chiru seem less tolerant of humans and livestock than are kiang and Tibetan gazelle. Therefore, we suggest that the main calving area of about 350 km² be established as a strictly protected core area in which no people are allowed when chiru are present, except with a prefecture permit, and that it should be completely closed to mining and other development. A large provincial and ultimately national reserve needs to be established in the western Kunlun, one that includes not just the whole calving ground but the whole surrounding region south to the Tibet border, east to the Mid-Kunlun Reserve, and west to add critical wild yak (*Bos grunniens*) habitat there. Wildlife inventories need to be made in the whole proposed West Kunlun Reserve, and local staff needs to monitor conditions. With good protection and management and close cooperation with Tibet, the chiru and other wildlife can persist in this remote, harsh but beautiful corner of China.

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