Ungulates in Northwest Tibet

GEORGE B SCHALLER AND GU BINYUAN

The northwestern part of China's Tibet Autonomous Region, north of ~32°N, consists of vast, rolling plains broken by hills and snow-capped ranges and by basins with usually brackish lakes (Figure 2). Part of the Chang Tang ("Northern Plain" in Tibetan), this area lies generally at elevations of 4600 to 5100 m and some peaks exceed 6000 m. Precipitation is scant with ~300 mm annually in the eastern part and ≤100 mm in the western part, much of it falling as hail and snow in summer. There is no frost-free season, although daytime temperatures in July and August may reach 15 to 20°C. Winters are cold with high winds and temperatures that may plunge below −40°C. Most of the area has permafrost 60 to 100 cm below the surface. Too arid and with too short a growing season to support trees, the Chang Tang has only a sparse cover of grasses, sedges, forbs, and low or procumbent shrubs. The northern part, roughly north of 34°N, is a high-altitude desert, ≥5000 m in elevation. Large tracts are almost devoid of vegetation except for the shrub Ceratoides compacta and patches of the coarse sedge Carex moorcroftii. This area is largely uninhabited. The southern part, an extensive grass steppe principally of Stipa spp., is used seasonally by pastoralists and has most of the region's wildlife.

Despite geography and climate, the Chang Tang supports a unique assemblage of 6 wild ungulates: Tibetan argali (Ovis ammon hodgsoni), blue sheep (Pseudois nayaur), chiru or Tibetan antelope (Pantholops hodgsoni; Figure 1), Tibetan gazelle (Procapra picticaudata), wild yak (Bos grunniens), and kiang or Tibetan wild ass (Equus kiang). With the exception of blue sheep, these ungulates are confined to the Tibetan Plateau; the northwest Chang Tang represents the last stronghold of chiru and wild yak.

Geographically remote and politically sensitive, the northern Chang Tang has seldom been visited by zoologists. S. Hedin in 1903,22 C. Rawling in 1905,24 and other explorers observed wildlife and in recent years several Chinese expeditions conducted general faunal surveys.2,3 Ungulates have been surveyed and studied from parts of the Chang Tang that extend east into Qinghai Province and north into the Xinjiang Uyghur Autonomous Region.3,14,30–41

The impetus for our project in the Chang Tang was to collect information that would help the government protect and manage a unique ecosystem and its wildlife. The Chang Tang Reserve (~284 000 km²) was legally established as a Tibet Autonomous Region reserve in November 1992, and as a national reserve in February 1993 (Figure 2). Our surveys showed that the Aru basin had the finest remaining concentration of large mammals in

Comparative Ecology of Ungulates in the Aru Basin of Northwest Tibet

The 6 wild and 4 domestic ungulate species in the 1800-km² Aru basin were studied and compared during the summers of 1990 and 1992. In August 1990, an estimated 2100 animals used 1150 km² of suitable habitat, an ecological density of 1.9 animals/km² of which 37% were wild yaks and 32% chiru (Tibetan antelopes), followed by kiangs (Tibetan wild ass), blue sheep, Tibetan gazelles, and Tibetan argali sheep; total biomass was ~313 kg/km² of wild ungulates and 139 kg/km² of domestic yaks, sheep, goats, and horses. Wild and domestic species overlapped broadly in the temporal and spatial use of their habitat, but somewhat different feeding strategies helped reduce competition. Commercial hunting threatens the future of all wildlife in the Aru basin. Wild yaks have been exterminated or decimated in large areas of northern Tibet for their meat, and chiru will soon be reduced to small remnants unless the illegal trade in their wool is halted.

Figure 1. A chiru or Tibetan antelope (Pantholops hodgsoni) suckles her month-old offspring. GEORGE B SCHALLER
Ungulate societies are molded most strongly by 2 selection pressures: the needs to find enough to eat and to escape predators. An animal's food habits influence its group size. Species which browse on small, high-quality items... generally do not congregate into herds. ... At the other extreme are grazers, whose abundant food resources in a typically open environment enable them to forage in herds of hundreds and even thousands. 38:288-289


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what is now the Chang Tang Reserve, a relict of a time when wildlife was abundant on the grasslands of the Tibetan Plateau. The Aru basin thus provides an ecological glimpse into the past, and a baseline for population size, structure, and other aspects. Moreover, species density and habitat diversity are closely correlated. In the Aru basin, plant species are few and vegetation has little vertical stratification, yet 6 wild and 4 domestic ungulate species coexist. We attempt here to explain how they do so.

In addition to our 39-day study in the Aru basin during 1988, 1990, and 1992, we draw on data collected elsewhere in the Chang Tang. (Between 1988 and 1992 we made 5 trips, each 1 to 3 months, through what is now the Chang Tang Reserve, and between 1985 and 1988, 2 trips to the Chang Tang of Qinghai, and 2 in Xinjiang [Figures 3 & 18].) Our work in the Aru basin was during summer when the nutritional quality of ungulate forage is highest and competition for resources probably lowest. Seasonal changes in nutrient level of plants may affect habitat choice, diet, movements, and grouping patterns of ungulates, and our data must be evaluated in that context.

Study Area

The Aru basin is 85 x 25 km wide at its widest point, an area of 1800 km² including 2 lakes connected by a river, the fresh-water Aru Co and the brackish Memar Co ("co" means "lake" in Tibetan). Old beach lines 40 m above present lake levels indicate that the 2 lakes comprised 1 large lake in early post-Pleistocene times. The rugged Aru Range, partly glaciated and with several peaks >6000 m in elevation, borders the western edge of the basin. The terrain drops from the crest of that range to an alluvial plain that descends gradually over several kilometers to the lake margins.
at ~4900 m. Rounded hills, most 5000 to 5500 m in elevation, demarcate the eastern rim of the basin and both ends (Figure 2).

Alluvial and eolian in origin, the alkaline soils (pH 7.4 to 8.0) consist of fine sands, silt, and clay interspersed with gravel. There is no sod layer except along the few seepages and streams where sedges (Kobresia sp) and forbs may form a dense mat. Plant cover is scant, only ~25%, equally divided between monocots and dicots. Most of the vegetation can be classified as alpine or high, cold steppe. Found on flat to moderately steep terrain up to an elevation of ~5100 m, this steppe is dominated by grasses (Stipa papurea, S glareosa) and small sedges such as Kobresia prainii. Certain plant communities are locally conspicuous. Carex moorei often dominates in sandy places; to the north, outside the basin, this sedge becomes the principal graminoid. A large patch of Ceratochloa compacta, a species widespread in xeric conditions, grows on the flats south of Aru Co, and another low shrub, Ajania fruticosa, dominates locally on old lake terraces. Broad gravel outwashes from the Aru Range bisect the plain. On these, the graminoids tend to be sparse, whereas several forbs are prominent, especially Biebersteinia ohorata and Oxytropis falcata. In general, forbs are inconspicuous on the steppe, although such species as Oxytropis glauca, Potentilla bifurca, Saussurea stoliczka, and the cushion plant Leontopodium pusillum are common.

Most steppe species extend up the hillsides to 5200 or 5300 m, close to the limit of vegetation, but plant dominance shifts with altitude. Kobresia replaces Stipa as the main graminoid, and cushion plants become more

Figure 3.
The authors' camp along a glacial stream was in the Aru basin in July. The Aru Range is in the background.

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Both the Tibet Autonomous Region and India are now vigorously attempting to suppress the illegal trade in chiru wool. In June 1993, Indian customs at Delhi airport seized a consignment of 105 kg of wool arriving by air from Katmandu. This shipment alone represented the killing of >750 chiru.

<table>
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<tr>
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<th>MOUNTAIN</th>
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**SPECIES COMPOSITION (PERCENTAGE OF PLANT COMMUNITIES)**

**GRAMINIDS**

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<td>Poa sp</td>
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<tr>
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<tr>
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<td>6.8</td>
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<td>Carex moorecroftii</td>
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**FORBS**

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**DWARF SHRUBS**

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<td>Ephedra gerardiana</td>
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<td>—</td>
<td>11.1</td>
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</table>

common, among them Leontopodium sp, Arenaria sp, Rhodiola sp, Oxytropis pauciflora, and Saussurea subulata. Of significance is that in the basin <12 graminoid and <20 forb and dwarf shrub species provide most vegetation cover (Table 1).

**Methods**

Traveling by car and on foot, we tallied ungulates on the west side and both ends of the basin. The east side is more arid than the west side, and hills crowd the lakes' edges in places. Wildlife there was generally scarce. We perused most of this area by scope. Kiangs and yaks could readily be observed at 2 to 3 km, and chirus tended to concentrate on flats, making them relatively easy to count. However, Tibetan gazelles often frequented small valleys, and blue sheep were in the rugged terrain of the Aru Range. These 2 species had to be sought on foot as well.
All animals were counted and classified according to age and sex when possible. Most species were exceedingly shy, sometimes fleeing from a person or a vehicle ≥1 km distant, and classifying counts of large herds were often not feasible. Yaks in particular avoided us; one herd moved ≥20 km out of the basin after we disturbed it. Since all species except perhaps the gazelles travel seasonally in and out of the basin, counts apply only to the time of our visits.

To obtain preliminary data on ungulate diets, we collected fecal samples for microhistological analysis. Each sample consisted of a mix of material from 10 fresh fecal piles. One or 3 slides were made from each sample, and 20 microscopic fields were checked on each slide. The percentage of relative frequency was defined as the number of fields in which a plant species was identified divided by the number of fields with identifiable material of any species multiplied times 100. Various biases inherent in this technique have been discussed. Of relevance to this study is that fecal analysis is accurate for graminoids but underestimates leguminous forbs.

Vegetation was sampled with a 10-point frame with pins at an angle of 57°. Transects were made at sites that seemed to be representative of various plant associations. A string, marked at 2-m intervals, was stretched along a selected transect and either 10 or 20 samples, each with 10 points, were taken; we made 19 transects for a total of 2400 points. A “hit” was recorded when a pin touched a plant. Calculations of species composition were based on 1 hit per individual stem or leaf, and of vegetation cover on a hit within 1 cm above ground. We also recorded whether the plant part was grazed or browsed. Along most transects we clipped a 1-m × 1-m plot at the site of the 10th sample to determine biomass dry weight (Figure 17). The percentage of crude protein was measured by the standard Kjeldahl N procedure.

Results

Body size, sexual dimorphism, population size and dynamics, grouping patterns, and food habits represent a functional whole. We must consider each of these if we are to understand the comparative ecology of ungulates in the Aru basin.
Most of what is now the Chang Tang Reserve was uninhabited until 20 years ago. The desolate north remains uninhabited. The south retains one of the last unspoiled grassland ecosystems in the world. However, >3000 families with ~1 million head of livestock now occupy the area. Some herders are giving up tents for permanent huts and are building fences. The future of the grasslands and the wildlife in the reserve as well as the traditional life of the pastoralists will depend on the development of proper management policies and programs.

THE UNGULATE POPULATIONS

TIBETAN ARGALI. Argalis favor hilly but not precipitous terrain. Adult males have massive horns and may weigh >100 kg whereas females weigh ~60 kg. The sexes tend to segregate except during the rut. In 1903, C. Rawling found that “near Aru Tso large numbers of ewes and young were daily found grazing in the neighbouring ravines.” For unknown reasons, the species has almost vanished from the Aru basin and is rare in the Chang Tang as a whole. Local informants said a few argalis live high in the hills during summer and descend into the basin for the winter. We observed 2 adult females in 1988 and 1 yearling female in 1992.

BLUE SHEEP. Blue sheep prefer alpine slopes with good grazing in the vicinity of cliffs, and in such habitat they remain widespread on the Tibetan Plateau. Closely allied to goats rather than sheep, they are stocky animals; adult males weigh 60 to 75 kg and females, 35 to 45 kg. In 1990 we checked all suitable terrain in the Aru Range, except the southernmost part, and counted 121 blue sheep; in 1992, covering less ground, we tallied 105. Few adult males were observed (22 in 1990, 4 in 1992), yet the ratio of males to females in populations tends to be close to equal. Many males appeared to spend the summer in other parts of the Aru Range (Figure 14). Horns found around corrals and elsewhere in the basin attested to the presence of males of all ages at certain seasons. Age rings of 32 horns indicated that 9% of the animals died as young adults (2 to 4 years), 75% in their prime (4 to 9 years), and 16% past prime (9 to 12 years). We estimated 200 blue sheep in the basin at the time of our survey but ≥300 may frequent it seasonally. In the 1992 blue sheep sample there were 28 young and 26 yearlings to 100 adult females; few young when compared to ratios of 53 to 75 young to 100 adult females in populations in Qinghai. Nine herds composed of females and young (and possibly an occasional yearling male), averaged 25.3 (7 to 52) animals per herd; 4 herds of males contained 3, 5, 8, and 16 individuals. Young were born from about mid-June to mid-July in the Chang Tang (Figure 6). Blue sheep are mixed feeders on graminoids and forbs (Table 2).

CHIRU. The chiru’s closest phylogenetic relatives are not antelopes and gazelles, as its name “Tibetan antelope” implies, but sheep and goats of
the subfamily Caprinae. This conclusion is based on morphological grounds\textsuperscript{13} and on recent studies of mitochondrial DNA (George Amato, Wildlife Conservation Society, conversation, 1993).

Adult males weigh 35 to 40 kg and have slender, lyre-shaped horns 50 to 60 cm long; females weigh 25 to 30 kg and are hornless. We noted that some populations in Tibet were relatively sedentary, making only local movements, but in the Chang Tang at least 4 populations were migratory. Most chiru in the western Chang Tang belong to 1 migratory population whose range includes the Aru basin. Pregnant females with their female offspring of the previous year migrate together in May and June from their

\textit{The fact that viable pastoral cultures and wildlife remain to this day bears witness to the remarkable diversity and resilience of this highly unique ecosystem, as well as the sustainability of its resources if wisely used.}\textsuperscript{31}

Figure 7.
Two female Tibetan wild asses or kiangs (Equus kangi).

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wintering grounds on the *Stipa* steppes ≥300 km north to the desolate uplands near the Xinjiang border where they give birth from late June to early July (Figure 1). Large aggregations and a synchronized birth peak are typical of such migratory ungulates. Many non-pregnant females did not accompany the migration. Most yearling males separated from their mothers before the migration and joined adult males, most of which moved north only part way. During summer the chirus were thus segregated by sex and the reproductive state of the female. Only during the December rut was it possible to obtain unbiased population composition counts. The ratio of adult males to females (yearling and adult combined) in southwest Qinghai during the 1985 winter was 31:100 (N=1529) and in the eastern Chang Tang reserve during the 1991 winter it was 52:100 (N=3381).

In 1992 we observed migrating herds on 16 June ~70 km northeast of the Aru basin near Toze Kangri, an ice-capped massif. The animals headed northeast across plains and hills at elevations of 5000 to 5200 m until, 90 km away, they reached Heishi Beihu, a lake near the Xinjiang border (Figure 8). They continued northeast through the lake basin presumably into Xinjiang. Heavy snows prevented us from following. The last stragglers moved north on 27 June, a few giving birth en route. After parturition the females soon returned south (Figure 10). In late July 1903, near Toze Kangri, Rawling noted that “as far as the eye could reach, were thousands upon thousands of doe antelope with their young.” In 1990 we first observed returning migrants in the Aru basin on 7 August, a herd of 170, and by 18 August many were 60 km south and 100 km southeast of the basin. In 1992 a herd of 69 migrants appeared in the basin on 28 July, and 2 days later a herd of 2000 was at Luotuo Hu, a lake just north of the Aru basin. Between 30 July and 3 August at least 8000 chirus passed that lake moving west across a pass of the Aru Range before turning south into the
Lumajangdong basin. Informants told us that another migratory route was just east of the Aru basin (Figure 8). For unknown reasons, few animals migrated through the Aru basin itself. In 1990 the ratio of young and yearling females to adult females was 60:11:100 (N=482), and in 1992 it was 47:8:100 (N=2140). Survival of young was better in 1990 than in 1992, probably because snow, wind, and cold (to ~9°C) in 1992 were severe.

The Aru basin was primarily a summer range for males and a few reproductionally inactive females; in addition, we were told that some animals aggregate there for the rut. In 1990, we tallied 617 males and 35 females and estimated a total of ~700. Of the males sampled (N=555), 12.4% were yearlings. In 1992 there were at least 1000 males in the basin. Most males were solitary or in small unstable herds of ≤15, but at times ≥100 congregated (Figure 9).

Males characteristically aggregated into large herds toward midday and stood clumped in shallow ponds or on overflow ice (Aufeis) until late afternoon when they dispersed to forage. Caribou (Rangifer tarandus) in the Arctic congregate to reduce harassment by insects, especially mosquitoes and 2 parasitic dipterous flies, the warble and nostril flies of the family Oestrídae. The oestrid flies but not the mosquitoes occur in the Chang Tang. Chirus have long been known to paw hollows ~1 m in diameter and ≥20 cm deep and to lie in them. It was assumed that chiru did so to escape wind or predators, or that the hollow served a function during the rut. We hypothesize that the dispersed hollows, like the bunched aggregations of animals, help chiru escape the attention of oestrid flies, especially of warble flies whose larvae live under the skin on the animal’s lower back, sometimes in large numbers.

Females are often alone or accompanied only by their offspring. Their herds consist of unstable social units which vary from large migrating aggregations, mixed herds of varying sizes, and 1-male harems during the rut to small herds of 3 to 7 females and young.

Chiru are mixed feeders, the proportion of monocots and dicots in their diet changing with the seasons.

TIBETAN GAZELLE. The small (14- to 15-kg) Tibetan gazelles remain the most widespread wild ungulate on the grasslands of the Tibetan Plateau, persisting even in areas where other species have been exterminated. Gazelles favor areas of good pasture, on plains or hills, and are absent from much of the northern Chang Tang Reserve with its arid uplands. In the Aru basin, males tended to be on the plains in summer, whereas

This is the 1st time an effort has been made to describe the wild ungulate community of the Tibetan plateau. In addition, the authors include data on introduced domestic ungulates. It goes without saying that this is an extremely valuable contribution of broad interest to terrestrial ecologists and students of ungulate communities.

A REVIEWER

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**Figure 9.** Percentage of chiru males (yearling and adult) in various herd sizes, Aru basin, July to August.

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females were often in the draws of hills up to an elevation of 5100 m. In 1990, we tallied 125 gazelles but the actual number was probably at least 200. We overlooked some adults and many young whose birth season peaked around the time of our census. Young hide for at least 2 weeks before following their mother (Figure 11). We observed 4 crouched young between 27 July and 9 August; we 1st saw a female with a young at heel on 6 August.

The 1990 census included 41 adult males and 44 adult females, suggesting an equal sex ratio. There was a ratio of 55 yearlings to 100 adult females. That year in August and September we also classified 406 gazelles outside the Aru basin and obtained ratios of 75 adult males, 48 yearlings, and 60 young to 100 adult females.

Adults tended to be sexually segregated. Of 134 yearling and adult males classified in the basin, 14.4% were alone, 53.2% in herds of 2 to 4, 17.3% in herds of 5 to 7, and 15.1% in herds of 8 to 12 animals. A few yearlings associated with females in summer but we only once saw an adult male join them. Female herds were small in part because it was the birth season; 17% of the females were alone and the rest were in herds of ≤8.

Gazelles forage primarily on forbs (Table 2).
Wild Yak. Wild yaks are massive: One male was 203 cm high at the shoulder and weighed 821 kg, but average weight is probably ~500 kg. Only one reliable female weight of 306 kg exists; we presume it to be about 1/3 less than males as is true of domestic yaks. The animals are typically black, except for a touch of light gray on the muzzle. A few yaks in the Aru region are a golden yellow-brown, a mutation 1st mentioned by H. Deasy in 1901 and unknown in other wild populations (Figure 16). Black females may have golden offspring and golden females may have black offspring. Of the yak samples, 2.2% were golden in 1988, 1.4% in 1990, and 1.3% in 1992 with an average of 1.6%.

Yaks were once abundant on the grasslands of the Tibetan Plateau. In 1891, W. Rockhill traveled through an area of eastern Qinghai that was “literally black with yaks, they could be seen by the thousands.” None survive there today. The species has been and still is so intensively hunted that viable populations in Tibet survive mainly in the Chang Tang north of 33°20’N.

Yaks tended to remain on or near hills and they usually fled toward them when disturbed. Whether this represented a habitat preference or a response to past human predation was unclear. Animals appeared to travel widely, and, according to local informants, they dispersed out of the basin when disturbed and during winter. Twice as many yaks were in the basin in 1990 as in 1992 when many animals had moved out with the arrival of pastoralists. In 1990 we tallied 681 yaks in the basin and 114 in the small Yalung basin on the west slopes of the Aru Range. The area supported probably at least 1000 yaks. In 1992 we counted 315 yaks in the basin concentrated in parts that had little human disturbance.

Animals in herds were difficult to classify because they were shy and fled bunched (Figure 16). Males were frequently alone or in small herds of 2 to 3 but sometimes as many as 11. In 1990, 7.2% of the yaks in the basin consisted of such males. Most of these males were large, and probably at least 6 to 8 years old, though small males, even yearlings, were occasionally in male herds. Mating in domestic yaks and apparently also in wild ones reaches its peak between July and September, a time when the males in our sample were not with females.

It was our impression that females outnumbered males by ~1/3. Males were often on the plains away from the base of hills and high ridges that females seemed to favor. This made males vulnerable to predation, especially to motorized hunters. Of 27 yak remains found in the basin, 78% were males. In addition, males may disperse far from areas occupied by females as we noted elsewhere in the Chang Tang. Yearlings comprised 7.8% in our population sample (N=514) in 1990. Because this sample excluded solitary males and male herds, the actual yearling figure was ~7%. Young that year comprised 6.7% of the total population sample (N=586) in the Aru basin and 5.3% (N=114) in the nearby Yalung basin. These figures are low even for a species in which a female gives birth at most every 2 years if her young survives. By contrast, in the eastern Chang Tang Reserve in 1990 there were 12.7% young in our sample (N=267). Even fewer young were observed in 1992 than in 1990: Only 1.0% of the population (N=315) in the basin consisted of young, and we noted just 1 yearling (N=225).

Yaks generally occurred in herds of a few males and many females of ~25 animals (Figure 12). Herds in areas with few yaks probably maintained considerable cohesion, similar to those of African buffalo (Syncerus caffer).
It is not realistic to expect the government to adopt a laissez faire, noninterventionist policy in Tibet. "Development" of animal husbandry is a major government goal. Not only has considerable infrastructure been created (eg, animal husbandry experimental stations in each of Tibet's prefectures), but Tibetan officials have begun to invite Western development experts to assist in the "moderization" of the pastoral economy and the preservation of the environment (eg, by establishing state parks). The impetus to increase livestock productivity under the "Four Modernizations" policy by the application of "science" is very strong in Tibet and likely to intensify in the years ahead.\textsuperscript{19,153} caffer),\textsuperscript{12} whereas in the Aru basin they readily split and joined. On 20 July 1992 we observed a distant herd of \textgreater 200 animals; the following day we tallied 236 yaks in the same general area but split into 5 distinct herds. Often just 1 large male accompanied a herd during the rut.

Yaks are mixed feeders but with an emphasis on Stipa grass (Table 2).\textsuperscript{30} Kiang. The kiang is the largest of the wild asses, a robust animal weighing 250 to 300 kg;\textsuperscript{30} like all equids the kiang shows little sexual dimorphism. It was often considered to be a subspecies of Asiatic wild ass (Equus hemionus), but recent molecular studies suggest that it is a distinct species.\textsuperscript{36} Once abundant on the plains and hills of the Tibetan Plateau, the kiang remains common only locally, particularly in parts of the Chang Tang where grazing is good and few humans live.

We tallied 212 kiangs in the Aru basin during the 1990 census and estimated a total of 250. Counts were made at the beginning of the main birth season (Figure 6): In 1990 we observed the first newborn on 28 July and in 1992 on 4 August. In the 1990 sample, yearlings comprised 5.7%. In a larger sample (N=929) outside the basin the same year, the figure was 6.9%. We lack data on number of young in the basin because we left before most were born, but elsewhere in the Chang Tang Reserve in 1990, 12.9% in the sample (N=1367) were young. Since the gestation period of kiangs is about a year, a female will produce an offspring only every 2 years. Females without young come into estrus during the same months that others give birth; we observed mounting on 28 and 30 July.

Of 620 kiangs counted in the basin, some probably more than once, during our 3 visits, 15.8% were solitary and the rest were in 79 herds of \textless=27 members (average, 6.6; Figure 12). More than 50 kiangs sometimes aggregated when disturbed by our presence. After the rut and until the following spring, kiangs tended to congregate on good pastures: In 1990, we observed 172 kiangs together on 3 October and 202 on 7 October (Figure 5).

Kiang males were often alone or in small herds of \textless=12 individuals. Rarely solitary, females were usually in small herds of \textgtr=2 other females and their offspring (Figure 7). Mixed herds either consisted of a male with \textless=10 females or temporary aggregations with many individuals of both sexes. Solitary males may occur at any season, but they were particularly prevalent during the rut. On 7 August 1990 we counted 15 males, 9 females, 1 yearling, and 2 young along 20 km of Aru Co. Twelve of these

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**Figure 12.**

Percentage of kiang and wild yak in various herd sizes, Aru basin, July to August (all ages and both sexes).
males were alone and well spaced, as if territorial. A territorial social system has been reported for African ass (Equus asinus) and feral ass.32

Kiangs eat mainly graminoids with a heavy emphasis on Sipta (Table 2).

**Livestock.** The first Western visitors to the Aru region met a few pastoralists,8 and currently ~21 families with a total of some 8000 sheep and goats, 600 yaks, and a few horses use the basin seasonally but not always simultaneously. Until 1990 the pastoralists rotated all livestock, using the basin usually for 2 to 3 months between May and September and spending the rest of the year mainly to the west and southwest (Figure 15). But in 1991, 5 families (~40 people) moved their 600 sheep and goats and 45 yaks into the basin permanently, primarily to hunt wildlife. Several families often camped together, so that only parts of the basin were in use at any one time.

The livestock added considerable biomass to the basin during the season of plant growth. Adult sheep and goats weigh an average of 20 to 42 kg and yaks 230 to 350 kg.611 Sheep, goats, and yaks are mixed feeders but favor graminoids, and horses subsist on graminoids (Table 2).

**Comparative Ecology**

**Numbers and Biomass.** The Aru basin contained an estimated total of 2100 wild ungulates in early August 1990, giving a crude density of 1.1 animals/km² in 1800 km². The ecological density in the 1150 km² of suitable habitat (excluding lakes, glaciers, and barren mountaintops) was 1.9 animals/km² of which 37% were wild yaks, 32% chirus, and 12% kiangs. Yaks were numerically the dominant species, an unusual situation now in the Chang Tang. Transects in a 20 000-km² area in southwest Qinghai during the winter of 1986 indicated a crude density of 0.3 to 0.4 animals/km² of which ~64% were chirus and 30% kiangs.41 Intensive surveys in 27 500 km² of the eastern Chang Tang Reserve during the winter of 1991 revealed a crude density of 0.3 animals/km² of which ~39% were chirus and 20% kiangs. Yaks in these 2 areas had been almost exterminated, leaving chirus as the most abundant ungulate. However, ungulate numbers in the Aru basin varied as yaks shifted in and out and chirus migrated past; shortly after our census a herd of ~2000 chirus entered briefly, almost doubling the total number of animals.

To obtain a rough estimate of biomass, we used the weights given earlier and adjusted these to the approximate composition of the populations. Average biomass in the 1150 km² was ~226 kg/km² of wild yak, 57 kg kiang, 21 kg chiru, 7 kg blue sheep, 2 kg gazelle, and a trace of argali; total was 313 kg/km². Of this total 72% was wild yak, whereas in areas outside the basin the kiang usually dominated the biomass.

At the time of our census about half of the usual number of livestock were in the basin, or ~4000 sheep and goats, 300 yaks, and a few horses for an ecological density of 3.8 animals/km². Assuming that the weight of an average animal approximated 75% of the female weight, the total biomass was ~139 kg/km², less than half the biomass of wild ungulates. In terms of livestock units, defined as 1 yak or equid being equal to 5 small animals, there were approximately the same number, 1100 domestic and 1220 wild units, during that period.

**Resource Base.** Most suitable ungulate habitat in the Aru basin stretched in a narrow band in the lakes at ~4900 m up the hillsides to 5200 m. Every wild and domestic ungulate species except blue sheep used the entire habitat. Seasonal changes in the distribution of critical resources

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*Figure 13. A Tibetan woolly hare. Hunting wild hare is taboo among some nomadic herdsmen; Tibetan Buddhism holds all life inviolate.*

*George B. Schaller*
had probably a greater impact on use than type of terrain. The animals had to be opportunistic feeders in such a simple environment. Plants are most nutritious and digestible during the early growth stages and decline in quality as they mature, becoming dry and fibrous. With plant growth limited to 3 months or a little longer, from late May to early September, ungulates had only senescent vegetation for most of the year. Competition for resources was least likely to be evident during the growing season, the time when we were there, than during other months. Nevertheless availability of nutritious forage appeared to affect the spatial distribution of ungulates even then. Species such as chiro and gazelle moved into the hills where plants were at a younger growth stage and certain palatable species more abundant. Movements in general seemed to be related to the caloric, protein, and mineral content of forage and not to availability of water. Except that they ate snow, animals usually obtained needed moisture from their diet.

The chiro migration is a special case. Migrants are thought to have greater access to nutritious food than residents, make more efficient use of resources, and be less vulnerable to predation. Yet chiro females moved north during a critical period of nutritional stress—late gestation and early lactation—to give birth in an area with severe weather and sparse vegetation of small variety that was just beginning its spring growth. And after giving birth they rapidly returned south to more equitable pastures. Possibly certain forage species at the parturition grounds were especially rich in nutrients or in magnesium, phosphorus, or other important minerals, or they may have better escaped predation. But we still lack a satisfactory explanation for this migratory pattern.

Different feeding strategies help reduce competition among ungulate species. Diet can be partitioned on the basis of plant species, growth stage, and plant part. For example, on Tanzania’s Serengeti plains the zebras (Equus burchelli) subsist on a coarse diet of grass stems, sheaths, and some leaves; the migratory wildebeests (Connochaetes taurinus) mainly on the leaves of grass; Thomson’s gazelles (Gazella thomsonii) on short grasses and forbs; Grant’s gazelles (Gazella granti) almost exclusively on forbs; and at the plain’s fringe, buffalo graze rather unselectively on tall grasses. This faunal assemblage—a large bovid, an equid, and several small to medium ungulates, one a major migrant—resembles that of the Chang Tang.

Much of the ground in the Aru basin was bare (72 to 83%). Graminoids were conspicuous, with the abundant Stipa growing stems ≤15 cm tall, but total biomass was low. Eight clip plots on Stipa steppe had an average graminoid biomass of 14.1 g/m² (range 8.5 to 21.5) dry weight. Vegetation composition varied from 87% graminoid on Stipa steppe and 67% on mountain slopes, to 22 to 27% on gravel outwashes and Ajania flats (Table 1). (No transects were made on Kobresia mts.) The ungulates ate graminoids in strikingly different amounts (Table 2). Kiangs grazers (95%), mostly on Stipa, and yaks also favored grass (54%). Chirus consumed some graminoids (32%), especially the coarse Carex moorcroftii. Blue sheep grazed a little (19%) but Tibetan gazelles virtually ignored graminoids (<1%). One argali fecal sample from outside the basin contained 70% graminoids, mostly Kobresia.

For those ungulates that prefer forbs and low shrubs to graminoids, the Stipa steppe offered an average of only 2 g/m² (range, 0 to 7), whereas the gravel outwashes and Ajania flats had several species in abundance.
These included *Biebersteinia* and *Ajania* (both aromatic plants), *Oxypolis falcata*, and *Arenaria pulvinata* (a cushion plant), but ungulates usually ignored these. The ungulates' favored forb species grew most abundantly on mountain slopes (Table 1).

Several uncommon forbs appeared in disproportionately large amounts in the diets. The small *Potentilla bifurca* had an availability of at most 4%, yet comprised ≥8% of the relative density of plant fragments in feces of all species (except kiang), and in gazelles it was 41%. *Leontopodium*, a cushion plant, was also eaten disproportionately often especially by blue sheep. Two legumes, *Oxypolis glacialis* and *O pauciflora*, were much favored by chirus and gazelles, and the animals also plucked the seed pods of *O pauciflora*, as did other ungulate species. Outside the Aru basin the ungulates selected monocots and dicots in a similar manner except that availability of forbs and shrubs affected proportions in the diet.

Domestic sheep and goats ate graminoids (46%) and forbs, especially *Leontopodium* (28%) and *Potentilla* (18%). Domestic yaks, like wild yaks, were mixed feeders, but with a preference for graminoids (79%). Livestock outside the basin had roughly similar food habits. Three late August samples of domestic sheep and goats contained 66% graminoids, and an early September sample of yak contained 97%. In a livestock study in central Chang Tang south of the reserve, eight direct observations revealed

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*Figure 15. A Tibetan nomad guides his flock over the Chang Tang.*

GEORGE B. SCHALLER

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In every direction antelope and yak in incredible numbers were seen, some grazing, some lying down. No trees, no signs of man, and this peaceful-looking lake, never before seen by a European eye, seemingly given over as a happy grazing ground to the wild animals.

Figure 16. (from upper left, clockwise)
A herd of wild yak (Bos grunniens) in the Aru basin.
The discarded head of a yak bull killed by poachers. The black hair turns brown after long exposure to the elements.
Golden wild yak is a rare mutation of the normally black-haired species.
Four yak bulls in June before the steppe has greene.

George B. Schaller, All
Muskox and caribou associate in the Arctic but, the two are not competing for food. Urial, wild goat, gazelle, and wild asses share the same habitat in some areas of Iran; and chiru, argali, gazelle, kiang, and yak associate in Tibet. The coexistence of these species indicates that they are not serious competitors—or some would have become locally extinct—but the details of their habitat division have not been studied.38,288

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<thead>
<tr>
<th></th>
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<tr>
<td></td>
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<tr>
<td></td>
<td>ARU</td>
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</tr>
<tr>
<td>UNGULATE HAIR</td>
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<td>—</td>
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<tr>
<td>BEAR</td>
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</tr>
<tr>
<td>MARMOT</td>
<td>35.3</td>
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</tr>
<tr>
<td>PIKA</td>
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<tr>
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<tr>
<td>ROOTS</td>
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Table 3. Prey Remains in Predator Droppings, as Percentage of Total Content in Sample

the diet of goats to consist of 46% graminoids, sheep 62%, and yaks 88%; the woody Potentilla parvifolia was favored browse, used most by goats and least by yaks. Two horse dung samples we collected outside the basin in August contained 100% graminoids.

As many herbivore studies have shown, food preferences are related to the nutritive quality of forage, animals tending to select for those plant parts that have the most protein and digestible energy. Small herbivores require food of higher nutritive value than do large ones because of their higher metabolic rate. To satisfy requirements, they must carefully select high-quality plants in contrast to large animals that can subsist on the abundant low-quality forage.9,16 Ungulates require crude protein levels of 5 to 9% for maintenance (Table 4).6,17 Crude protein contents in most species of plants were well above maintenance limits for ungulates. Our figures are probably lower than the actual diet because animals most likely plucked vegetation more selectively than we did.

Competition for resources is most likely in winter when plants are dead or senescent and their nutritive levels are low. We lack winter data for the Aru basin, but elsewhere crude protein in Stipa average 4.4% (3.7 to 5.5%, n=4) and Oxystropis glacialis, 8.7% (see also Schaller et al44). These figures are barely at maintenance levels for ungulates. By the end of September, graminoids had stored their nutrients below ground. Chiru on occasion pawed away soils to uncover and feed on the corns of grass tufts. The relative density of graminoid fragments in the feces of chiru was higher in December than in August, 64% (35 to 88%, n=9). Domestic sheep and goats averaged 89% (79 to 100%, n=3) graminoids, and domestic yaks 97% (94 to 100%). All species, domestic and wild, except gazelle (and possibly blue sheep and argali) subsisted primarily on graminoids during winter.

Population Dynamics. Except for the rare argalis, moderately large ungulate populations still frequent the Aru basin. But even our brief visits

Figure 17. Biologist Zhang Yaozong studies a vegetation plot in the Aru basin.
GEORGE B. SCHALLER
revealed that populations were at risk from various causes.

Two populations had fewer than the expected number of young. Our data for blue sheep were based on too small a sample to warrant speculation. However, yaks had poor reproductive years at least since 1989, judging by the percentage of yearlings and young in the population, and indeed 1991 and 1992 were almost reproductive failures. Whether this was due to a disease such as brucellosis which may cause spontaneous abortion, or to high postpartum mortality is unknown. What is clear is that so few young have survived in recent years that the population cannot sustain itself if the trend continues.

Blizzards and other inclement weather affect survival of newborn migratory caribou and probably of churu as well. Fewer chiru young were present in 1992 after the snowy and cold June than in 1990. Another population, in the eastern part of the Chang Tang Reserve, had a ratio of 14 young to 100 females (yearling and adult combined) in December 1991, indicating exceptionally poor survival that year.

In October 1985 a severe snowstorm followed by calm, cold (−40°C and below) days—during which the 30-cm snow cover neither melted nor was blown aside to expose vegetation—caused widespread starvation of wildlife and livestock at the eastern edge of the Chang Tang in Qinghai. We found 193 dead chirus in one valley alone. Many females and young but few adult males died, apparently in part because the smaller animals expended proportionately more energy in digging through the snow for forage. Many gazelles and a few kiangs also starved as did much livestock.
Local conditions on the Northern [Chang Tang] Plateau are so variable that development and conservation decisions must be made on the basis of micro-level data. However, at present, far too little is understood about the Northern Plateau's ecosystems for informed decisions to be made about intervening to force the nomads to alter basic components of their traditional system(s). It is essential, therefore, that systematic research . . . be conducted before . . . drastic measures [are] imposed in the name of science and progress.\textsuperscript{19,153}

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>SAMPLE SIZE</th>
<th>%CRUDE PROTEIN (RANGE)</th>
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</tr>
<tr>
<td>Stipa sp</td>
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</tr>
<tr>
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<td>14.8 (12.3–17.3)</td>
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<tr>
<td><strong>FORBS</strong></td>
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<td></td>
</tr>
<tr>
<td>Oxytropis glacialis</td>
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<td>16.9 (12.9–20.8)</td>
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</tr>
<tr>
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<td>Biebersteinia odorata</td>
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<tr>
<td>Potentilla bifurca</td>
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<td>Ceratoides compacta\textsuperscript{*}</td>
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\textsuperscript{*}Collected north of Aru basin in June.

including ~66% of 86,000 sheep and goats and half of 8,200 yaks.\textsuperscript{40} Such periodic and unpredictable snowstorms have a major impact on wild and domestic ungulate populations by causing catastrophic declines over large areas, declines from which it may take years to recover (Figures 19\&20).

Our only evidence of disease was 2 lactating female chirus dying of acute bacterial infection that led to pneumonia. Both animals died on 3 August at the edge of the Aru basin during the southward migration after a period of stress induced by bad weather, travel, and parturition.

Wolves were the most important large predators in the Aru basin (Figure 4). Two packs comprising ~12 individuals were observed in 1990. They preyed particularly on blue sheep, chirus, marmots (Marmota himalayana), and pikas (Ochotona curzoniae) (Table 3). A pack of 5 wolves was observed as it harassed a wild yak herd, and a lone wolf was seen with a freshly killed domestic sheep. Prey selection varied greatly with availability. North of the Aru basin, wolves captured mainly migrating chirus and pikas, and in an eastern area of the Chang Tang Reserve, where ungulate prey was scarce, they subsisted principally on pikas. All other predators were rare throughout the Chang Tang Reserve. One snow leopard (Panthera uncia) dropping in the Aru Range contained the remains of 2 blue sheep young. Outside the basin, a male lynx (Felis lynx) killed a 27.9-kg chirus female and a pair of lynx killed a marmot. In 1990 we observed a female Tibetan brown bear (Ursus arctos pruinosus) with 2 cubs and a medium-sized bear within the basin; droppings there contained mainly pikas and vegetation (Table 3). Predation affected populations of wild ungulates but marmots and especially pikas were important buffers in deflecting some of this pressure.

Knives, scrapers, microblades, and other stone tools found in the Chang Tang indicate that hunters have been part of the ecological scene.
since at least the Neolithic, 5000 or more years ago. During the winter of
1906 to 1907, S Hedin came upon a woman with 3 children: “She had
arrived from Gertse seventeen days before with her two husbands, who
had returned to Gertse after they had filled the tent for her with wild ass
meat. She owned a few yaks and a small flock of sheep, and would live for
the next three months on game—yaks, kiangs and antelopes.” Such sub-
sistence hunting continues to the present.

With the advent of vehicles in the Chang Tang ~3 decades ago, truck
drivers, officials, military personnel, and other outsiders also began to
shoot wildlife. In recent years commercial hunting for yak meat and chiru
wool has become a major threat to the survival of these 2 species, even
though both are fully protected by law. In 1992 a herdsman could sell 1
chiru hide for the equivalent price of 4 sheep. Traders smuggle the wool
through Nepal to Kashmir in India where it is woven into expensive
scarves and shawls for sale in Europe and elsewhere. At a winter hunting
camp in the reserve we met 3 men who had killed 22 chirus in 10 days,
not only for meat and wool but also for the horns which are widely used
in China in traditional medicines (Figure 21). One truck driver and his
accomplices from the town of Gerze were arrested for killing 300 chirus.
The 5 families that settled in the Aru basin in 1991 have had such success
in hunting chirus that they jointly bought a truck.

Discussion

The Aru basin contains a diverse assemblage of 6 ungulate species ranging
in size from 15-kg gazelles to 500-kg wild yaks. Gazelles and kiangs show
only slight sexual dimorphism, whereas males are considerably larger than
females in the other species. Rutting argali, blue sheep, and yak males close-

Figure 19.
An exhausted Tibetan gazelle (Procapra
cincta) awaits its fate after a snowstorm in the far eastern Chang Tang.
GEORGE R SCHALLER

SCHALLER & GU : UNGULATES IN NORTHWEST TIBET

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The high altitudes are a special world. Born of the Pleistocene, at home among pulsating glaciers and wind-swept rocks, the animals have survived and thrived, the harshness of the environment breeding a strength and resilience which the lowland animals often lack. At these heights, in this remote universe of stone and sky, the fauna and flora of the Pleistocene have endured while many species of lower realms have vanished in the uproar of the elements. Just as we become aware of this hidden splendor of the past, we are in danger of denying it to the future.\textsuperscript{38}336-337

ly tend 1 estrous female, chihu males maintain harems, and gazelle and kiang males are probably territorial. All species are to some extent sexually segregated for part of the year, kiangs and yaks to the least degree. Herd size varies from small resident ones, as in gazelles, to the large migratory aggregations of chihu. What strategies these diverse but sympathetic species use to avoid extensive competition for resources in their spartan environment is of ecological interest as well as of urgent relevance to conservation.

The abundance and movements of animals, plant growth, plant response to grazing, and the chemical and physical structure of soils and terrain all influence the way herbivores affect the ecosystem.\textsuperscript{7} In simple habitats, large herbivores require relatively large niches.\textsuperscript{38} How does the cold, high, and semiarid ecosystem of the Chang Tang sustain its ungulate species? That a cold, dry steppe could once support a highly diverse large-mammal fauna is shown by the Pleistocene assemblage in Alaska which included mammoth (\textit{Mammuthus}), woolly rhinoceros (\textit{Coelodonta}), camel (\textit{Camelops}), muskox (\textit{Ovibos}), \textit{Bison}, \textit{Equus}, and \textit{Rangifer}.\textsuperscript{21} However, 4 domestic ungulate species intruded on the Chang Tang at some time during the past few thousand years. Livestock and wildlife then adapted and coexisted in a sustainable manner largely because pastoralists managed their animals well and hunted mainly for subsistence. In recent decades, many pastoralists have moved into areas that were once unoccupied or virtually unoccupied, the traditional and well-adapted system of pasture allocation has been modified by the government,\textsuperscript{19} and wildlife is hunted commercially. Can wildlife sustain itself under current conditions?

The 10 ungulate species in the Aru basin overlapped broadly in the temporal and spatial use of their limited habitat. Several species sometimes congregated in a locality. However, during summer, when forage was abundant and nutritious, there was probably little competition for resources. Even so, clear differences in food habits existed. Kiangs and gazelles were the least flexible in their selection of forage types (monocot or dicot) but at opposite ends of the nutrient spectrum: Kiangs grazed almost exclusively on coarse, abundant fodder of low quality whereas gazelles selected tender, dispersed, high-quality forbs. The other species were versatile opportunistic feeders with wild yaks eating mainly graminoids, and blue sheep primarily forbs; argals also consumed both monocots and dicots but we lack data on preference. Chirius had the most elastic diet, feeding on a large variety of forbs when available, selecting particularly for legumes, or subsisting on coarse \textit{Carex} and twigs of \textit{Ceratoideae}. During winter, when competition for resources is likely to be highest, the gazelles, kiangs, and yaks (and perhaps blue sheep) seemed to maintain their dietary preferences but chirius increased their consumption of graminoids. Of the domestic species, horses were dietary analogues to kiangs, and domestic yaks to wild yaks. Sheep and goats were flexible feeders, switching between monocots and dicots with availability.

Although a certain degree of resource partitioning is evident, all domestic and several wild ungulates overlapped in their extensive use of \textit{Sipta} grass from autumn to spring. But several factors have so far minimized competition. Wildlife density is now low and pastoralists employ a complex system of grazing rotation.\textsuperscript{19} Livestock numbers have as yet not increased to a level where they stress resources. With nutrients stored underground for much of the year, graminoids can tolerate heavy grazing on their senescent leaves and stems.\textsuperscript{8} The wild ungulates on the Serengeti
Figure 20.
Antelope struggle through a heavy snowfall that starved hundreds of animals.

Figure 21.
A market hunter’s camp. Using foot traps and guns, the hunters killed >20 chiru in 10 days. The meat will be eaten, the wool sold for illegal export to India, and the horns used in traditional medicines.

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The emphasis of most conservation efforts has been on individual species rather than on whole communities. Recent work has shown that this approach may be inadequate. Small islands and islands far from others support relatively fewer species and extinction rates on such islands are remarkably high. This concept has been expanded to include isolated habitats such as those on mountains. Large species are particularly prone to extinction, when limited to small areas, because of their intrinsically low population density. plains consumed ~66% of the annual primary production. By contrast, grazing in the Chang Tang Reserve was generally light. Transects in the Aru basin showed that only 6.8% of graminoid leaves and stems (n=1081) had been grazed on Stipa steppe and 8.8% (n=407) on hillsides, some probably by pikas. Waves of seedheads glint in autumn wind on the Stipa steppe, an indication that grazing during the growing season is not significant. We observed no general environmental degradation in the reserve, although certain favored forbs may have been decimated and unpalatable ones may have increased in areas of heavy livestock use.

The northern half of the reserve remains unpopulated because grazing in most areas is so poor that livestock cannot exist there long. For similar reasons, wildlife is also scarce. But the southern half, south of ~34°N and including the Aru basin, with its grass steppes, is critical both to the livelihood of pastoralists and the survival of wildlife. That area represents the principal habitat of gazelles and kiangs and the winter range of chirus; wild yaks have already been almost exterminated for their meat, and argalis are, for unexplained reasons, extremely rare. The population of pastoralists is increasing and the government encourages further development of livestock production. There is now less tolerance toward any wild species, especially toward kiangs, which are thought to compete with livestock for forage. Yet few wild ungulates survive, even in areas of winter concentration where crude densities were only ~0.3 animals/km². Localities such as the Aru basin with higher densities are now rare exceptions. Even though wildlife and livestock overlap in their selection of forage there is so far little competition: The two can readily coexist.

During recent years the pastoralists have maintained or revived their traditional customs and beliefs, but their economy has been modified. Herdsmen once made long annual treks by yak caravan to barter livestock products for basic supplies. Now trucks visit even the most remote tents, providing a ready market for livestock as well as wildlife products such as chirus wool. Communes were abolished in 1981 (except those that elected to continue) and commune livestock was evenly divided and returned to private ownership. Some families thrived, others failed and their existence became marginal. Poor families, we were told, are most likely to hunt commercially, making this a social issue without easy resolution. Some officials, soldiers, truck drivers, and others also kill both casually and for the market. Wildlife populations cannot sustain themselves under such heavy pressure. In 1903, Rawling, while camped north of the Aru basin, observed migrating chirus and noted that “there could not have been less than 15,000 or 20,000 visible at one time.” Such huge concentrations have ceased to exist. If current trends continue, all species will within a few years be reduced to mere remnants. However, the Tibet Forest Bureau, which has jurisdiction over the reserve, is attempting to reduce the illegal wildlife trade by apprehending middlemen.

The establishment of the huge Chang Tang Reserve was a remarkable conservation initiative by China. The government now has an opportunity to manage this relatively pristine ecosystem in such a way that the nomadic pastoralists can continue their traditional pattern of life, and the wild species can continue to roam the uplands unfettered. Humans, livestock, and wild animals can live there in the ecological harmony that is the basis of Tibetan Buddhism (Figure 13). Once the Chang Tang has lost the heraldic presence of its last wild yaks, and the chirus do not surge north toward the rim of the world anymore, Tibet will have lost part of its natural and cultural heritage.