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ARGALI ON THE TIBETAN PLATEAU

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Abstract

I focus on what little is known about the argali living in the various mountain ranges of western China that form the northern boundaries of the Tibetan Plateau. I summarize our current state of knowledge regarding just what this animal is, how it might differ from other argali, its geographic distribution, and specific characteristics of living in this particular environment that affect its life-history. After treating the issue of the uncertainty about their abundance, I focus on the conservation problems facing these argali, and offer some thoughts on their future prospects.

Key Words: argali, China, conservation status, *Ovis ammon*, Tibetan Plateau.

Resumen

El argali en la meseta tibetana

En este trabajo se trata de recopilar la información existente sobre el argali en diversos sistemas montañosos del oeste de China los cuales constituyen los límites norte de la meseta tibetana. Se resume el estado actual del conocimiento sobre este ungulado y como puede diferir de otros argalis, fundamentalmente su distribución geográfica y las características específicas de la vida en este ambiente particular que afectan a su ciclo vital. Después de tratar la cuestión de la incertidumbre acerca de su abundancia, me centro en los problemas de conservación a los que se enfrentan estos argalis y se ofrecen algunas reflexiones sobre sus perspectivas de futuro.

Palabras clave: argali, China, estado de conservación, meseta tibetana, *Ovis ammon*.

Introduction

The Tibetan Plateau is generally considered to begin at northern slopes of the Himalaya, but I focus here on the northern portion of this immense highland area. North of the Qilian Mountains, the landscape quickly descends to much lower elevations, and vegetation types change from predominately alpine to desert shrub or desert grassland. This review is limited to animals living within the greater Tibetan Plateau, where elevations are without exception high, and

in which even summers are relatively cold. Readers should be mindful of the tentative state of our existing knowledge of these animals: due in part to their own nature, in part to mankind's interactions with them, and in part to the sheer challenges of travel through this forbidding country, argali on the Tibetan Plateau remain poorly understood.

In addition to published sources, information herein is based on my observations during 1988-2009 in various portions of the Qilian and Arjin Shan of Gansu and the Kunlun Shan of Qinghai, as well as various others travels in those 2 provinces. I've also had opportunity to observe other types of argali in the Tian Shan (in Hejing county) Xinjiang; in the lows hills on the Xinjiang-Kazakstan border west of Buerjin, Ili Autonomous Prefecture, Xinjiang; in the Pamirs of Afghanistan; and in the Gobi Gurvhan Saichan, Ik Nart, and Gun Gulut reserves in Mongolia's Gobi.

What is the animal?

The issue of what "type" of argali live on the Tibetan Plateau cannot be entirely avoided. Most biologists (Feng *et al.* 1986, Li 1989, Shackleton 1997, Schaller 1998, Wang 1998:335) agree with Geist (1991) in considering that all Plateau argali belong to *O. a. hodgsoni*, and that *O. a. dalai-lamae* is a secondary synonym for hodgsoni. Another view is that although hodgsoni is the predominant subspecies throughout most of the Plateau, *O. a. dalai-lamae* is a legitimate subspecies but with a geographic distribution limited to a relatively small section of the Arjin Mountains of southeastern Xinjiang (based on an early specimen collected by Przewalski, Wang 2002:136, Abudukadier 2003: 28). In contrast, official Chinese taxonomy considers only argali south of the Yarlung Tzampo River in the Tibetan Autonomous Region (TAR) as hodgsoni, and all argali further north on the Plateau (including all those that are subject to trophy hunting in the Kunlun and Qilian ranges) as *O. a. dalai-lamae*. Official government information refers to these animals in English as "Gansu argali", a term that has neither scientific backing nor makes any geographic sense (as it is intended to include argali in Qinghai as well as Gansu province). International hunters have generally echoed the official Chinese taxonomy, but hunter taxonomy has not

necessarily followed evolutionary arguments regarding differentiation of taxa, preferring to rely solely on phenotypic characteristics of interest to hunters.

The Chinese preference for restricting *O. a. hodgsoni* to those animals living in the southern part of the TAR is not coincidental. This governmental position was taken at a small meeting in Xian during summer 1991, a time when the future of the newly established trophy hunting programs in Qinghai and Gansu was at risk due to regulatory uncertainty: the legality of 4 rams taken in Subei County, Gansu by Americans in fall 1988 had yet to be finalized by the American justice system, and EU import regulations were also in a state of flux (Grimm 2002). In summer 1991, the only intra-specific regulatory distinction within *O. ammon* was that of CITES, which classified *O. a. hodgsoni* in Appendix I while all other argali were classified in Appendix II. This distinction had earlier been adopted at the behest of India, which desired stricter protection for its small and vulnerable population of argali while recognizing that the species needed less strict protection in countries further north. At the time, few if any thought about the implications for a species with such murky sub-specific taxonomy, but the implications had by now become clear to Chinese officials: obtaining international approval for killing and exporting argali from Qinghai and Gansu would be vastly more complicated if these animals were considered the subspecies the Indians had succeeded in placing in Appendix I. Much more flexibility could be obtained by simply concluding that animals in Qinghai and Gansu were of a subspecies listed only in Appendix II. Thus, the Ministry of Forestry (since reorganized into the State Forestry Administration) issued an unpublished report declaring that argali in Qinghai and Gansu were to be considered dalai-lamae.

Muddying these taxonomic waters is the status of *O. a. darwini*, a subspecific name generally associated with the Gobi desert of southern Mongolia, but which may also exist in China. In concluding that all specimens earlier labeled as dalai-lamae should actually be considered hodgsoni, Cai (2000) confused things further by declaring that Qilian mountain argali from both Subei (in Gansu) and Tianjun (in Qinghai) counties were actually darwini, whereas those elsewhere from within the Qilian were hodgsoni (while declining to speculate on where or whether, a geographic barrier between these existed). This unexplained incursion

of darwini into the Qilian range was reiterated by Liu *et al.* (2000) in their review of hunting programs in Gansu. Zheng (1994) mapped the boundary between hodgsoni and dalai-lamae rather conveniently as the Qinghai-Gansu border (which, owing to reasons far removed from Caprinae taxonomy, has since been officially moved further south). Using mtDNA (but small sample sizes from geographically disparate study sites), Feng (2000) concluded that the Tibetan Plateau possesses 3 argali clades, although she declined to recommend concrete changes in subspecific taxonomy. Wu *et al.* (2003) also declined to suggest a subspecific revision, but noted that argali from Subei in Gansu's Qilian were genetically more closely related to those from Qinghai's Kunlun and the TAR than to those from Mazongshan, north of Dunhuang in Gansu. Perhaps sensing that subspecific taxonomy has recently become less important politically as the regulatory world evolves, Zheng (2003) returned full circle, referring to argali in the provincially-published survey of wildlife in Qinghai as *O. a. hodgsoni*.

I can offer only three small additions to this grand mess. First, it seems clear that in both the Qilian complex and the Kunlun complex (as well as in associated ranges such as the Turgendaba Shan), we are dealing with an animal that is particularly adapted to cold grasslands rather than deserts. From a coarse phenotypic view, they appear stouter and more densely furred than desert-adapted morphs of Mongolia's Gobi. They have thicker but shorter horns than Tianshan morphs (usually considered *O. a. karelini*) to the west (as well as those living west of Buerjin, which are sometimes considered *O. a. sairensis*, Yu *et al.* 1999). Although standardized weights and measurements for comparison are still lacking, they appear to be intermediate in size among argalis, smaller bodied than Altai argali (usually considered *O. a. ammon*) but larger than desert-adapted forms to the north or the small argalis of Uzbekistan or Kazakstan's Kar-Tau. In breeding pelage, the white ruff of mature males is particularly striking, and its contrast with the brown shoulder (and, in old rams, blackish "saddle") is probably greater than in other argalis. Breeding and parturition for Plateau argali, in common with Plateau endemics such as chiru (*Pantholops hodgsoni*), Tibetan gazelle (*Procapra picticaudata*), and blue sheep (*Pseudois nayaur*), tend to be late rather than early, with females coming into estrous no sooner than late

December (Harris & Ali 2002) and parturition occurring no earlier than mid-June (unpublished data). Whether or not these phenotypic differences reflect important evolutionary histories, and whether or not they merit subspecific designation, is beyond my expertise. That said, subspecific designations are most useful in conservation when they are associated with local adaptations.

Second, my observations provide no basis to suggest that there are gross morphological differences among argali within the Tibetan Plateau, from as far north as the Yemanan Shan through the Danghenan Shan, (or any of the associated western Qilian ranges), eastern Arjin Shan, to at least as far south as the eastern Kunlun Shan. I've often observed individuals within a given aggregation –no doubt closely related to one another– who differ superficially from each other more so than do Qilian argali from Kunlun argali. In short, I think all these argali are similar animals.

Thirdly, as I will discuss below, these animals are capable of making long-distance movements, including across terrain that would appear superficially inhospitable to argali. Therefore it seems unlikely that there are natural barriers to gene flow among argali within the Qilian and Kunlun Shan (or, at least historically, between them). Argali likely constitute a genetic cline rather than discrete "types", and what appear to us as visible phenotypic categories or statistically significant genetic differences may reflect our pointillistic sampling as much as it does true biological thresholds. (In contrast, the low and broad valley known at the Gansu Corridor, north of the Qilian Mountains, may well have historically acted as a natural impediment to gene flow between these animals and those in the low hills of the Gobi. As Schaller (1998:84) has argued, permeability no doubt was further reduced when the Great Wall was built). In arguing that any subspecific differences are inconsequential, I would add that local adaptations no doubt exist and deserve to be considered. But toward this end, we should work to conserve argali regardless of their location rather than worry about developing increasingly sharp instruments with which to split taxonomic hairs. I refer to the animals simply as "Plateau argali" to avoid any inference that I'm making a taxonomic statement.

Where and how do plateau argali live?

In a broad sense, argali live everywhere on the Tibetan Plateau where graminoids are sufficiently abundant to provide forage, and where terrain is hilly (although not so steep or rugged that they cannot be negotiated by these long-legged, running animals). In a narrower sense however, argali seem to thrive only when a number of factors come together to minimize what would otherwise be an extremely inhospitable environment. Argali on the Tibetan Plateau have a very wide geographic distribution, but a surprisingly narrow ecological niche.

Except for the most southeasterly region where abundant moisture from the Bay of Bengal surges up the valleys of the Salween, Mekong, and Yangtze Rivers into the eastern portion of the TAR, southwestern Sichuan, and southeastern Qinghai, the Tibetan Plateau is fundamentally an arid place. Plateau argali appear tolerant of arid environments (observations suggest they require drinking water only every 2nd or 3rd day, and not at all when snow cover is sufficient), but they are not a true desert-adapted species. To support such a large body, they require more high-quality grass than deserts can usually provide, and thus depend on the orographic precipitation of their preferred mountain habitats to provide sufficient quantity of grass. For example, argali have never been reported from the low hills surrounding the arid Chaidam Basin or the parched foothills that lead from them to the peaks of the Qilian (to the north) or Kunlun (to the south), probably because these arid hills produce little grass.

However, argali also seem relatively rare among mountain ranges in the very high elevation vastness of the Kekexili (southwestern Qinghai) or Qiangtang (northern TAR; see Feng 1990, Schaller 1998). (In contrast, blue sheep are abundant not only in high elevation areas, but also in extremely arid, sparsely vegetated, rocky hills at lower elevations as long as their required cliffy escape terrain is present). My own observations suggest that argali cannot tolerate deep snow in winter; thus, they must either live year-round where snow depths are moderate, or must have access to winter ranges where snow depths are usually low.

For example, during November-December 1998, and then again in April 1999, I worked with staff at the Kharteng International Hunting Area (KIHA) in Aksai county in western Gansu, to identify areas of argali concentration. Despite days of searching from both vehicle and by climbing ridges where we knew argali were often seen during summer, we found argali routinely only within the relatively low-lying hills (at elevations generally below 4,000 m) on either side of the Kharteng River. Unconvinced that either of these surveys had uncovered the full extent of argali winter range in this area, I returned in early February 2002 to map their full extent of winter occupancy, by specifically extending our survey beyond the geographic bounds that KIHA staff believed argali to use. The results of this winter survey confirmed that their anecdotal knowledge had probably been correct: argali were indeed restricted in winter to the low hills KIHA staff had previously directed me to. Every argali group we saw was located in regions that were either completely snow-free or had only patchy snow cover. Our observations of tracks (or their lack) suggested that argali avoided areas with more than ~ 0.2 m of snow cover (Harris & Ali 2002).

The argali's available niche along this moisture gradient is exemplified by their geographic distribution in the Danghenan Shan in Gansu. The entire range (one of a series of ranges within the ~ 1,000 km long Qilian Shan) extends some 200 km from approximately Hala Hu (lake) in the southeast to Dangjin Shankou (pass) in the northwest. Yet KIHA staff has brought hunters only to camps in the roughly 65 km constituting its middle third. The Danghenan Shan is has relatively uniform topographically: might argali not be found in similar abundance both southeast and northwest of KIHA's preferred hunting camps? In 2000 we had an opportunity to survey almost the entire range and obtained an answer to this question. As KIHA staff had predicted, we found neither argali nor their sign southeast or northwest of the areas in which they'd been hosting hunters. However, we observed no differences in levels of poaching, livestock grazing, or other human disturbance that could plausibly have caused their restricted distribution.

Why then, do argali seemingly avoid the superficially similar southeastern and northwestern sections of the mountain range? My best inference is that

climatic patterns (acting together with elevation and topography) simply don't allow for argali to meet their needs anywhere but in the central portion of the range. Due to prevailing storm patterns, the Danghenan Shan becomes considerably wetter from northwest to southeast (as evidenced by the much greater extent of snowfields and glaciers in the southeast despite broadly similar elevations). Although this generally means increasing quantity and quality of forage, it also means that winter snow cover lasts longer and becomes deeper as one goes further southeast. Additionally, although the mountain peaks are of similar elevation throughout, the valley floor rises gradually from northwest to southeast (from about 3,000m to about 4,000m), effectively narrowing the space between habitats too flat for argali to find comfort and too high for them to find forage. By contrast, in the northwestern portion of the Danghenan Shan, extreme aridity allows for growth of abundant grasses only in a very narrow elevational band, high enough to produce orographic precipitation, but not so high that the as to preclude a growing season altogether. Thus, in the southeast, the abrupt transition from steppe to alpine leaves argali with no possible winter range (because of deep snows), and in the northwest the abrupt transition from true desert to rock talus leaves argali with insufficient vegetation. As a result, argali seem restricted to a narrow belt above the relatively flat steppe habitats (where disturbance from people and livestock was high) and below the upper limit of vegetation (where disturbance was low but forage non-existent). If my conclusion regarding the Danghenan Shan is correct and can be generalized, it goes some way toward explaining some apparent anomalies in the geographic distribution of argali on the Tibetan Plateau. Argali do well only where conditions are neither too arid nor too mesic, where topography is neither too rugged nor too flat.

Obviously, argali are a mountain ungulate. One need not bother looking for them if no mountains are in sight. That said, argali often seem to be uninterested in (or perhaps incapable of) using steep terrain as a refuge from predators. On the Tibetan Plateau, they largely cede the steepest slopes and most broken terrain to blue sheep. It appears that Plateau argali most often use slopes and ridges not so much to benefit from any topographic refuge they provide as to facilitate

scanning for potential predators visually, a higher platform allowing a more encompassing view than a lower one. Their favorite haunts include ridges where they can see multiple directions simultaneously. Upon sensing potential danger, argali may continue to move upwards along a ridge, but if danger is perceived to be imminent, they are as likely to run down as up (i.e., away from the most forbidding topography), seemingly trusting in their speed rather than their maneuverability in difficult terrain. In fact, excepting the preceding and during the rut, argali seem to be interested in only two things: finding abundant forage and looking out for wolves (*Canis lupus*). Their primary defense against wolves is space; their location at any given time is a continual compromise between proximity to good forage and distance from wolves. (Lambs are also susceptible to predation from eagles (*Aquila* spp.) and other raptors, but in this, they do not differ from blue sheep, or indeed, most other ungulates). Thus, topography that is too broken, jagged, or cliffy may actually be avoided by argali. Rough topography may limit their ability to see the full landscape surrounding them (and thus to ensure their perceived measure of an adequate distance from any threat), while also compromising their ability to use their long legs and endurance to outpace wolves.

In sum, argali are hemmed in. Although they will cross surprisingly wide valleys, even moving between discontinuous mountain ranges, they cannot be considered a plains animal; they need topography. But steep topography fails to capture the nuance of argali habitat needs, because they can't handle too much of it. Although they are basically a denizen of arid climates, they appear to require both quantity and quality of graminoids (in summer) and shrubs (in winter) more similar to that of the even-larger bodied wild yak (*Bos grunniens*) than the desert-adapted goitered gazelle (*Gazella subgutturosa*). But considering precipitation as a surrogate for forage would similarly fail to capture argali habitat needs, because on the Tibetan Plateau, too much moisture means too much snow, and they appear restricted to winter ranges that are either blown-free of snow, or simply don't accumulate much. And because argali use solitude as a defense against predation, they further limit themselves to undisturbed habitats – which, I'll argue below, constitutes their greatest conservation challenge. Thus argali on the

Plateau must find an elusive compromise, negotiating a host of adverse factors in order to successfully maintain their populations.

How abundant are Plateau argali?

The only honest answer to the question of how many argali occupy the Tibetan Plateau is "we simply don't know". That is, of course, an unsatisfactory response, especially because estimates have been suggested and public media have sometimes repeated them. I will not add another numeric estimate, but will assert that argali are far less numerous on the Tibetan Plateau than most Chinese estimates would suggest.

In a widely repeated estimate, Schaller (1998:90) considered that "…the total number of Tibetan argalis could be as low as 7,000". Many Chinese would dispute this figure, considering it far too low. There are many Chinese abundance estimates, but none are accompanied by sufficient information to judge their reliability. Here I review those with which I'm familiar.

For Gansu, in a letter to the US Fish and Wildlife Service dated May 17, 1991, Wang Zhangyun of China's CITES Management Office suggested that there were as many as 20,000 argali in this province alone. There are at least 4 written estimates of argali abundance in the Hashiha'er International Hunting Area encompassing the northern slopes of the Danghenan Shan and the nearby Yemanan Shan in Subei County, Gansu (which, at approximately 13,000 km^2 would constitute about 0.03% of the area to which Schaller's extrapolation would apply). A provincial survey from 1990 estimated 1,452 argali (with unspecified confidence limits of 831-2,073; Gao Jun, Gansu Wildlife Protection Bureau, Lanzhou, unpublished data), an internal report of unclear origin estimated 1,525 (with confidence limits of 990-2,060; Zhao Lianghong, Subei International Hunting Area, unpublished data), Liu *et al.* (2000) cited a mean density figure of 0.482/km^2 (which is higher than either of the 2 density estimates underlying the above abundance estimates, and which equates to an abundance estimate of 4,479), and Liu (2001) estimated a population of 3,294 within Yanchiwan township (which roughly equates with the Hashiha'er hunting area boundary).

All of these estimates relied on some variation of ground-based distance sampling, but in no case were sampling methods described. Neither can the reader learn much about sampling intensity from these reports, although Liu (2001) revealed that his density estimate was based on a sample size of 6 and the total number of animals observed was 60.

For the adjacent (and slightly smaller) KIHA in Aksai county, Gansu, the 1990 provincial population estimate was 1,545 (with confidence limits of 1,127-1,963; Gao Jun, unpublished data), and the density estimate from Liu *et al.* (2000) suggested a population size of 3,879. In contrast, our ~ 1-month-long surveys in both 2000 and 2003 with KIHA staff, focusing on what was believed to be the best argali habitat, documented 204-255 individual argali, and although we no doubt failed to detect them all, we concluded that it was highly unlikely that the total population exceeded 500 (Harris *et al.* 2005).

In Qinghai, based on part of the national "wildlife census" program from the late 1990's, Zheng (2003) estimated a total population for Qinghai of 3,588 (with a confidence interval of 828, although this point estimate was calculated using mean densities from sample areas unweighted for differing sample area; using a weighted estimate, the point estimate for the province would have been 2,795). Earlier, Zheng & Zhu (1990) had estimated a population size of 665 (with 95% confidence interval of 245) within selected study sites totaling approximately 600 km^2 of the Bu'erhanbuda Shan portion of the Kunlun Shan (based on 18 groups observed).

Estimates of the number of Plateau argali in Xinjiang vary greatly, but a frequently cited estimate for the Arjin Shan region (the principal portion of Xinjiang overlapping the Tibetan Plateau) is "about 10,000" (e.g., Butler *et al.* 1986), but this is based largely on questionable surveys conducted in the early 1980's by personnel from the Institute of Desert Biology and Pedology in Urumqi (see Wang 1998:399). Butler *et al.* (1986) observed no argali in the Arjin Shan Nature Reserve, and Achuff and Petocz (1988) observed a total of 9, concluding that "...the argali population in the western part of the reserve is far less numerous than previously estimated". For the TAR, Liu and Yin (1993) published an estimate of 5,000 argali.

Thus, accumulated Chinese estimates of argali over their entire Tibetan Plateau range are considerably higher than Schaller's estimated 7,000. The group charged with estimating numbers of all Caprinae species in China put forward an estimate of 29,000-36,000 for *O. a. hodgsoni* alone (although Wang 1998 seemed to disavow this estimate, and Shackleton 1997 distanced himself from it). More recently, the scientist in charge of the argali portion of the "national census" suggested that the total number of argali in China (including many "non-Plateau" animals in Xinjiang) was between 23,298 and 31,910 (Yu Yuqun, Northwest Institute of Endangered Species, Xian, personal communication, July 11, 2004).

Notwithstanding the frequent claim that Chinese surveys are done "scientifically", there is ample reason to believe that, in general, Chinese estimates are biased high because they are extrapolated from sampling done in those areas known (either from previous experience or from reports of local herdsmen or agency staff) to have the highest densities. (Flaws in quantitative methods often add a small positive bias as well, see Harris & Burnham 2002). For example, the late 1980's provincial estimate for KIHA in Gansu that suggested a mean density of nearly 1 argali/km^2 (and extrapolated to a population size of 1,545) came from observing a total of 237 argali within a survey area of only 222 km^2 - similar to 204-255 argali I estimate that we documented in the same area during 2000 and 2003 (Harris *et al.* 2005). Provincial biologists in China almost always follow the suggestion of local guides or county-level staff, who, faced with a short-term visit from somebody wishing to "count argali" would be very likely to lead them to those places where argali had previously been seen. Thus it seems very likely that this provincial survey succeeded in observing a relatively large number of argali within their favored habitats, but then blindly extrapolated this "density" to areas containing few if any argali.

In Qinghai, despite the fact that Zheng & Zhu (1990) claim to have selected sites "randomly" from within their study area, the second author revealed to me that sampling locations had been selected on the basis of local guides knowing where argali were most likely to be found (Zhu Shenwu, Northwest Plateau Institute of Biology, Xining, personal communication, 1991). Even for the standardized national "census" of the late 1990's, in which field workers were

instructed to select sites randomly, the fact that fully half of the 173 total argali tallied (province-wide) came from sample sites in or near the Dulan Hunting Area (Zheng 2003:89), where general argali distribution was already known to local staff, is suspicious.

The problem of extrapolating densities from unrepresentative samples to areas never surveyed or visited bedevils all existing attempts to enumerate argali over their entire Plateau range (and is not restricted to work by Chinese authors, e.g., R. Mitchell, unpublished comments to the U.S. Fish and Wildlife Service, May 10, 1991.). Could there really be 20,000 argali in Gansu when our intensive surveys suggested that not more than 500 occupied the southern slopes of the Danghenan Shan (one of their supposed strongholds), and when, evidently, they have been almost extirpated from adjacent Sunan county (Anonymous 2002, Harris 2002) in the Qilian? Could there be so many argali outside of the known hunting reserves in Qinghai, when Schaller *et al.* (1988) found none in Zhiduo or Zaduo counties, Kaji *et al.* (1993) documented only 86 in southern Qinghai and adjacent Sichuan (during surveys in which they observed 1,669 white-lipped deer and 2,939 blue sheep), Mallon and Bayar (2002) failed to observe a single individual in 6 weeks of field work in Suojia township, Zhiduo county (despite its reputation of being one of the least disturbed areas in all of southern Qinghai), and I never documented them or heard locals indicate they existed in Nangqian county (Harris 1991)? Could there really be 5,000 argali in the TAR, when Schaller and Gu (1994) observed only 3 during 2 field seasons, and Fox *et al.* (2004) failed to document any in the Qiangtang Reserve's Aru Basin? Could there really be "10,000" argali in the Arjin Shan Nature Reserve, when Bleisch (2000), after 5 survey trips and very few argali observations, concluded that "argali may be rapidly approaching local extinction in the reserve".

As an alternative to extrapolations, it may be tempting to infer patterns in abundance from observations of group size, because when an argali group is observed, documenting its size and composition is one of the few things a biologist can usefully do. If group sizes are large, it may seem a logical inference to assume that overall populations are correspondingly large (with the reverse presumably also being true). Although comparative data to test this hypothesis are lacking,

I urge against uncritical acceptance of any relationship between group size and overall density. First, argali group size is highly variable seasonally, with females isolating themselves (thus reducing average group size) during lambing, and with males joining with females and young to create very large groups in winter. Equally importantly, group size appears to be largely a function of efficiency in predator avoidance and escape. A larger group contains more eyes with which to detect predators, but too large a group makes itself obvious to predators and therefore becomes a liability. In the gentle slopes and rounded peaks of the Kunlun and Qilian Shan where visibility is unhindered, a large group is a benefit. Maternal bands of 30-40 during summer and 70-80 during winter are common (Harris 1993, Harris *et al.* 1999, Harris & Ali 2002; larger groups are common in the similarly open Pamirs; Harris *et al.* 2010), but may be separated by huge areas devoid of any argali. In contrast, argali living in portions of Mongolia's Gobi, where topographic relief takes the form of small, isolated rock outcrops, live in much smaller groups (Reading *et al.* 1997). Here, a large group would provide no advantage. Most outcrops used for resting and detecting predators in the Ik Nartiin Reserve, for example, are not large enough to contain many argali; groups of 30-40 would leave many individuals in poor locations. Group sizes of argali in Ik Nartiin are quite small, but it does not follow that overall density is lower in Ik Nartiin (Frisina *et al.* 2004) than in the Qilian or Kunlun.

Almost certainly, argali occur in places where neither Chinese nor Western scientists have documented them. There appears no imminent danger of their loss from broad areas of the Qilian or Kunlun Shan. However, both their narrow ecological niche, and the fact that surveys have often found relatively few even where tenuous extrapolations suggested there ought to have been many, argues in favor of accepting rather conservative guesses.

How much have Plateau argali declined?

If we don't know the present abundance of Plateau argali, we can hardly claim to know their recent rate of decline, as that would require knowing past abundance as well. I have little doubt that many fewer argali existed when the Chinese national wildlife law was enacted in 1988 than historically, and given

my own surveys of 2 key areas, I fear continued declines since then (Harris & Loggers 2004, Harris *et al.* 2005). However, my interpretation is that Tibetan argali may never have been terribly numerous. Schaller (1998) provides a good overview of historic records, and although some early explorers seemed to find them common, most reported them as rare. In addition to those Schaller (1998) cited, Waddell (1905) used "occasional" or even "rare" to describe argali, whereas he used "common" to describe blue sheep. In an account of his 1948 exploration of the eastern Kunlun Shan and adjacent Amnye Machin range, Clark (1954:87) frustratingly refers to both blue sheep and argali as "bighorns", never indicates which he is talking about, but when accompanied by descriptions, they tend to suggest he was observing (and eating) blue sheep rather than argali (Clark 1954:153, 174, see also the photo of a "bighorn sheep" in Clark 1949). Elkvall (1968) is similarly vague about which species of "wild sheep" were present during the 1930's in the upper Yellow River basin, although he, along with others (e.g., Shelton 1921, Norbu 1979, Huber 1991, 2003) have stressed that many Tibetans hunted wild game traditionally. The reduction of Plateau wildlife that is sometimes assumed to have begun only after 1949 may in fact have added to existing hunting pressure from pastoral nomads. Plateau wildlife populations were certainly healthy at the outset of the People's Republic, but they were not, as is sometimes assumed, untouched by humans.

These reports, together with my interpretation of the rather narrow ecological niche that Plateau argali occupy, suggest that they have never been abundant. If their recent rate of decline has thus been gradual rather than dramatic, it doesn't make the situation any less critical; it simply means that their present conservation difficulties should be understood as adding to existing challenges for the species.

If argali are declining, we should theoretically see it played out demographically, i.e., in lamb production or early survival that fails to balance adult mortality. A continual frustration has been the inability to document the components of population change in Plateau argali, i.e., rates of reproduction or survival. Lacking this, it may be tempting to infer population trends from lamb:ewe ratios or related indices. Beyond the well-known limitations of this approach in general

(McCullough 1994), field surveys of argali, often necessarily obtained at great distance, are particularly vulnerable to misinterpretation. Because females in the wild first breed as yearlings (or later) and produce their first lambs as 2 year-olds, differentiating yearlings in the field is critical before any interpretation of age distribution is meaningful. Yet distinguishing yearlings from adult females can be quite difficult. Additionally, as they approach their first birthday, size differences between males and females become sufficiently pronounced that fawns can appear to be of 2 different age-classes from a distance. Finally, I have observed young males to separate from maternal groups and join bachelors as young as the yearling or even lamb age, further complicating interpretation of production or early survival from the constitution of maternal groups.

Current management

Chinese policy to conserving argali uses two approaches: nature reserves and international hunting areas. Both have potential to provide significant benefits to argali, but both are problematic as currently managed and implemented (Harris 2007).

The amount of area currently under formal nature reserve protection that, at least on paper, contains Plateau argali is an awe-inspiring 638,553 km^2, almost twice the size of Kyrgyzstan and Tajikistan put together. This impressive acreage must be viewed, however, with three important caveats in mind. First, some large reserves that claim argali as resident barely touch on appropriate habitat (e.g., the 3,960 km^2 Annanba Wild Camel Nature Reserve in Gansu that is almost entirely desert), or no longer contain substantial argali populations (e.g., the 4,790 km^2 Qilian Shan reserve). Second, the largest and most undisturbed nature reserves, such as the 247,120 km^2 Qiangtang Reserve in the TAR and the 83,000 km^2 Kekexili Reserve in Qinghai, are predominately made up of habitats that seem to lack winter range for argali. Despite their size and relatively undisturbed nature, they appear to contain low densities of argali. Third, most Chinese nature reserves, particularly those in the poorer western provinces, are not managed appreciably differently than are non-protected lands. Funding and staffing levels are low, and few resources are spent on patrol or law enforcement. More critically, nature

reserve staff lack authority to prioritize nature conservation when competing economic land uses are favored by county governments. Anti-poaching patrols may further reduce illegal hunting within reserves, but mineral development and livestock grazing are not effectively prohibited or even limited.

Three international hunting areas with Plateau argali have been established and operated during 1988-2006 (Hashiha'er in Subei and Kharteng in Aksai, Gansu; and Dulan in Qinghai), and permits for argali hunts have occasionally been issued in other areas (including in the TAR). These hunting areas have generally succeeded in recruiting and retaining energetic and dedicated staff, and raising awareness of wildlife conservation in their communities. Due to the presence of these staff, poaching probably declined within these hunting areas well before the general confiscation of firearms in China's pastoral areas. Although trend surveys have been lacking (or sporadic at best), and harvest quotas set from Beijing based on little more than hunches, there is no evidence that offtake of argali by trophy hunters has been excessive. Judged by the available demographic and genetic indicators, trophy hunting of Plateau argali appears to be sustainable. As well, the existence of discrete hunting areas with local staff provides the potential seeds for local co-management that could mobilize the funds and energy produced by these hunting programs for both conservation and improvement of pastoral livelihoods.

Unfortunately, these hunting areas have had no more success than have nature reserves in prioritizing argali conservation when land management conflicts arise. Contrary to the impression one might obtain upon seeing the term "Hunting Reserve", competing land uses are in no way restricted in these areas. Hunting area managers have neither funds nor authority to restrict livestock grazing that may be detrimental to argali, or to prevent industrial development that would be entirely incompatible with conserving them. The hoped-for incentives, harnessing market forces to keep argali habitat wild in the face of pressures to transform it to other economic uses, have not yet materialized.

In part, this is because of the top-down and leaky system of funds-transfer from hunters to the local level, in which only about 5% of the hunter fee remains in the till for conservation after all the grabbing hands have first taken their

share. Harris & Pletscher (2002) and Harris (2007) provided details of this system. Generally, high-level offices first take their share (as well, of course, as do fixed travel costs and travel agents), leaving the hunting area itself to cope with the leftovers, which are usually only sufficient to cover the cost of the hunt itself. Recently, the price of vehicle fuel, one of the major components of locally-born costs, has roughly quadrupled in China, whereas fees paid by hunters have remained static. This ever tightening margin for hunting areas has caused them to look for ever-more creative ways to economize or produce income (including, of late, obtaining hunters' permission to retrieve otherwise unused meat, pack it up, and sell it to restaurants in distant cities). Under these conditions, the potential to support habitat protection financially is essentially nonexistent.

However, even were the economics of trophy hunting friendlier at the local level, these international hunting areas would be poorly positioned to help argali. Although nominally run by county-level forestry bureau, they continue to be treated by more powerful government units as though they were private, profit-making enterprises rather than as crucial elements of a socially-desired conservation system. That they generate hard currency from foreigners tends to instill in other government offices greed and envy rather than gratitude. They are expected to produce a marketable product (argali trophies) without control of the means of production (argali habitat). That habitat, in turn, is always heavily (and sometimes excessively) grazed by domestic livestock, and increasingly threatened by industrial projects such as the construction of mines, reservoirs, water diversion systems, and highways.

Conservation outlook

Schaller (1998) considered that the primary threats to argali populations on the Tibetan Plateau were poaching, the isolation and fragmentation of herds, and possibly disease. Although I agree that the status of argali on the Plateau is precarious and its future at risk, my take on the relative importance of various limiting factors is somewhat different. Until the mid-1990's, poaching was certainly rampant in western China, and even today, no doubt occurs occasionally. But recent Chinese efforts to crack down on organized poaching have begun to

reap dividends, and subsistence poaching by local pastoralists has become all but impossible with the governmental confiscation of all guns. (As noted above, killing by trophy hunters, at least at levels similar to those seen thus far, is not a direct, demographic concern).

Argali herds are geographically disparate, but this probably reflects their restricted habitat needs, and does not necessarily implicate anthropogenic fragmentation. Further, my observations suggest that Schaller's (1998:89) characterization of argali as "sedentary" and slow to resettle areas once removed is misleading. I have observed large argali groups that have recolonized mountains believed, by a reliable local guide, to have been previously poached out (Harris 1993). On numerous occasions (including just prior to the breeding season) I've observed argali traverse minor hillocks and frozen rivers between distant mountain ranges that a superficial view of topographic maps would suggest would act as barriers to movement. I've also observed argali within a few hundred meters of highways, suggesting (albeit not demonstrating) that they can cross at least some man-made structures. Genetic concerns stemming from small population size should never be dismissed, but Plateau argali appear to be capable of substantial gene flow among seemingly distant groups, relegating these concerns to a secondary status.

We know little of disease in Plateau argali; local reports suggest that they are susceptible to eye diseases (instance of blindness have been reported), and the well-documented history of problems when bighorn sheep (*O. canadensis*) encounter domestic sheep serves as an appropriate caution. However, there are no documented instances of the dramatic die-offs among Plateau argali we typically observe among North American bighorns when diseases are transmitted to them by livestock. And unlike in North America where old-world domestic sheep (and their pathogens) are a relative newcomer, argali have lived in the same mountains with domestic sheep for millennia. Resistance to pathogens that bighorns lack may thus have had time to develop in argali.

Instead, my concerns for the future of Plateau argali center on their seeming need for isolation from human activity, and the steadily increasing magnitude of human presence in just those areas where argali can find their biological needs.

Livestock grazing exists at relatively heavy densities throughout argali distribution on the Plateau, both within and outside of designated nature reserves, and both within and outside of designated international hunting areas. Pastoralists have lived in the same mountains as argali for centuries, and in many areas (particularly in the Plateau's more mesic sections) the recent Chinese publicity about grassland degradation or destruction is simplistic and exaggerated (Harris 2010). However, the recent trend toward sedentarization of pastoralists, combined with continued market pressures toward short-term profits associated with large herd sizes, portends trouble for argali. Chinese officials continue to focus on mortality management while imminent threats to the argali's already restricted habitat are ignored.

In Yanchiwan township, in Gansu's Subei county, where argali hunting began and where the Chinese consider one of the healthiest argali populations to be, an American hunter recently phoned me to express horror at the habitat conditions caused by large number of livestock. In adjacent Jianshe township in Aksai county, which unlike Yanchiwan does not benefit from extensive sub-irrigated pasture land for livestock, our work concluded that domestic sheep densities and pastoral practices were unsustainable, and no doubt limited argali to a fraction of the number that might otherwise be supported (Bedunah & Harris 2002). Although we do not yet know the population trend of argali there, removal of all guns and the absence of any known poaching during 2000-2003 failed to produce any obvious increase in argali numbers (we documented fewer in 2003 than 2000, although survey limitations preclude us from concluding a true decline occurred), suggesting that habitats or competition, rather than hunting, were limiting.

In part, domestic sheep form a competitor to argali for forage resources. But perhaps even more importantly, domestic sheep (with their attendant herders, horses, and sometimes dogs) appear to displace argali from otherwise preferred foraging areas, relegating argali to dry, cold ridges that pastoralists don't bother herding their domestic sheep to. We earlier documented how seasonal movements of pastoralists in Jianshe, Aksai County (Gansu) displaced argali (Harris & Bedunah 2001, Harris & Pletscher 2002). Similarly, near Arjin Mountain, where Gansu abuts Qinghai and Xinjiang, KIHA staff and I observed a surprising 116

argali in just 2 days of driving (through ~ 50 km) in August, 1997. Habitats here were extremely arid and stony, almost entirely devoid of graminoids; we found ourselves puzzled by why argali density appeared so high. Toward the end of the 2nd day when we began descending the western slopes, grasses suddenly appeared in lush abundance but we ceased finding argali. The seeming anomaly could best be explained by the complete lack of domestic livestock in the arid areas, and the high density of livestock where moisture allowed for lush pastures. In Yeniugou, Qinghai, our surveys suggested that argali had declined from the early 1990s to 2002, again despite any evidence of poaching or disease. Here, livestock numbers remained approximately constant and grassland conditions had not markedly declined, but in contrast to the situation in the early 1990's, pastoral camps had by 2002 become increasingly fixed in the very areas favored by argali (in both summer and winter; Harris & Loggers 2004), and argali had evidently forsaken these productive areas for arid grasslands that offered more security. In Gouli township of the Dulan International Hunting Area in Qinghai where blue sheep are extraordinarily abundant (and well protected) and grassland conditions still relatively good, argali remain rare. All of my argali observations there have been in those areas furthest domestic sheep herds, where grasslands begin to be replaced by cushion-plant communities or alpine fell-fields.

Thus, despite the fact that they require considerable growth of graminoids, Plateau argali are often found precisely where grassland conditions are poor. Perversely, poor grassland conditions, arising from either natural conditions or heavy livestock grazing, have become a promising omen for finding argali.

Conclusion

Argali on the Tibetan Plateau have persisted despite the presence of mankind and his livestock for centuries, so it seems simplistic to conclude that coexistence is impossible. We cannot recreate the past, so have no way to detail the ways in which argali earlier met their needs and maintained their population levels in the face of traditional pastoralism and traditional hunting. More research is obviously needed, particularly on their habitat use and movements and in response to human disturbance, but Plateau argali are fiendishly difficult to study (in part

because of that very mobility). As well, patterns of pastoralism and development are in a state of rapid change on the Tibetan Plateau; human influences on argali may be very different in 10 years from what we see today.

That said, it appears that increasingly intensive livestock grazing -typically in areas valued by argali- threatens to exacerbate the species' refugee-like status. Argali appear to tolerate close proximity only of domestic camels; all other human disturbance elicits a similar response, i.e., finding elsewhere to graze, rest, and avoid predators. As highways, mines, and tourist facilities increase on the Plateau, these argali will find that fewer and fewer of these 'elsewheres' provide for their life-history needs.

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