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Help Fund Mongolian Argali/Ibex Research

With the support of Wild Sheep Foundation members and chapters as well as the Turner Foundation, Dr. Richard Harris and colleagues conducted critical research on Mongolian ungulates (argali and ibex) in the fall of 2009. Dr. Harris' comprehensive research report is included below.

WSF wishes to thank the following donors to this important international wild sheep and goat research (in order of donation received to date.)

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Thank you!

2009 National Assessment of Mountain Ungulates in Mongolia

Report to
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Mongolian Academy of Sciences
Mongolian Ministry of Nature, Environment, and Tourism
Worldwide Fund for Nature – Mongolia

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Argali males. Photo by Tony Ernst

Ibex females. Photo by Tony Ernst

2009 National Assessment of Mountain Ungulates in Mongolia

Executive Summary

As part of a comprehensive assessment of the population status and conservation program for argali (*Ovis ammon*) and ibex (*Capra sibirica*) in Mongolia, a nationwide survey was conducted in October, 2009. Organized by the Ministry of Nature, Environment, and Tourism, the Academy of Science's Institute of Biology, and WWF-Mongolia, the survey also involved training and oversight from US-based wildlife scientists.

After 2 training and organization workshops (the first held in late March 2009, the second just prior to field work in late September 2009), eleven separate field teams spent from 6 to 21 days each in 12 aimags (provinces) of Mongolia. The teams' objectives were to update our understanding of the distribution of argali and ibex in their respective aimags, collect indirect information on the status of these animals by interviewing local officials and rangers, and conduct field surveys via walking, horseback, or vehicle in pre-selected sample areas.

To reduce possible bias, areas previously mapped as containing argali (argali distribution units, ADUs) were prioritized for survey using a randomization scheme that favored larger over smaller areas (but was otherwise objective with regard to habitat conditions, previous knowledge of animal density, and ease of access). Within each ADU, field teams most often pre-selected fixed vantage points from which to view the surrounding terrain, using maps produced from satellite-imagery (1:40,000 or 1:50,000 scale). In cases where obtaining an objective sample of terrain within the ADU was impossible, teams attempted to maximize the number of animals seen. All teams used GPS units to document their own observation locations; most teams also mapped locations of animal groups observed and recorded subsidiary information related to detection probability; some teams additionally recorded radial (i.e., straight-line) distances between their observation points and animal groups. Subsequent to field work, we used viewshed analysis in a GIS context to estimate the area effectively surveyed by each team.

Where appropriate, we used distance sampling, treating observation points as point transects, to estimate the density of argali and ibex. We estimated abundance on an aimag basis, using the cumulative area of ADUs in each aimag as an expansion factor. Where distance methods were inappropriate but sampling was sufficiently objective, we used the estimates of effectively surveyed area as a sampling fraction for extrapolation of raw (i.e., minimum) counts. Where field sampling appeared to be inappropriate as a basis for extrapolation, we treated counts as indices, and report only raw numbers.

Field teams sampled from a total of 134 argali distribution units within Mongolia, which we estimate occupied approximately 46,603 km^2 of the total 60,237 km^2 of previously mapped as occupied by argali. In addition to 20 line transects (of 10-20 km each), teams reported observing from 857 fixed points (Table 1).

Aimag	ADUs sampled	Line transects sampled	Point transects sampled	Mapped ADU in aimag (km^2)	ADU subject to survey (km^2)
Bayankhongor	12	0	50	3,561	4,393
Bayan-Ulgii	9	0	59	4,749	4,383
N. Dornogovb/GoviSumber (ex Ikh Nart)	unknown	2	0		unknown
S. Dornogobi	12		67	8,951	5,166
Dornogobi (Ikh Nart Nature Reserve)	1	12	0	331	331
Dundgovi	18	6	90	4,439	4,258
Gobi-Altai	15	0	72	12,162	10,440
Khovd	11	0	51	8,370	6,296
Umnu-gobi	23	0	194	8,743	7,067
Uvurkhangai	1	0	41	3,894	1,522
Tuv	22	0	75	1,401	1,200
Uvs	5	0	23	2,247	1,547
Zavkhan	5	0	135	1,389	unknown
Total	**134**	**20**	**857**	**60,237**	**46,603**

Table 1. Argali distribution units (ADUs, previously mapped by IOB) sampled, and number of line transects and fixed points from which observations of argali and ibex were made during the October 2009 survey of mountain ungulates in Mongolia. Also shown are the cumulative area of ADUS within each aimag, and the area of those surveyed.

Topography in mountainous areas makes estimating the amount of area effectively surveyed difficult. As well, the distance at which argali or ibex could be seen, even if the landscape was visible, varied depending on local conditions. We produced 4 different estimates of the amount of Mongolia effectively covered by the field teams, in each case using an underlying digital elevation base map (80m pixels), but varying our assumptions regarding the maximum observation distance, and whether or not viewsheds were constrained by argali distribution units (Table 2).

	Irrespective of ADU (km^2)		Within ADU (km^2)	
Aimag	Bounded 3K	Bounded 3K	Bounded 3K	Bounded 3K
Bayankhongor	776	1,948	550	1,148
Bayan-Ulgii	588	1,223	347	674
N. Dornogovb/GoviSumber (ex Ikh Nart)	-	-	-	-
S. Dornogobi	831	2,014	476	964
Dornogobi (Ikh Nart Nature Reserve)	-	-	-	-
Dundgovi	936	2,037	582	1,030
Gobi-Altai	771	1,904	396	834
Khovd	-	-	-	-
Umnu-gobi	1,340	3,228	832	1,941
Uvurkhangai	243	407	199	304
Tuv	798	1,683	391	705
Uvs	157	339	110	180
Zavkhan	586	1,093	36	61
Total	**6,839**	**15,224**	**3,128**	**6,023**

Table 2. Estimates of the area (expressed in km^2) actually visible to and surveyed by field teams during the October 2009 survey of mountain ungulates in Mongolia. First two columns are total area; second two columns are only area within previously mapped argali distribution units (ADUs). We assumed that observations could be made as far as 3 or 5 kilometers from each observation point.

Field teams directly observed a total of 385 groups of argali, totaling 3,373 individuals (Table 3). On the basis of extrapolation methods described above (and in more detail in the Methods section of the main report), our point estimate of argali is 19,701, with a lower 95% confidence limit of 9,193 and an upper 95% confidence limit of 43,135 (Table 3). However, post survey concerns about sampling in some aimags and estimates derived previously allowed adjustments that resulted in the best single estimate for argali in Mongolia being 17,903.

Argali					
	Observed directly		Abundance estimate		
Aimag	Groups	Animals	Point estimate	Lower 95% CL	Upper 95% CL
Bayankhongor	15	143	572	444	927
Bayan-Ulgii	41	505	2,123	931	3,761
Dornogobi	156	841	2,913	1,361	4,967
Dundgovi	46	294	4,812 2,338	1,505	15,408
Gobi-Altai	16	81	3,904[a] 1,556[b]	1,666	9,158
Khovd	9	341	341[c] 2,311[b]	341	341
Umnu-gobi	17	102	2,404	1,198	4,852
Uvurkhangai	39	310	1,756	1,160	2,368
Tuv	19	142	834	417	1,664
Uvs	19	591	591[c] 1,033[b]	591	591
Zavkhan	8	23	23	23	23
Total	**385**	**3,373**	**19,701[d]** **17,903[b]**	**9,193**	**43,135**

Table 3. Argali observed directly, and population estimates, October 2009, Mongolia

[a] Estimate derived from methods as reported, which was later judged to be an overestimate because of unrepresentative sampling

[b] Adjusted estimate by Institute of Biology, Ulaanbaatar

[c] Raw count only, and thus not a true reflection of aimag abundance

[d] Using aimag totals as in footnotes a and c, above.

Field teams directly observed a total of 161 groups of ibex, totaling 2,537 individuals (Table 4). On the basis of extrapolation methods described above (and in more detail in the Methods section of the main report), our point estimate of ibex is 24,371 with a lower 95% confidence limit of 13,840 and an upper 95% confidence limit of 43,873 (Table 4). This should not be understood as a nationwide estimate, however. The total number of ibex in Mongolia is almost certainly higher than this.

Ibex					
	Observed directly		Abundance estimate		
Aimag	Groups	Animals	Point estimate	Lower 95% CL	Upper 95% CL
Bayankhongor	3	37	148	115	240
Bayan-Ulgii	15	249	1,524	724	2,550
Dornogobi	-	-	-	-	-
Dundgovi	14	75	2,814	1,278	6,179
Gobi-Altai	32	314	4,913	2,372	10,180
Khovd	35	1547	1,547	1,547	1,547
Umnu-gobi	57	204	13,324	7,671	23,169
Uvurkhangai	-	-	-	-	-
Tuv	1	11	11	11	11
Uvs	1	78	78	78	78
Zavkhan	3	22	22	22	22
Total	**161**	**2,537**	**24,382**	**13,818**	**43,976**

Table 4. Ibex observed directly, and population estimates, October 2009, Mongolia

We estimate that ibex outnumbered argali within Mongolia, despite having recorded fewer of them directly, because i) where we had reliable methods of estimating it, density of ibex generally exceeded density of argali, and ii) we prioritized searching for ibex within previously mapped argali distribution units. Many of these also contained ibex (although some evidently did not), but ibex were also distributed in many mountain areas of Mongolia that did not contain argali as of 2009. The survey contributed to the mapping of ibex distribution areas within Mongolia, but additional areas with ibex probably existed and were not surveyed.

The total number of argali in Mongolia may exceed our estimates slightly, because we could only report raw numbers observed for some aimags. Confidence intervals for both species were broad, however, reminding us that, even with a survey with as much effort and intensity as this one, estimates of wildlife abundance over such a large area are usually imprecise.

Despite that imprecision and uncertainty, we believe these survey results represent the best available information on abundance of these two mountain ungulates in Mongolia, and that they can be useful in management planning. Unsurprisingly, our estimates for argali on an aimag basis differ from those of the previous nationwide survey

(IOB 2001); direct comparisons are difficult because the previous survey report lacked details regarding areas visited, field methods, and analytical methods. Apparent increases or decreases in each aimag may be real, or may have been caused by differences in methods.

The survey documented threats and general conditions both species face. In general, threats and conservation challenges were greater for argali than for ibex. Field teams reported that poaching was minor or absent from most areas surveyed. However, possible biases in reporting this (most poaching was not observed directly, but rather inferred from interviews) must be born in mind. Mining activity with potential to affect argali and ibex was reported from some areas; livestock was present in almost all areas, with its intensity variously categorized as light to heavy. Interpreting threats to argali from this survey should consider that field teams prioritized spending time in areas already known to contain argali. It is possible that human factors have combined to reduce this area of distribution from earlier levels. Some field teams documented a loss of argali completely from areas that we had assumed contained them as of autumn 2009.

Most field teams reported that drought conditions over the previous year or two had influenced both wildlife and domestic livestock. Most field teams reported relatively low numbers of lambs and yearlings, and low numbers of males relative to the number of females. These are causes for concern, but we urge caution in interpretation. Management actions that prioritize conservation of argali and ibex while simultaneously allowing for local livelihoods are best made on a local scale. We suggest that future monitoring efforts take the form of local scale monitoring, with training and oversight from the national level.

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This report represents the combined work of many people: field participants, office staff, GIS specialists, and others. Apologies to any who should be acknowledged here but are not.

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Abbreviations Used in Document

ADU – argali distribution unit
ETM – Enhanced Thematic Mapper
GPS – Global Positioning System
IOB – Institute of Biology, Mongolian Academy of Sciences
MAS – Mongolian Academy of Sciences
UTM – Universal Transverse Mercator
WWF-Mongolia – Worldwide Fund for Nature, Mongolia

Note: For consistency, English spelling of place names follows those in the Oxford Monsudar English Mongolian/Mongolian English Pocket Dictionary (2008), page 860).

1. Introduction

Mongolia is a country whose wildlife heritage is not merely an important part of its economy and of people's livelihood. In Mongolia, wildlife helps define the place and the people. Mongolians identify themselves, in large measure, by their connection with wide open spaces and wild animals.

The majestic giant Asian sheep, the argali (*Ovis ammon*), and the lithe and graceful Asian mountain goat, the ibex (*Capra sibirica*) are two of Mongolia's most iconic and valuable species of wildlife. Although both species also live in China and the remaining central Asian countries, Mongolia is among the most important countries for both, and both are among Mongolia's most treasured assets. (Despite the many other languages spoken in countries that harbor argali, the name itself is of Mongolian origin).

Despite this, conserving these 2 mountain ungulates is no easier in Mongolia than in the rest of central Asia. The country faces the tremendous challenges of developing elevating the economic status of its roughly 3 million citizens, while ensuring that large mammals which require vast expanses of the landscape for themselves can also survive. As in other central Asian countries, wildlife management is not yet at the level of technical expertise, public appreciation, or funding seen in European or North American countries. Add to this the inherent difficulties of understanding the population status of species that inhabit remote and difficult landscapes in a country with poor transportation infrastructure, and it is no surprise that our understanding of the status of these animals remains poor.

As part of an overall initiative to improve conservation and management of mountain ungulates[1] the Ministry of Nature, Environment, and Tourism made a formal request in spring 2009 that the Mongolian Academy of Science's Institute of Biology IOB), acting cooperatively with non-governmental organizations and outside experts as it saw fit, organize and implement a nationwide status assessment of argali and ibex. This report forms part of that overall assessment. It details the efforts made, and the results of, quantitative surveys of abundance of argali and ibex, as well as qualitative descriptions of threats facing them throughout the country.

[1] see http://www.panda.org/who_we_are/wwf_offices/mongolia/aboutmongolia/wildlife/wild_sheep/

Because they live in varying ecosystems, from low elevation Gobi deserts to the sedge meadows bordering the highest peaks of the Kunlun, Tianshan, and Pamir Mountains, argali vary in outward appearance, morphology, and to some degree, in genetic constitution. Numerous classifications of argali exist, most dividing the species into various subspecies, but there is as yet no overall consensus on argali taxonomy. The most commonly accepted sources (Geist 1991, Shackleton 1997, IUCN 2008) recognize a difference between the Gobi argali (*O. a. darwini*), and the Altai argali (*O. a. ammon*). However, there is not consensus on exactly what differentiates them, and where the dividing line between them may be. Work by Tserenbata et al. (2004) cast doubt on whether differences between desert and Altai argali were sufficiently marked geographically to justify considering the 2 separate subspecies. Many hunting groups also recognize the existence of a separate, intermediate type of argali in the Khangai Mountains.

Prior to 2001, no rigorous, nationwide population estimates existed for Mongolia. Prior to the transformation of Mongolian society in the late 1980s, the Mongolian Academy of Sciences had conducted a few country-wide surveys; however, methods used did not permit accurate population estimation. These surveys yielded round number estimates (lacking measures of precision) of 40,000 in 1970, 50,000 in 1975, 60,000 in 1985 (Dulamtseren 1970, Luschekina 1994, Amgalanbaatar et al. 2002b, Zahler et al. 2004, Clark et al. 2006, Mongolian Academy of Sciences, unpubl. data). Reading et al. 1997 suggested that no more than 20,000 argali inhabited Mongolia in 1994.

In 2001, the Mongolian Academy of Sciences sponsored a nationwide survey of argali, the in many ways constituted to fore-runner of the current effort. The 2001 survey concluded “that 13,000 – 15,000 argali are inhabiting 47,898 km2 territory of Mongolia”. However, it is difficult to gauge the accuracy of these figures given the methods and data provided. The 2001 report (IOB 2001) included very little detail on survey or analytical methods, nor on how various counts forming the raw data were treated.

That said, on the basis of regional distribution data, conventional wisdom during the past 10-20 years has been that argali have been declining in western and central Mongolia, but expanding in eastern Mongolia. Argali populations in southern Mongolia appear to be relatively stable.

Argali are difficult to conserve, on the whole, because they are adapted to exploiting much the same habitat niche as valued by humans who depend on livestock. Argali may be subject to both scramble (forage) competition, and to interference (displacement) competition by livestock. They are also displaced by industrial activity. It is likely that argali are sensitive to disturbance because they are so finely attuned to maximizing distance between themselves and their primary predator, the wolf (*Canis lupus*). Argali are occasionally taken by snow leopards (*Uncia uncia*), and lambs are subject to predation by eagles (*Aquila* spp.) and other birds of prey. Argali also suffer the misfortune of tending to prefer low elevation pastures in winter and having extremely tasty flesh, leading to various levels of poaching pressure (Zahler et al. 2004).

The Mongolian Red Data Book 1987 (Shagdarsuren et al. 1987) estimated a total of 80,000 ibex in Mongolia in the mid-1980s (Fedosenko and Blank 2001). Mallon et al. (1997) stated that ibex numbers declined since that peak estimate of 80,000 due to exploitation, habitat degradation and competition for resources. Despite Mallon et al.'s (1997) assertions, the Mongolian Academy of Sciences again estimated that 80,000 inhabited Mongolia in 2002. However, the MAS 2002 estimate may have been biased if researchers surveyed very few areas, selected survey locations with the highest reported ibex densities based on information from local people, and extrapolated their data to regions for which they had little to no data for the existence of ibex. Still, relatively large numbers of ibex likely persist in Mongolia.

IOB (2001) did not provide data on the geographic distribution or abundance of ibex. Although it is likely that ibex persist in more locations than argali, they may be even more difficult to count, because the terrain they inhabit tends to be even less hospitable to human investigators, and because their smaller size can make them more difficult to see. Ibex are subject to largely the same conservation difficulties facing argali, although they tend to be considerably less sensitive to human disturbance (and livestock presence in particular) than argali. Their use of steep escape terrain makes it very difficult for wolves to successfully attack them; their primary predators are snow leopards and, when young, eagles.

Argali are protected as "Rare" under the 2001 revision (Mongolian Government Act No. 264) of the 2000 Mongolian Law on Animals. General hunting of argali has been prohibited since 1953. Argali are included in Appendix II of CITES, with an export quota of 80 hunting trophies with horns and 44 skins and horns in 2005. Altai argali (*O. a. ammon*) were listed as Rare" in both the 1987 and 1997 Mongolian Red Books, and the species was upgraded to "Endangered" in Mongolia in the most recent nationwide assessment (Clark et al. 2006). Approximately 14% of the species' range in Mongolia occurs within federal protected areas, including Altai Taivan Bogd National Conservation Park (NCP), Gobi Gurvan Saikhan NCP, Great Gobi Strictly Protected Area (SPA) sections A and B, Ikh Nart NR, Khokh Serkh SPA, Khoredal Saridag SPA, Khustai Nuruu NCP, Myangan Ugalzat Nature Reserve (NR), Sielkhem Uul NCP, Tsagaan Shuvuut SPA, Tsambagarav Uul NCP, and Turgen Uul SPA (Amgalanbaatar et al. 2002b). Small populations likely occur in other federal and provincial (aimag) or county (soum) protected areas as well.

Although protected from general hunting, trophy hunters can purchase licenses for argali. Under the Mongolian Hunting Fee Law of 1995, revenue generated from argali trophy hunting is divided among the federal government's general funds (70%), the local province (20%), and the hunting organization (10%); specifically, US$ 18,000 for *O. a. ammon* trophies and US$ 9,000 for *O. a. darwini* trophies is allocated to local and federal governments. Mongolia's argali hunting program has been assessed as failing to meet its objectives of providing incentives for conservation ((Amgalanbaatar et al. 2002a).

Ibex in Mongolia is legally protected as a rare species under the Mongolian Law on Fauna and the Mongolian Hunting Law. No general hunting is allowed, but a limited amount of licensed trophy hunting is permitted. The species is listed as Near-Threatened in most recent Mongolian Red List (Clark et al. 2006), which represents an upgrade in status from the last 2 Mongolian Red Books. Approximately 14% of the species' range is protected (Clark et al. 2006) and it occurs in at least the following protected areas: Altai-Taivan Bogd, Bodgkhan Mountains, Eej Khairkhan Mountain, Great Gobi, Gobi Gurvan Saikhan, Ikh Nart, Khangai Nuruu, Khar-Uvs Lake, Khokh Serkh Mountain, Khovsgol Lake, Otgontenger Mountain, Sharga Natural Reserve, Silkhem Mountain, Tarvagatai Mountain, Tsambagarav, Uvs Lake, and Yoliin Valley. Khokh Serkh Nature Reserve in the Altai region was established specifically for the conservation of this species.

2. Objectives

The goal of this survey was to provide reliable quantitative information on the status of argali and ibex throughout their natural ranges in Mongolia. This goal was seen as part of a larger assessment of the status and management of these species being produced by the Ministry of Nature, Environment, and Tourism of Mongolia.

Specifically, objectives the survey were to:

1. Verify, confirm, and update existing maps of argali distribution in each aimag;

2. Develop estimates of abundance for argali within each aimag;

3. Report on factors presumed to be relevant to the status of argali in each of their distribution areas. These included the presence and relative density of livestock, the presence and intensity of industrial activity such as mining, and the presence and magnitude of poaching;

4. Document other species of terrestrial vertebrate wildlife of interest.

For ibex, objectives were similar, except that i) greater emphasis was placed on developing better maps than existed for ibex distribution, so that future abundance estimates could be produced based on this estimated area of occupancy, and ii) less emphasis was placed on developing a Mongolia-wide abundance estimate, because we lacked a map of ibex distribution, and thus had no objective basis for extrapolating from the number of ibex seen to larger areas.

3. General Methods

3. A. Preparation of argali distribution maps in each aimag

For a number of years prior to this survey effort, biologists with IOB have worked with staff of protected areas, nature rangers, government staffs, and others with knowledge of wildlife distribution at the local levels, to provide maps showing the distribution of argali within each aimag. This resulted in a national map of argali distribution, such as the one reproduced in Zakharenka (2008). Estimated boundaries of argali presence were hand-drawn on Mongolian 1:500,000 scale topographic maps, and were subsequently digitized and stored as shape files in ArcGIS. In March 2009, IOB requested aimag representatives to update these maps. Updated maps were received from most, although not all, aimags prior to design of this survey. These formed the basis of sampling regimes and for extrapolation of densities to unsampled areas in each aimag surveyed. We termed this geographic area Argali Distribution Units (ADUs).

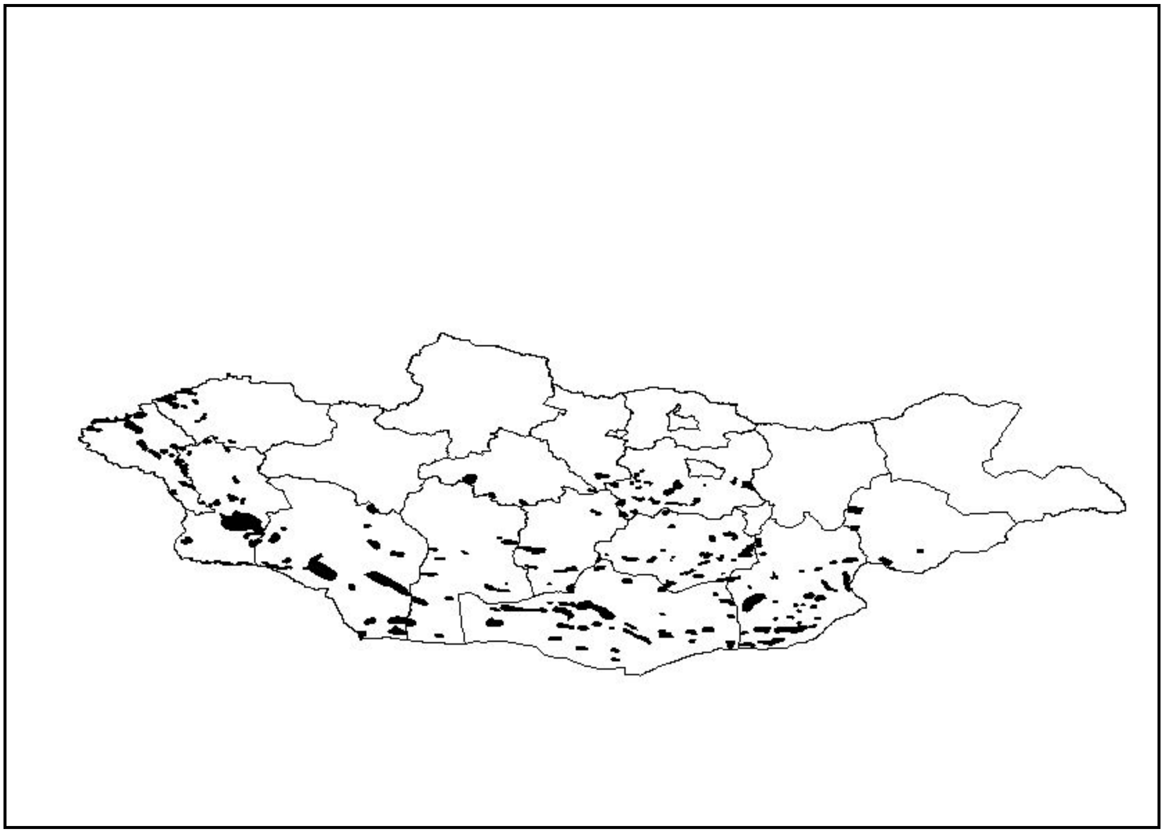

Figure 1. Mongolia, showing argali distribution units (ADUs, shaded polygons), as mapped prior to the October 2001 national assessment of mountain ungulates. ADUs for Zavkhan are missing.

3. B. Training

With principal funding from the Wild Sheep Foundation (WSF) of the US (formerly the Foundation for North American Wild Sheep, FNAWS), and subsidiary funding from the Denver Zoological Foundation (DZF) Dr. Rich Harris and Ganchimeg Wingard provided 2 days of training on technical, statistical, and field issues surrounding estimating population size of mountain ungulates in late March 2009 (Harris 2009). Topics covered included the history of wildlife population estimation, the general impossibility of counting all the animals in any give area, basics of sampling, the importance of mapping and documenting observations. Also covered were basic issues surrounding probability of detection, and classes of methods that exist to deal with imperfect detectability (e.g., distance sampling, mark-recapture, and the application of mark-recapture by using multiple observers and mapped animals).

During September 16-17, 2009, an refresher of this overview training was provided to the field teams, as well as training on field equipment (GPS, compasses, range-finders, and spotting scopes), introduction to the data forms, additional details on field methods, and instruction on using 1:40,000 and 1:50,000 scale satellite imagery maps. Each team was provided with an instruction sheet giving the priority order of ADUs to survey within their aimag (see section 3.D., below), and spent time with the technical advisors reviewing maps.

3. C. Teams for aimags

IOB staff made the decision early on to limit survey efforts to those aimags thought to contain sizeable populations of argali. Thus, the decision was taken to omit surveys in Sukhbaatar, Khentii and Khuvsgul aimags entirely. IOB (2001) reported an estimated 200 argali in Khentii aimag and 63 argali in Khuvsgul aimag during the previous survey; no quantitative estimate was made for Sukhbaatar. IOB staff also made the decision to combine survey work for the aimags of Arkhangai with that in Uvurkhangai, and that of Gobi-Sumber aimag with Dornogobi aimags. Team membership is detailed in Appendix A.

3. D. Selection of ADUs for sampling

Mapping of ADUs as of September 2009 suggested that there were approximately 200 ADUs that might potentially be visited. It seemed unlikely that even a relatively-well funded and intensive effort would succeed in thoroughly sampling from every single ADU. With less than 100% sampling, a potential danger was that ADUs could be selected for sampling based on *a priori* knowledge of argali density or distribution within them. If, for example, field team – knowing they had neither time or resources to visit every ADU within their aimag – preferentially selected for sampling ADUs known or suspected to have high argali density or accessible argali populations, any resulting extrapolation would have been biased positively. Thus, we developed a series of simple, Excel-based randomizations of all ADUS within each aimag for sampling, which provided a prioritization based on objective criteria rather than on *a priori* knowledge of argali density or ease of travel.

In no case were IOB of other field staff able to provide data useful for stratifying ADUs based on approximate density or other ecological factors. Thus, all ADUs within each aimag were treated equally, and were prioritized for sampling based on area. To do this, we obtained the area of each ADU (either from their polygon sizes as documented in the IOB Arc/GIS database, or, when that was lacking, through approximation based on the overlays of each polygon on the 1:40,000 scale maps), and from these, the proportion of the total argali distribution within the aimag of each was calculated. We then used a routine (in Excel) to randomly select each ADU in order, but with probability proportional to relative size of the ADU. Thus, for example, an ADU of size 1,000 km^2 was 5 times more likely than one of size 200 km^2 to be ranked 1st among candidate ADUs for sampling (but this ordering was not guaranteed due to the random selection). Within each aimag then, ADUs were prioritized for sampling by this random procedure, in a way that biased their ranking by their relative size. Field teams were then instructed to sample from as many ADUs within their aimag as could reasonably and thoroughly be visited following this prioritization scheme. This scheme made it unlikely that teams would selectively visit only ADUs known (or suspected) to have particularly high or low densities of argali or ibex, or have easier (or more difficult) access.

3. E. Maps

For the 4 western aimags of Bayan-Ulgii, Khovd, Uvs, and Gobi-Altai, we produced satellite imagery maps at the 1:40,000 scale which covered all known argali distribution units (ADUs, plus a variable geographic buffer surrounding each). These images derived from publicly available Enhanced Thematic Mapper (ETM) imagery, obtained during summer seasons (on various days with minimal cloud cover) during summer 2000-2002 (depending on cloud cover). Topographic contours at 200 m derived from Shuttle Radar Topography Mission elevation data set were added, as were ADU boundaries, aimag boundaries, and major river courses (provided by IOB). Color paper copies of these were produced for Bayan-Ulgii, Khovd, and Uvs. Gray-scale paper copies were produced for Gobi-Altai. We used data already collected by IOB to overlay roads, major water courses, and polygons representing known argali distribution units. (Electronic copies of all resulting 1:40,000 satellite maps were stored by IOB).

For the remaining aimags, we made use of satellite imagery maps at the scale of 1:50,000 earlier produced by WWF-Mongolia. Paper copies of these maps, separated by aimag, were provided to each aimag team leader.

3. F. Approaches to dealing with imperfect detectability

Even with increased intensity of sampling from within a reduced set of ADUs, we assumed that the probability of detecting any given animal group would be < 1.0. During training sessions, field teams were instructed on the 2 approaches that might be used in any given situation to account for imperfect detectability in the absence of marked animals, distance methods, and multiple-observer mapping methods (using mark-recapture).

Distance sampling (Buckland et al. 1993) using line transects, can be used when randomly placed transects can feasibly by surveyed and points from which large areas can be surveyed are not available (e.g., gentle mountain ranges in the Gobi). In distance sampling from line transects, radial distances between observers and animal groups would be estimated (either using a range-finder if available, or estimated by eye- if not), and straight-line distances would later be calculated (using angles and trigonometry). Some team members believed they might be able to walk randomly or systematically placed transects through some of the ADUs in their aimag. Four IOB biologists had recently participated in an intensive workshop on distance sampling sponsored by the Wildlife Conservation Society in Missoula, Montana, USA in February 2009, and thus were familiar with the method.

Where line transects are not feasible but vantage points can be identified which allow observation of large areas, two alternatives are possible: 1) Distance sampling using point transects rather than line transects, and 2) Observations made by multiple, independent observers who use maps to identify animal groups as “marked” and “recapture” (i.e., if seen independently by another team member), and using Huggins closed-capture modeling (White 2008) to estimate the number of animal groups never observed (e.g., Nichols et al. 2000, Forcey et al. 2006, Smith et al. 2006). In either case, observers were instructed to document their own locations when searching for animals using GPS units, and to map all animals seen on 1:40,000 or 1:50,000 maps. Documenting both observer and animal coordinates would allow estimation of radial distances (needed for point-transect distance sampling), and potentially modeling distance as a covariate in Huggins closed-capture modeling.

Field protocols also were that each observer documented their own best estimate of the size of each animal group (rather than simply documenting and reporting a single, consensus estimate), thus potentially allowing the use of an estimator developed by Walsh et al. (2009). We suggested that teams employing this latter approach use teams of 3 (possibly 4) observers who would independently count all animals (or animal groups) seen, and afterwards, agree which were seen by multiple observers (using maps). Additional factors likely related to the probability of observation would also be collected, allowing modeling of the detection probability.

In some circumstances, neither of these methods to estimate the probability of detection may be possible. In such cases, or if field teams found themselves irresistibly moving toward where they believed they would most like find argali (as opposed to sampling in an objective way, as required by the other 3 approaches), we would consider counts in these areas to be indices, understanding that there were almost certain to under-count the true number of animals, but that we would have no basis for correcting for imperfect detection.

Given the variety of terrain and logistic issues that would be faced by each team as it coped with the difficulties of surveying mountain ungulates in each ADU, we avoided specifying which of the four approaches to probability of detection would be appropriate in any given case (distance sampling using line transects, distance sampling using point transects, Huggins closed-capture modeling using mapped locations as "captures", or uncorrected (i.e., index) counts). Instead, teams were given enough background information that they could decide which would be most appropriate in any given situation. Teams were encouraged to sample in ways that would allow correcting for imperfect detectability (and extrapolation of numbers to unsampled areas), but were allowed to make their own choices. Teams were instructed to document their travel routes and the locations of all observed animals, using GPS units and satellite-based maps, under all conditions. Data sheets were provided for each eventuality (copies of data sheets reproduced in Appendix B).

In all cases where data allowed exploration of using the Huggins closed-capture approach, we found insufficient variability in capture history to justify treating imperfect detection using the multiple independent observer approach. Similarly, attempts to use the approach to correcting for undercounts of group size of Walsh et al. (2009) were unsatisfactory, suggesting only very modest increases in group size over the maximum recorded by any of the observers. Because we lacked an objective basis for assigning a value to the parameter α (which is needed for the Walsh et al. 2009 correction), we elected not to use this estimator, and instead to simply use the highest count recorded by the group as the best estimate of true group size. Thus, although data were collected to allow this alternate approach to correcting for imperfect detection, we were not able to use it.

3.G. Methods of extrapolation to unsampled areas

Subsequent to field work, we plotted the locations of all observation points (whether or not animals were seen at these points) as shape files in ArcGIS (ESRI, Inc.). To obtain an estimate of the total area effectively surveyed, we employed viewshed analysis, as implemented in ArcGIS V. 9.2., using digital elevation model (DEM) data from Shuttle Radar Topography Mission[2] (SRTM) as base layers to represent topography. Because Viewshed analyses report the total area that can be seen from a specified point regardless of distance, but ability to detect animal groups on distant mountain slopes can be expected to decline with distance, we selected 2 threshold distances to bound the areas assumed to have been effectively sampled, 3 and 5 km. The 3 km threshold was chosen as a reasonable distance within which most, but not all, animal groups would have been visible (if not occluded by terrain). Some animal groups closer than 3 km and not hidden by terrain, would probably have been missed by observers, but this characteristic was accounted for in cases where distance sampling was used (or deliberately ignored where counts were unadjusted). The 5 km threshold was deliberately chosen to be conservative, and no doubt included more area than was effectively surveyed. We also clipped each viewshed area by the mapped ADU, to restrict the area effectively surveyed to the area that was earlier mapped as having argali. However, because some argali were observed outside of the clipped areas, and all boundary distances were approximate, we

[2] http://www2.jpl.nasa.gov/srtm/cbanddataproducts.html

extrapolated apparent density by all 4 ratios of viewshed to total AUD area, and report the mean of these 4 as the single best estimate of abundance.

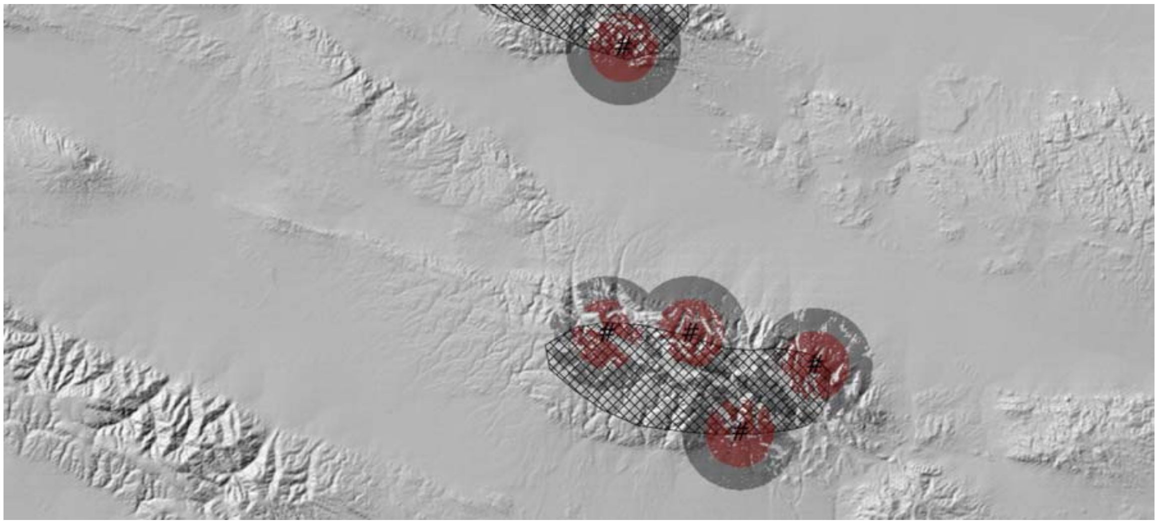

Figure 2 Example of viewshed analysis, showing observation location (#), 3 km buffer (blue), 5 km buffer (gray) and ADU (hatched). Note unshaded areas within buffer; these areas were unseen by observers and therefore not tallied as area observed

For aimags in which distance sampling provided reasonable estimate of density, we extrapolated density from sampled ADUs to unsampled ADUs. This was justifiable because i) ADUs were chosen for sampling by a randomization process, and ii) field teams that reported observations from fixed points made efforts to avoid biasing their point locations by prior knowledge of argali or ibex presence. Extrapolations were made of point estimates, as well as upper and lower 95% confidence intervals of density. In most cases, field teams were able to visit > 85% of mapped ADUs, so we did not further broaden confidence intervals by the standard binomial sampling formula.

For aimags in which distance sampling was not possible, we estimated aimag-wide numbers of argali and ibex by applying the proportion of the total area within that aimag's ADU effectively sampled (using the Viewshed analysis, above), applying both 3 and 5 km thresholds.

4. Specific methods for each aimag

Because each team faced unique field challenges and handled them differently, detailed methods are provided here separately for each aimag. Here (and in Section 5, Results), aimags are ordered geographically, approximately from west to east.

4. A. Bayan-Ulgii

Two teams, each consisting of 2-4 observers, surveyed for argali and ibex during the period October 12-18, 2009. Of the 11 ADUs previously identified in Bayan-Ulgii, the teams visited 9. The two ADUs not visited were identified as the lowest priority ADUs, based on the random sampling of ADUs within the aimag. Multiple observers were present at all observation points.

Locations of observers and all argali and ibex groups were mapped at the 1:40,000 scale on the satellite imagery maps. This allowed us to calculate approximate radial distances between observers and animal groups. We thus used point distance sampling, as applied in program DISTANCE 6.0, release 2 (Thomas et al. 2009) to estimate density of argali. Groups seen at > 1 point were assigned to the first point at which they were seen. We then removed points from sample that were < 3 km from another point, to avoid overestimating the search effort (points closer than this distance were considered not independent from one another). Multiple covariate distance analysis (using weather and seen prior as additional variables) added nothing to analysis, so conventional distance sampling was used.

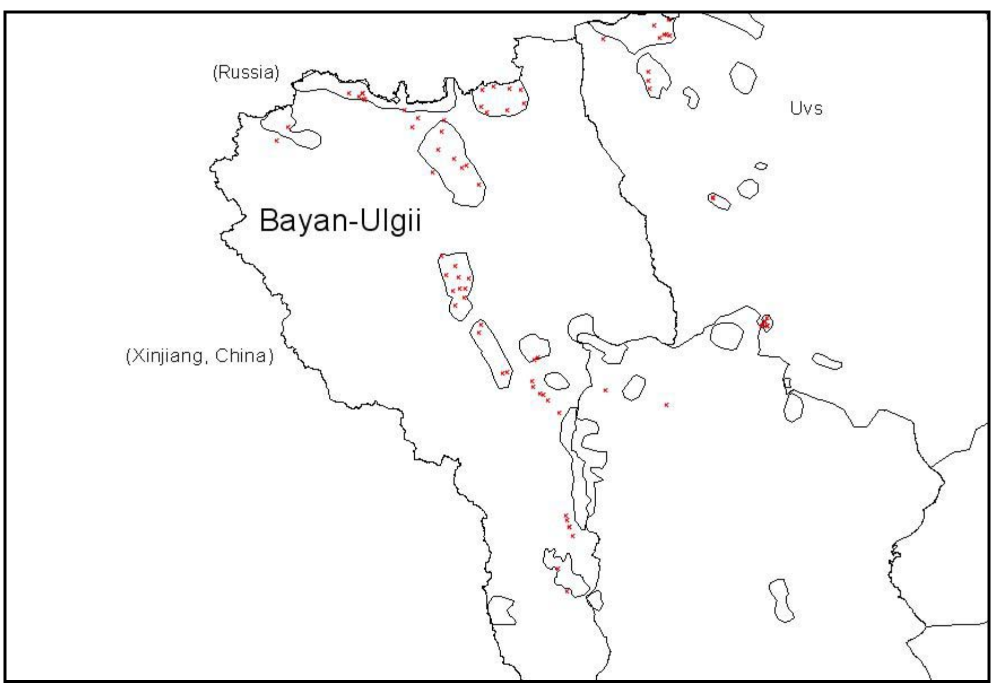

Figure 3. Bayan-Ulgii aimag, showing argali distribution units (open polygons) and fixed points from which observers searched for argali and ibex (red x marks).

Insufficient number of ibex observations (6) prevented using any known method to correct for imperfect detection. However, viewshed analyses allowed us to extrapolate the likely number of ibex, based on the proportion of ADU area within Bayan-Ulgii that was effectively sampled.

4. B. Uvs

One team, consisting of 3 observers, surveyed for argali and ibex and collected observations during the period October 15-20, 2009. IOB personal had earlier mapped 10 ADUs within Uvs, with a total area of approximately 2,247 km^2. The originally planned prioritization of ADUs to visit (to provide objectivity) could not be followed for weather and other reasons. Two of the high priority ADUs were dropped from the survey because local environmental officers (as well as local people) informed the team that argali no longer persisted in them. A total of 5 ADUs, with a total area of approximately 1,532 km^2 were visited.

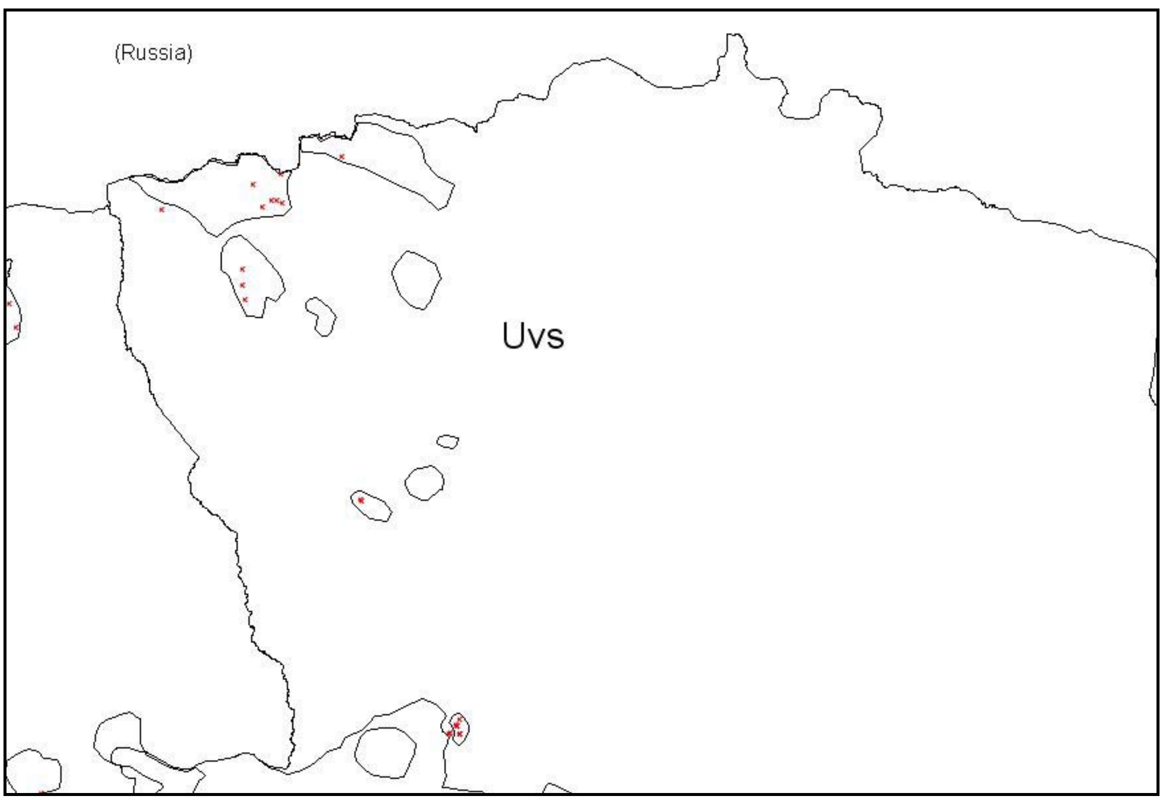

Figure 4. Uvs aimag, showing argali distribution units (open polygons) and fixed points from which observers searched for argali and ibex (red x marks).

4. C. Khovd

Two teams, each consisting of 2-4 observers, surveyed for argali and ibex during the period October 5-22, 2009. Of the 15 ADUs previously identified in Khovd, the teams visited 8. The 7 ADUs not visited were identified as the lowest priority ADUs, based on the random sampling of ADUs within the aimag. An additional 3 areas, which were not previously mapped and assumed not to contain argali, were surveyed for ibex. Multiple observers were present at all observation points.

Locations of observers and all argali and ibex groups were mapped at the 1:40,000 scale on the satellite imagery maps. Documentation did not allow for estimation of density using point transects.

4. D. Gobi-Altai

Two teams, each consisting of 2-4 observers, surveyed for argali and ibex during the period October 6-21, 2009. Of the 15 ADUs previously identified in Gobi-Altai, the teams visited 12; in addition, they visited 3 other areas that had not been previously mapped (primarily to search for ibex).

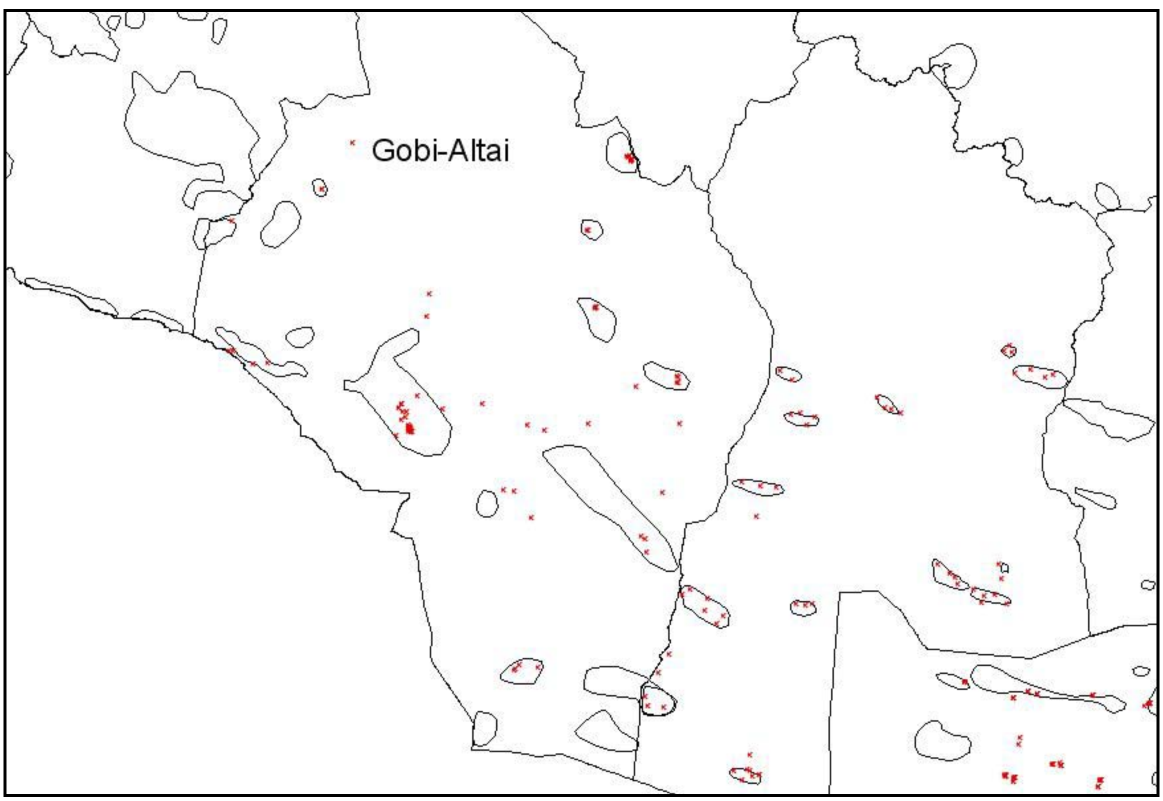

Figure 5 Gobi-Altai aimag, showing argali distribution units (open polygons) and fixed points from which observers searched for argali and ibex (red x marks).

Locations of observers and all argali and ibex groups were mapped at the 1:40,000 scale on the satellite imagery maps. This allowed us to calculate approximate radial distances between observers and animal groups. We thus used point distance sampling, as applied in program DISTANCE 6.0, release 2 (Thomas et al. 2009) to estimate density of argali and ibex. Groups seen at > 1 point were assigned to the first point at which they were seen. We then removed points from sample that were < 3 km from another point, to avoid overestimating the search effort (points closer than this distance were considered not independent from one another). Multiple covariate distance analysis (using weather and seen prior as additional variables) added nothing to analysis, so conventional distance sampling was used.

4. E. Zavkhan

Three teams, each consisting of 1-3 observers, surveyed for argali and ibex during the period October 7-16, 2009. Three officials from Protected Area Administration worked in Ikh Miyangan, on the east side of Otgontenger Mountain. Three officials from the Zavhkan Environmental Inspection office worked in the Shiluustei area. The IOB team, lead by Ya. Adiya worked in the direction of Yaruu Erdenehairhan. Observation points and sighting details were recorded.

Figure 6 Zavkhan, showing observation points (ADU boundaries unavailable).

4. F. Bayankhongor

One team, consisting of 3 observers, surveyed for argali and ibex and collected observations during the period October 14-25, 2009. Observers visited all 11 of the previously mapped ADUs in Bayankhongor, and added two additional areas, bringing to 13 the number of mapped ADUs. Observers made detailed documentation of each observation as well as noted locations were searching yielded no animals. However, neither radial distances, nor maps of observers and animal locations, were provided. Thus, we had no way to use Distance-based methods to account for imperfect detectability. However, viewshed analyses allowed us to extrapolate the likely number of argali, based on the proportion of ADU area within Bayankhongor that was effectively sampled.

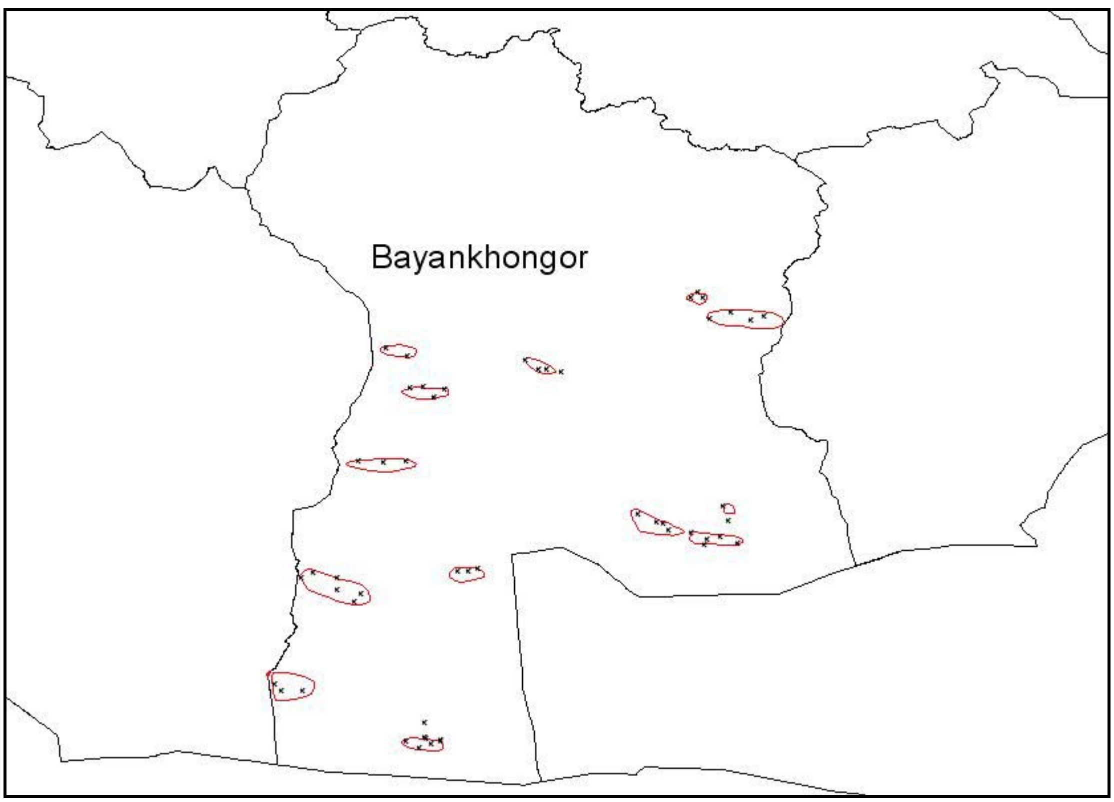

Figure 7. Bayankhongor aimag, showing argali distribution units (open polygons) and fixed points from which observers searched for argali and ibex

4. G. Uvurkhangai (and Arkhangai)

Three team, each consisting of 2-3 observers, surveyed the Oshig area of Uvurkhangai for argali during October 8-11, 2009. Local officials informed the survey team that all other ADUs within Uvurkhangai did not contain argali. The Oshig area was considered a seasonal concentration area because of the presence of water. Teams began each day together but split up during the day. Thus, multiple observations of most argali groups were recorded, but recording details did not allow use of the Huggins closed-capture model. Locations were not mapped in sufficient detail to estimate radial distances, thus point transect distance sampling was not feasible. However, viewshed analyses allowed us to extrapolate the likely number of ibex, based on the proportion of the Oshig ADU area within it that was effectively sampled.

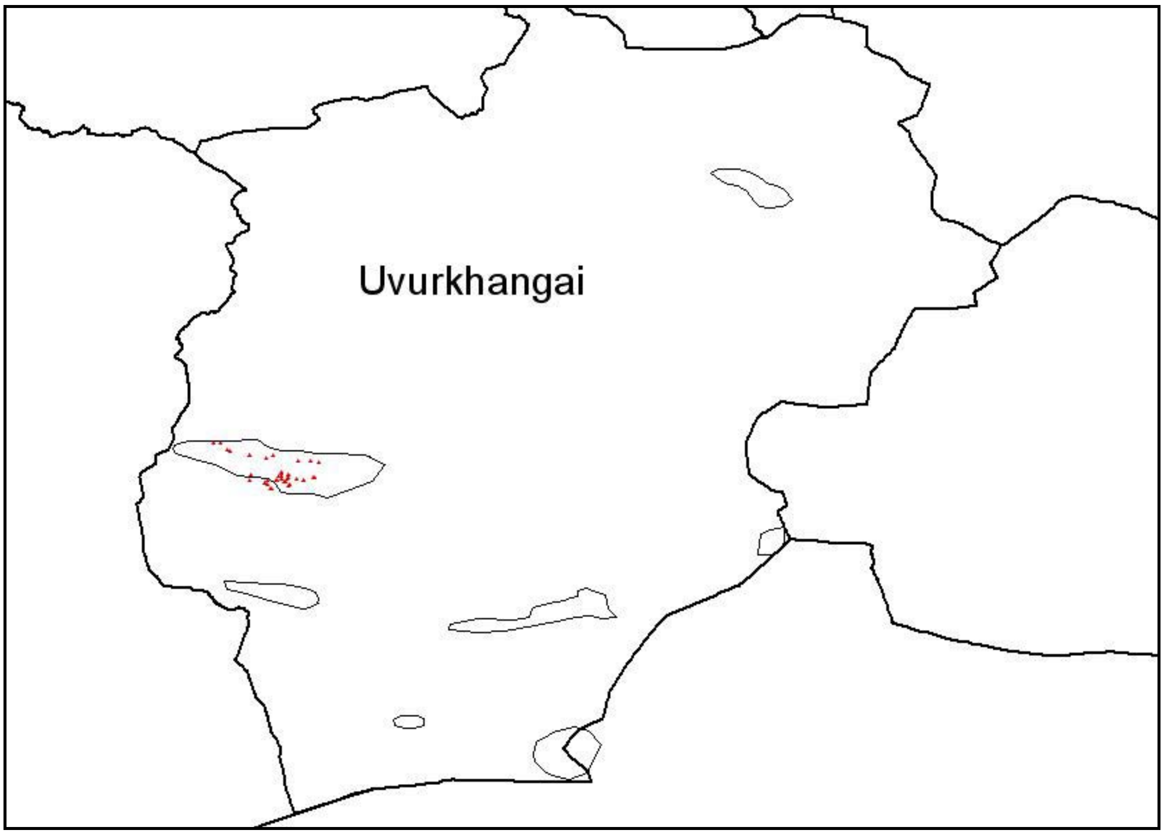

Figure 8 Uvurkhangai aimag, showing argali distribution units (open polygons) and fixed points from which observers searched for argali and ibex

4. H. Umnu-gobi

Two teams, each consisting of 2-4 observers, surveyed for argali and ibex during the period October 9-23, 2009. Of the 31 ADUs previously identified in Gobi-Altai, the teams visited 23; in addition, they visited 1 other area that had not been previously mapped (primarily to search for ibex).

Locations of observers and all argali and ibex groups were mapped at the 1:50,000 scale on the satellite imagery maps. This allowed us to calculate approximate radial distances between observers and animal groups. We thus used point distance sampling, as applied in program DISTANCE 6.0, release 2 (Thomas et al. 2009) to estimate density of argali and ibex. Groups seen at > 1 point were assigned to the first point at which they were seen. We then removed points from sample that were < 3 km from another point, to avoid overestimating the search effort (points closer than this distance were considered not independent from one another). Multiple covariate distance analysis (using weather and seen prior as additional variables) added nothing to analysis, so conventional distance sampling was used.

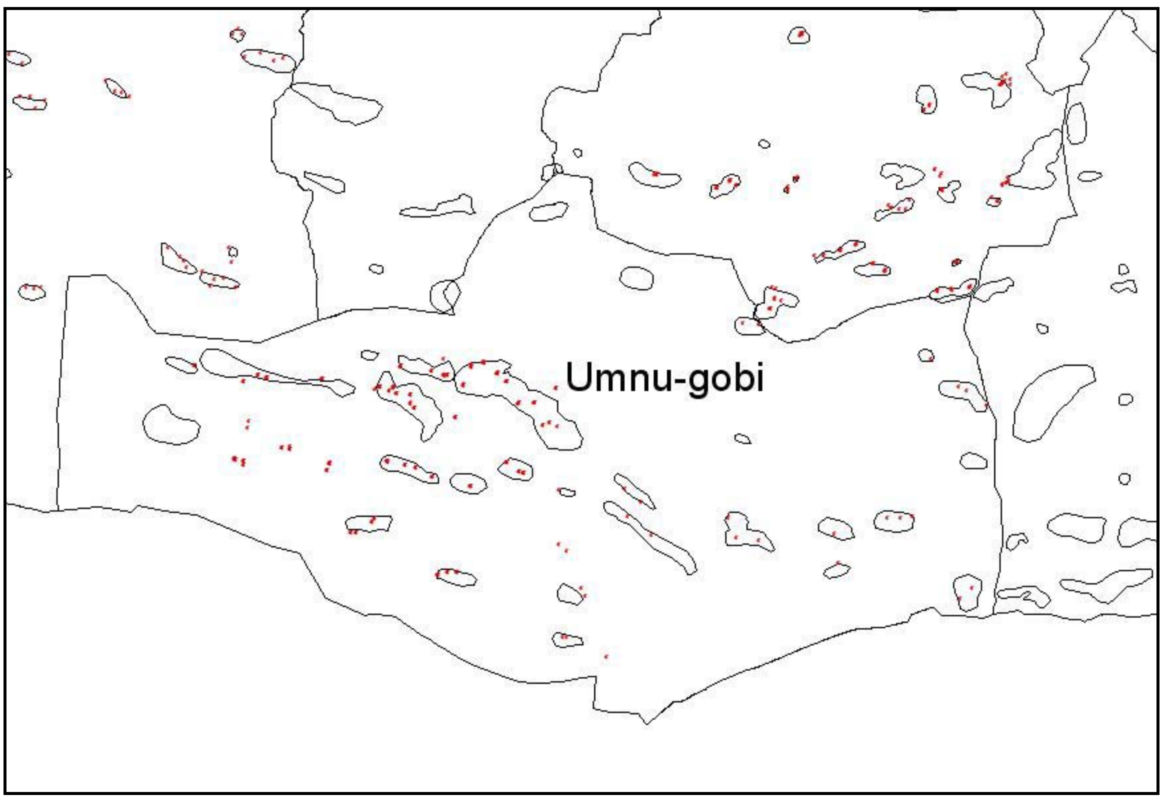

Figure 9 Umnu-gobi aimag, showing argali distribution units (open polygons) and fixed points from which observers searched for argali and ibex (red x marks).

4. I. Tuv

One teams consisting of 3 observers, surveyed for argali and ibex during the period October 10-18, 2009. Of the 24 ADUs previously identified in Bayan-Ulgii, the teams visited 21. The 3 ADUs not visited were identified as among the lowest priority ADUs, based on the random sampling of ADUs within the aimag.

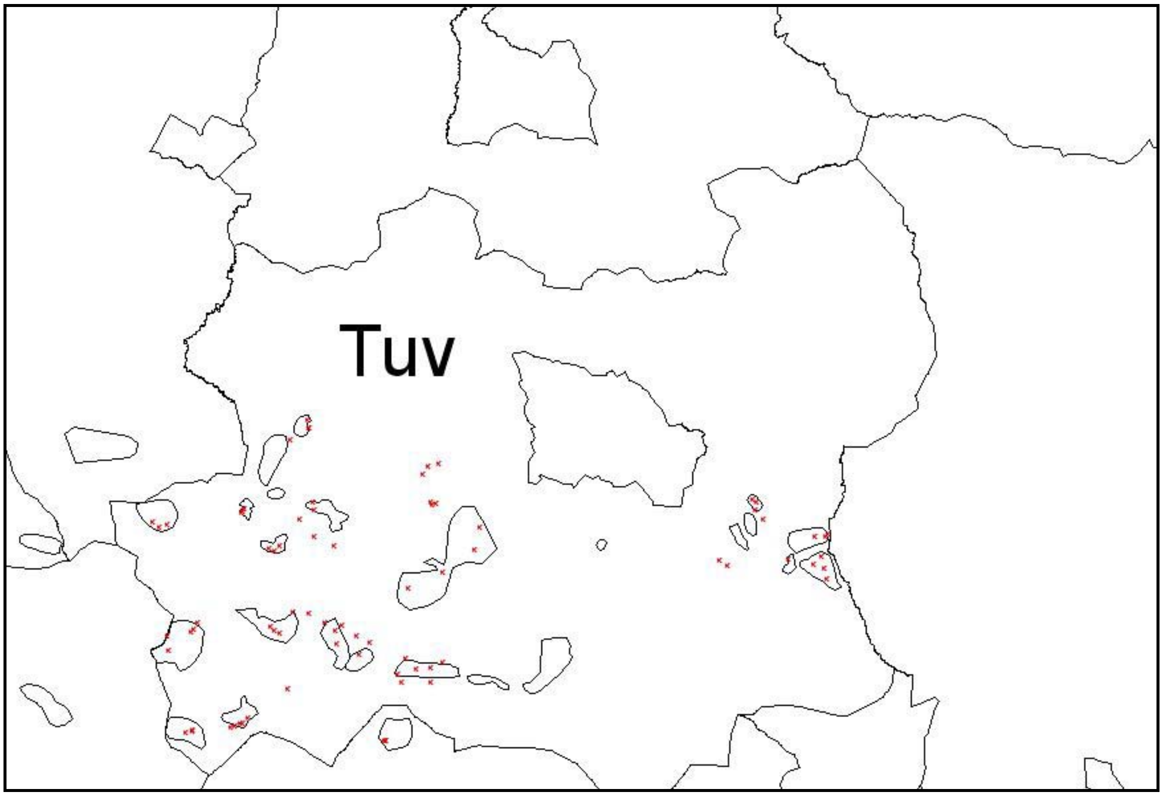

Figure 10 Tuv aimag, showing argali distribution units (open polygons) and fixed points from which observers searched for argali and ibex (red x marks).

Locations of observers and all argali and ibex groups were mapped only crudely,; however, radial distances between observers and animal groups were estimated using a Laser Range Finder (or, if distances were too great, without technical assistance). We thus used point distance sampling, as applied in program DISTANCE 6.0, release 2 (Thomas et al. 2009) to estimate density of argali. Groups seen at > 1 point were assigned to the first point at which they were seen. We then removed points from sample that were < 3 km from another point, to avoid overestimating the search effort (points closer than this distance were considered not independent from one another). Multiple covariate distance analysis (using weather and seen prior as additional variables) added nothing to analysis, so conventional distance sampling was used.

4. J. Dundgobi

One team consisting of 3-4 observers, surveyed for argali and ibex during the period October 7-20, 2009. Of the 21 ADUs previously identified in Dundgobi, the teams visited 18. The 3 ADUs not visited were identified as among the lowest priority ADUs, based on the random sampling of ADUs within the aimag.

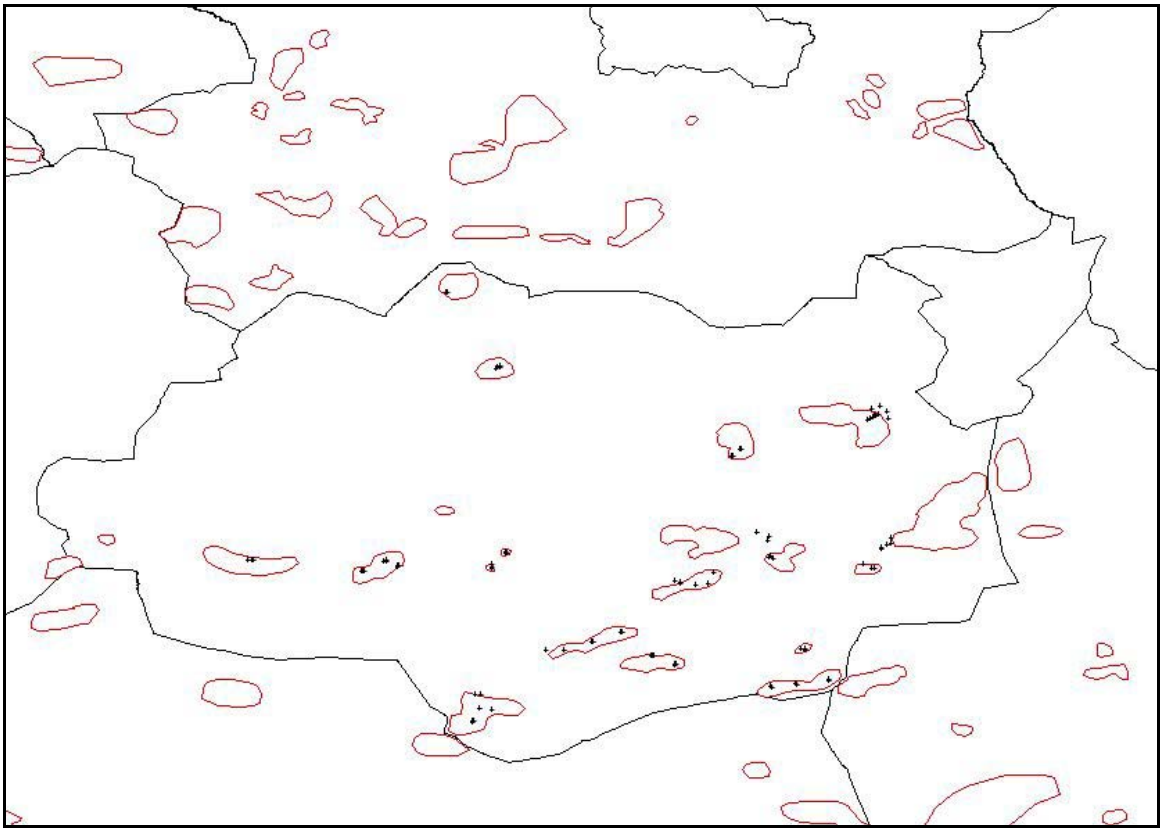

Figure 11. Dundgobi aimag, showing argali distribution units (open polygons) and fixed points from which observers searched for argali and ibex

Locations of observers and all argali and ibex groups were mapped at the 1:50,000 scale on the satellite imagery maps. This allowed us to calculate approximate radial distances between observers and animal groups. We thus used point distance sampling, as applied in program DISTANCE 6.0, release 2 (Thomas et al. 2009) to estimate density of argali and ibex. Groups seen at > 1 point were assigned to the first point at which they were seen. We then removed points from sample that were < 3 km from another point, to avoid overestimating the search effort (points closer than this distance were considered not independent from one another). Multiple covariate distance analysis (using weather and seen prior as additional variables) added nothing to analysis, so conventional distance sampling was used.

4. K. Dornogobi (and Gobi-Sumber)

Two separate teams took responsibility for mountain ungulate surveys in Dornogobi aimag (including the Choiriin region of adjacent Gobi-Sumber). Dornogobi aimag also contains the Ikh Nart Nature Reserve, where ecological studies of argali and ibex have been ongoing since 2000, with principal funding provided by the Denver Zoological Society (USA). The presence of radio-marked animals, as well as of a year-round study, supplemented occasionally by large teams of volunteers, allowed us to conduct a more rigorous population estimate in Ikh Nart than elsewhere in Mongolia. Thus, although constituting only a small part of the overall argali range (and not necessarily being representative in terms of habitat characteristics or conservation status), we treat Ikh Nart separately in this report. This not only allows us to examine methodology in greater detail there, but also provides some insight into issues of imperfect detection and extrapolation of numbers in other areas of Mongolia that did not have the benefit of an ongoing scientific study. Thus, we divide the analysis of mountain ungulates in Dornogobi aimag into 3 separate parts.

Raw data on number and types of animals seen are combined however, because the methods of observation probably had little effect on them, and because any ecological factors influencing these numbers were probably similar throughout the aimag.

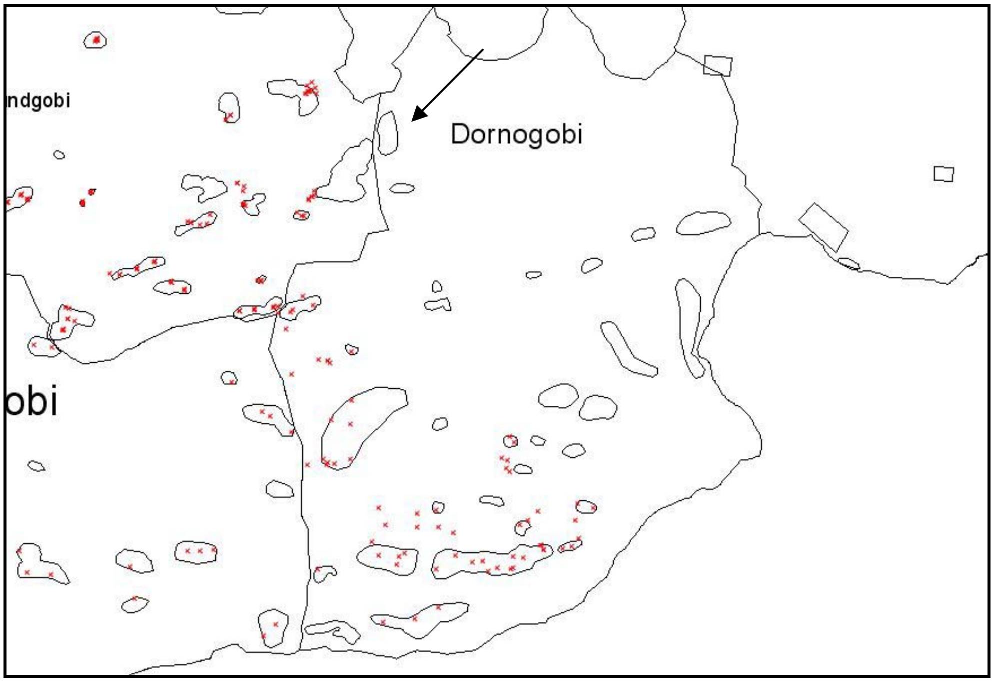

Figure 12. Dornogobi aimag showing locations of point observations within ADUs in southern portion of aimag (ADUs in northern portion were also surveyed but point locations were unavailable). Arrow indicates Ikk Nart Nature Resserve.

4 K.i. Southern Dornogobi. One small team surveyed (primarily by jeep) a number of small ADUs in Hovsgol, Hatanbulag and Mandah soums. Of 20 ADUs previously identified and mapped in southern Dornogobi, the field team visited 12. A few additional sites, not mapped, but suggested by local officials as worthy of survey, were also included. At each ADU, team members walked to high points and ridges, scanning the area and recording argali (or ibex) seen for 20 minutes.

Locations were not mapped in sufficient detail to estimate radial distances, thus point transect distance sampling was not feasible. However, viewshed analyses allowed us to extrapolate the likely number of ibex, based on the proportion of the Oshig ADU area within it that was effectively sampled.

4. K. ii. Northern Dornogobi. A small team surveyed (primarily by jeep) a number of small ADUs in northern Dornogobi, in Argaliin, Dorvolj, Khashaat, Khanginuu, Baga Bogd, Khonich, Argalant, Khar Uul, and Khetsuu areas (the latter is formally part of Ikh Nart Nature Reserve, but was not included in rigorous surveys done there, and thus is included here). Also surveyed was the Choiriin region of adjacent Gobi-Sumber aimag. No attempts were made to sample objectively in this portion of

Dornogobi, and recorded data did not allow any type of correction for imperfect detectability. Thus, raw counts only are reported from this area.

4. K. iii. Ikh Nart Nature Reserve

We conducted distances sampling on 12 ~ 10km-long transects. We also took advantage of the presence of 24 radio-collared animals to conduct mark-resight estimates on 2 separate occasions, which were analyzed together. See Appendix F for details.

5. Results

A. Bayan-Ulgii

5. A. 1. Argali in Bayan-Ulgii

Nine of the 11 ADUs identified in the aimag were visited; these nine represented approximately 92.3% of the 4,749 km^2 of argali distribution included in the mapped units. Observations were made from a total of 60 fixed observation points (varying from 3 to 10 per ADU). One of these was removed from the point distance sampling analysis to avoid over-estimating the actual observation effort, resulting in a total sample size of 59 points.

A total of 41 argali groups, consisting of 500 argali were seen. Argali were observed in 7 of the 9 ADUs surveyed. Argali groups varied in size from 2 to 76 animals ($\bar{x}$ = 12.5, SD = 13.8). Of 424 argali that could be identified, 291 were classified as adult ewes, 30 as adult rams, 93 as yearlings, and 10 as lambs. Field teams appeared to record yearling and lambs inconsistently, as many observations were made at long distances (> 2 km) and weather conditions also interfered, making these identifications uncertain.

Cluster size was not a significant factor, so mean cluster size was used in the analysis. We ran 3 different competing models of detection function (hazard rate key function with Hermite polynomial adjustments, hazard rate key function with a maximum of 2 cosine adjustments, half-normal key function with maximum of 2 cosine adjustments) and because AICc and goodness-of-fit statistics were similar among them, report the model averaged estimate here. The estimated detection radius was 2,627m, (SE = 212m). Estimated density of argali was 0.447 argali/km^2 (95% CI: 0.196 – 0.792). Applying these density estimates to the 4,749 km2 of mapped argali distribution within the aimag resulted in an estimate of 2,123 (95% CI 931 - 3,761) argali.

5. A .2. Ibex in Bayan-Ulgii

A total of 249 ibex were observed in 13 groups, but only 6 of these groups were observed during observations at fixed points (the remainder was observed while traveling between points). This sample size was too small to conduct either multiple observer or distance sampling. Thus, we had no way to correct for imperfect detection of ibex directly Of the 249 ibex observed, 109 were classified (as follows: 78 adult females, 6 adult males, 2 yearlings, and 23 lambs).

We were able to use the viewshed analysis to provide an estimate of the number of ibex in Bayan-Ulgii, by projecting the number observed by the reciprocal of the sampling fraction. Depending on assumptions, viewshed analysis suggested that the field team effectively surveyed from 7 to 26% of mapped ADU area within the aimag. This suggested a population size of some 1,524 ibex (bounded by possible estimates of 724 and 2,550) within argali distribution areas of Bayan-Ulgii.

5. A. 3. Other species in Bayan-Ulgii

Other species seen by the teams were not recorded.

5. A. 4. Discussion: Bayan-Ulgii

Information from local sources can be used to supplement and add nuance to the numbers reported by the Bayan-Ulgii survey team. Many local informants provided approximate numbers of argali that had been seen during recent years; these generally were similar to, or slightly higher than numbers seen by the field team. Weather conditions in mid-October 2009 often prevented the survey team from counting as many argali as were likely present. In some cases, livestock had recently moved into survey areas, and the relatively early onset of winter had caused some argali move to away from survey locations. Local rangers observed that there are generally more argali in the fall around here, however, they believe that argali wintering areas are somewhere else other than in Bayan-Ulgii.

Livestock disturbance in Bayan-Ulgii was judged by the field team to be low to moderate; however, where large numbers of encampments were found, argali were either absent or rare. Neither mining nor poaching was considered a problem. There were some good local conservation groups working and apparently, 2 local conservation units obtained a hunting permit to be hunted by foreign hunters as community based hunting management model. Previous monitoring of argali and ibex had evidently been conducted locally, although formal reports were not available. Local officials conduct frequent training and seminars to local people and also hired local volunteer rangers. Also there are 2 hunting camps working and also some good ibex habitat. Local protection units also supplied argali with some hay and salt during the winter.

5.B. Uvs

5. B. 1. Argali in Uvs

A total of 19 argali groups, consisting of 417 argali were seen. Argali were observed in 3 of the 5 ADUs surveyed. Argali groups varied in size from 1 to 76 animals ($\bar{x}$ = 19.4, SD = 21.9). Of 164 argali that could be identified, 89 were classified as adult ewes, 15 as adult rams, 11 as yearlings, and 49 as lambs.

WWF personnel had earlier conducted a separate survey in the Tsagaan Gol area on the Russian border (July 23-28, 2009). This area was included in our October 2009 survey (above), and 217 of the 417 reported came from this area. In the July survey, a total of 391 argali were observed, of which 134 were classified as adult females, 95 as adult males, 19 as yearlings, 67 as lambs, and 76 could not be classified. Based on previous knowledge of the area, biologists at the Mongolian Academy of Sciences consider that there were probably about 1,033 argali in Uvs (See Appendix E).

5. B. 2. Ibex in Uvs

A single group of 76 ibex was observed in the Tsagaan shuvuut area. Based on time spent in the area and interviews with local officials, the field team identified the following areas (separate from the existing ADUs) that are considered to contain ibex: Tsagaan shuvuut, Buraat, Han Hohiin nuruu, Duns termis, Harhiraa, Omno otor uul, Hoid otor uul, Ikh Buural, Harganat uul, Tsagaan huushiin oroi, and Ulaan lonh. These areas were all mapped on the 1:500,000 scale. According to local officials, some 2,570-2,770 ibex are distributed in these areas, but our field team could not confirm this.

5. B. 3. Other species in Uvs

Other species seen by the teams were not recorded.

5. B. 4. Discussion: Uvs

Numbers reported in this survey are minimum numbers: field sampling was not amenable to providing estimates or extrapolations. If the slightly higher counts obtained in July 2009 by the WWF team for the Tsagaan gol are substituted for the total counts the field team obtained, a total of 591 argali are accounted for. Interpreting this figure is difficult, both because we cannot extrapolate from this, and because the main argali distribution areas in Uvs abut the Russian border, and cross-boundary movements are possible, depending on weather and disturbance. Argali status appears to vary considerably among the ADUs within Uvs; in some, community conservation efforts are active, livestock disturbance is moderate, and mining activity is absent. In others, livestock disturbance is higher and mining exists.

Argali in some of these areas are not necessarily full-time residents – (see also reports by WWF on these areas). Livestock disturbance was noted by the team as a frequent issue, particularly during winter. According local officials and people, with recent increases in livestock numbers in the area, argali are been pushed and disturbed and dispersed from the area. Also, during the last 2 years significant drought occurred and it's been difficult for livestock and wildlife grazing too. Some of the areas previously mapped as having had argali are now said to contain only ibex.

5. C. Khovd

5. C. 1. Argali in Khovd

From data forms, a total of 125 argali, in 9 separate groups were observed directly. Of these 1 group (12 animals) was observed approximately 1 km from the border with Gansu, China. Team members interviewed local rangers, however, based on this, added 216 argali thought to be in the area, for a total count of 341. Argali were observed directly in 5 of the pre-mapped areas, as well as in 2 of the 3 additional areas visited. Based on previous knowledge of the area, biologists at the Mongolian Academy of Sciences consider that there were probably about 2,311 argali in Khovd (Appendix E).

5. C. 2. Ibex in Khovd

From data forms, a total of 780 ibex argali in 33 separate groups were observed directly. Few of these were observed at close enough range to allow sex/age identification. Team members interviewed local rangers, however, based on this, added 1,246 ibex thought to be in the area, for a total tally of approximately 2,200 ibex. Ibex were observed directly in 4 of the pre-mapped areas, as well as in 2 of the 3 additional areas visited. However, considering local opinion, it seems likely that ibex were present in most all mountainous areas of Khovd.

5. C. 3. Other species in Khovd

While traveling between observation areas, 3 groups of black-tailed gazelles were seen (group sizes 8, 14, and 141). In the same region where the large group (141) of gazelles was seen (in Altai soum, just north of the border with Gansu, China), a group of 115 khulan (*Equus hemionus*) were observed. Two foxes (*Vulpes vulpes*) and 2 wolves were also seen during the course of the survey.

5. C. 4. Discussion: Khovd

Interpreting the number of argali seen during the survey in Khovd is made difficult by the fact that no extrapolation to unsurveyed areas was possible. The number of argali in the aimag is almost certainly higher than the numbers reported here. That said, the overall impression from the survey is that argali are nowhere abundant in Khovd, and that their density in many of the large areas that are mapped as containing them is low. Khovd has among the largest area of argali distribution within Mongolia, but it does not necessarily follow that it has among the higher numbers of argali.

The team categorized livestock disturbance as low to moderate through the areas surveyed, but this description is subject to uncertainty: the density of livestock may be low relative to other areas, but may be high relative to the habitat's capacity to support them. Mining and poaching were not identified as problems by the team. Instead, the team reported that a majority of areas mapped as argali habitat were more appropriate habitat for ibex. A number of areas were mapped on the 1;500,000 scale aimag map as suitable for and occupied by ibex. This will help in future ibex monitoring efforts.

5. D. Gobi-Altai

5. D. 1. Argali in Gobi-Altai

Twelve of the 15 ADUs identified in the aimag were visited; these 12 represented approximately 85.8% of the 12,162 km^2 of argali distribution included in the mapped units. Observations were made from a total of 72 fixed observation points (varying from 3 to 10 per ADU). Twelve of these were removed from the point distance sampling analysis to avoid over-estimating the actual observation effort, resulting in a total sample size of 50 points.

A total of 16 argali groups, consisting of 83 argali were seen. Argali were observed in 6 of the 12 ADUs surveyed. Argali groups varied in size from 1 to 13 animals ($\bar{x}$ = 5.2, SD = 3.4). Of 83 argali that could be identified, 38 were classified as adult ewes, 20 as adult rams, 16 as yearlings, and 9 as lambs. Field teams appeared to record yearling and lambs inconsistently, as many observations were made at long distances (> 2 km), making these identifications uncertain.

Cluster size was not a significant factor, so mean cluster size was used in the analysis. We ran 2 different competing models of detection function (hazard rate key function with a maximum of 2 cosine adjustments, half-normal key function with maximum of 2 cosine adjustments) and report the best fitting model (half-normal) here. The estimated detection radius was 1,236m, (SE = 282m). Estimated density of argali was 0.321 individuals/km^2 (95% CI: 0.137 – 0.753). Applying these density estimates to the 12,162 km^2 of mapped argali distribution within the aimag resulted in an estimate of 3,904 (95% CI 1,666 - 9,158) argali.

In post-analysis work however, it was discovered that survey teams probably biased their surveys toward areas more likely to have argali. Based on previous knowledge of the area, biologists at the Mongolian Academy of Sciences consider that there were probably about 1,556 argali in Gobi-Altai (Appendix E).

5. D. 2. Ibex in Gobi-Altai

A total of 314 ibex were observed in 32 groups; of these, 7 groups, consisting of 34 ibex were observed while traveling between fixed points, and thus could not enter the point count distance analysis. An additional 140 ibex (in 12 groups) were recorded but were not mapped sufficiently accurately to allow estimation of distance. Thus, we had only 13 ibex groups from which to estimate density. Of the 314 ibex observed, 258 were classified as 135 adult females, 71 adult males, 34 yearlings, and 18 lambs. Field teams appeared to record yearling and lambs inconsistently, as many observations were made at long distances (> 2 km), making these identifications uncertain.

Cluster size was not a significant factor, so mean cluster size was used in the analysis. We ran 2 different competing models of detection function (hazard rate key function with a maximum of 2 cosine adjustments, half-normal key function with maximum of 2 cosine adjustments) and report the best fitting model (half-normal) here. The estimated detection radius was 1,865m, (SE = 92m). Estimated density of ibex was 0.404 individuals/km^2 (95% CI: 0.195 – 0.837. Applying these density estimates to the

12,162 km^2 of mapped argali distribution within the aimag resulted in an estimate of 4,913 (95% CI 2,372 - 10,180) ibex. We note however that ibex were seen in 3 unmapped areas beyond ADUs, suggesting that the total number of ibex in Gobi-Altai probably exceeds this estimate.

5. D. 3. Other species in Gobi-Altai

Wolves were documented in most of the areas surveyed. It is unclear whether wolves were more common in Gobi-Altai than other aimags, are whether the field team was more active in finding and reporting them. The team also reported observing vultures, hedgehogs and hares.

5. D. 4. Discussion: Gobi-Altai

From the quantitative results, it appears that Gobi-Altai harbors that largest number of argali of any Mongolian aimag, and the 2nd larger number of ibex. In viewing these results, the small sample size on which they depend should be kept in mind. Because Gobi-Altai has by far the largest area of mapped argali distribution, small differences in estimated density produce large differences in estimated abundance. The small number of argali groups (16) and animals (83) observed cautions against over-confidence in these figures.

A number of areas were mapped on the 1;500,000 scale aimag map as suitable for and occupied by ibex. This will help in future ibex monitoring efforts. lots of drought – local officials seem to think argali have been declining in recent years

Gobi-Altai also contains substantial area in the Gobi Strictly Protected Area ‘A’, which, which likely contributes positively to wildlife protection (although much of this area is not ideal argali habitat). Livestock disturbance was within the Protected Area was categorized as low by the field team, although as moderate in the buffer zone surrounding it, and as high some other areas. The team members returned with specific recommendations for including currently unprotected areas occupied by argali for local protection. The team noted illegal gold mining and geological exploration in some areas. In contrast to most other field teams, poaching was also reported, some which had been investigated by local rangers or environmental inspectors. Legal hunting also occurred during the survey (2 hunting camps were recorded).

5. E. Zavkhan

Teams in Zavkhan recorded a total of 135 observation points in the 3 areas. However, they observed only 5 groups of argali, totaling 23 individuals. Classification of animals by sex and age was uncertain. The total number of argali in Zavkhan is probably higher than this, but perhaps not by too much. According oral information collected from by local people and rangers, approximately 27 argali wintered in areas called Gyalgariin Eh and Tsagaan, and local officials in Yaruu Erdenehairhan, where teams observed only 7 argali, were of the opinion that there might be 40 in the area. (This area borders Gobi-Altai). The general consensus appeared to be that livestock numbers were high and that argali in the aimag tended to live only in the most remote areas.

A total of 22 ibex in 3 groups was observed. However, there may have been ibex habitat that the teams were not able to visit.

We lack an estimate of the proportion of argali habitat within each of Zavkhan's ADUs that was effectively surveyed. Of the total estimated 1,389 km^2 mapped argali habitat in the aimag, viewshed analyses suggested that only 36-61 km^2 was effectively surveyed; much of the area surveyed in Zavkhan was evidently outside of ADU boundaries. ADUs within Zavkhan are in need of field confirmation and clarification. Other wildlife species seen during the survey in Zavhkan were not recorded.

5. F. Bayankhongor

A total of 15 argali groups, consisting of 143 argali were seen. Argali were observed in all 6 ADUs surveyed specifically for argali (but not in any of the additional areas surveyed). Argali groups varied in size from 1 to 40 animals ($\bar{x}$ = 9.5, SD = 9.6). Of 62 argali that could be identified, 29 were classified as adult ewes, 20 as adult rams, 2 as yearlings, and 11 as lambs. Three groups of ibex were observed, totaling 37 animals. As part of the survey, additional ADUs were recognized in this aimag.

From the viewshed analyses, we extrapolated to an estimated number of argali, based on a suite of assumptions regarding how far the team could see argali, and how much of the true argali distribution was included within ADUs. These calculations suggested from 444 to 927 argali within Bayankhongor; the mean of the 4 extrapolations was 572. Because so few ibex were observed, we elected not to extrapolate ibex numbers to the entire aimag. No doubt the total number is larger than the 37 recorded.

Other wildlife species seen during the survey in Bayankhongor included wolves and black-tailed gazelles.

5. G. Uvurkhangai (Arkhangai)

A total of 39 argali groups, consisting of 310 argali were seen. Argali were observed in only 1 ADU. Argali groups varied in size from 1 to 50 animals ($\bar{x}$ = 7.9, SD = 9.1). Of 192 argali that could be identified, 90 were classified as adult ewes, 53 as adult rams, 1 as a yearling, and 48 as lambs. Field teams appeared to record yearling and lambs inconsistently, as many observations were made at long distances (> 2 km), making these identifications uncertain.

From the viewshed analyses, we extrapolated to an estimated number of argali, based on a suite of assumptions regarding how far the team could see argali, and how much of the true argali distribution was included within the Oshig ADU (the only one believed to contain argali during the survey period). These calculations suggested from 1,160 to 2,368 argali within Bayankhongor; the mean of the 4 extrapolations was 1,756. No ibex were observed in this ADU, although local officials indicated that ibex were present in other, unsurveyed ADUs. Other wildlife species seen during the survey in Uvurkhangai were not recorded.

5. H. Umnu-gobi

5. H. 1. Argali in Umnu-gobi

Twenty-three of the 31 ADUs identified in the aimag were visited; these represented approximately 80.8% of the 8,743 km^2 of argali distribution included in the mapped units. Observations were made from a total of 194 fixed observation points (varying from 1 to 41 per ADU). Eight-two of these were removed from the point distance sampling analysis to avoid over-estimating the actual observation effort, resulting in a total sample size of 112 points.

A total of 17 argali groups, consisting of 102 argali were seen. Argali were observed in 11 of the 23 ADUs surveyed. Argali groups varied in size from 1 to 22 animals ($\bar{x}$ = 4.6, SD = 4.7). Of 66 argali that could be identified, 41 were classified as adult ewes, 15 as adult rams, 3 as yearlings, and 7 as lambs. Field teams appeared to record yearling and lambs inconsistently, as many observations were made at long distances (> 2 km), making these identifications uncertain.

Cluster size was not a significant factor, so mean cluster size was used in the analysis. We ran only the half-normal key function with maximum of 2 cosine adjustments) because other detection models appeared unreasonable, given the limited sample size. The estimated detection radius was 1,006m, (SE = 140m). Estimated density of argali was 0.275 argali/km^2 (95% CI: 0.137 – 0.555). Applying these density estimates to the 8,743 km^2 of mapped argali distribution within the aimag resulted in an estimate of 2,404 (95% CI 1,198 - 4,852) argali within Umnu-gobi.

5. H. 2. Ibex in Umnu-gobi

A total of 249 ibex were observed in 13 groups, but only 6 of these groups were observed during observations at fixed points (the remainder was observed while traveling between points). Of the 249 ibex observed, 109 were classified (as follows: 78 adult females, 6 adult males, 2 yearlings, and 23 lambs).

We were able to use 52 observations of ibex at which radial distances were documented (a total of 190 ibex) to estimate density using point transect distance methods. Cluster size was not a significant factor, so mean cluster size was used in the analysis. We ran 2 different competing models of detection function (hazard rate key function with a maximum of 2 cosine adjustments, half-normal key function with maximum of 2 cosine adjustments) and report the model averaged results here. The estimated detection radius was 530m (SE = 682m). Estimated density of ibex was 1.524 individuals/km^2 (95% CI: 0.877 – 2.65). Applying these density estimates to the 12,162 km^2 of mapped argali distribution within the aimag resulted in an estimate of 13,324 (95% CI 7,671 - 23,169) ibex.

5.H.3. Other species in Umnu-gobi

A herd of approximately 200 khulan (Mongolian wild ass) was observed on October 15 in Manlai soum. A group of 7 black-tailed gazelles was seen on October 12 in Bayan-Ovoo soum.

5.H.4. Discussion: Umnu-gobi

In viewing these results, the small sample size on which they depend should be kept in mind. Umnu-gobi is a very large aimag, and sampling over such a large area necessarily involved compromises. The small number of argali groups (17) and animals (102) observed cautions against over-confidence in these figures. It appears that Umnu-gobi may contain the largest number of ibex of any Mongolian aimag. Again, the relatively small sample size underlying the estimate of ibex abundance should be kept firmly in mind. Ibex density was estimated to be high largely because ibex that were observed were at relatively close proximity to the point transects ($\overline{X}$ = 530 m), and this density was extrapolated over a large area.

Umnu-gobi aimag contains Gobi Gurvhan National Park, one of the best known and protected areas within Mongolia. However, many of the areas containing argali in Umnu-gobi were reported by the field team to be substantially affected by mining or poaching.

5. I. Tuv

5. I. 1. Argali in Tuv

Twenty-one of the 24 ADUs identified (which total approximately 1,401 km^2) in the aimag were visited. Observations were made from a total of 72 fixed observation points.

A total of 19 argali groups, consisting of 142 argali were seen. Argali were observed in 11 of the 21 ADUs surveyed. Argali groups varied in size from 1 to 17 animals ($\bar{x}$ = 7.5, SD = 4.6). Of these 142 argali that could be identified, 84 were classified as adult ewes, 26 as adult rams, 7 as yearlings, and 25 as lambs.

Cluster size was not a significant factor, so mean cluster size was used in the analysis. We ran only the half-normal key function with maximum of 2 cosine adjustments) because other detection models appeared unreasonable, given the limited sample size. The estimated detection radius was 894m, (SE = 1160m). Estimated density of argali was 0.595 argali/km^2 (95% CI: 0.298 – 1.188). Applying these density estimates to the 1,401 km^2 of mapped argali distribution within the aimag resulted in an estimate of 834 (95% CI 417 - 1,664) argali within Tuv.

5. I. 2. Ibex in Tuv

Only a single ibex group (of 11 unidentified individuals) was observed during the survey in Tuv.

5. I .3. Other species in Tuv

A group of 57 Mongolian gazelles was seen on October 6 in Undershireet Soum. A group of 11 red deer were seen on October 8, 2009 in Ondorsheeret soum.

5. I. 4. Discussion: Tuv

Habitats where argali persist in Tuv aimag are small and somewhat scattered from one another; individual populations, if they are indeed distinct from one another, are probably small. However, the survey team found some heartening indications that argali may be fairing surprisingly well in Tuv. Despite modest survey effort, argali were documented in about half of the small ADUs in Tuv, and density, estimated at almost 0.6 km^2, was not particularly low. Neither mining nor poaching was noted as a serious concern by the survey team. Livestock density varied considerably, from low to high, among ADUs within Tuv. Ibex were not common, but a few isolated populations may persist.

5. J. Dundgobi

5. J. 1. Argali in Dundgobi

Eighteen of the 21 ADUs identified in the aimag were visited; these represented approximately 96% of the 4,439 km^2 of argali distribution included in the mapped units within Dundgobi. Observations were made from a total of 90 fixed observation points (varying from 2 to 9 per ADU). Forty-one of these were removed from the point distance sampling analysis to avoid over-estimating the actual observation effort, resulting in a total sample size of 49 points from which distance calculations were made. In addition, 6 line transects, totaling 108 km were walked (2 in one ADU, 4 in another).

A total of 46 argali groups, consisting of 293 argali were seen. Argali were observed in 10 of the 21 ADUs surveyed. Argali groups varied in size from 1 to 27 animals ($\bar{x}$ = 6.2, SD = 5.9). Of 236 argali that could be identified, 176 were classified as adult ewes, 20 as adult rams, 3 as yearlings, and 37 as lambs. Field teams appeared to record yearling and lambs inconsistently, as many observations were made at long distances (> 2 km), making these identifications uncertain.

Cluster size was not a significant factor, so mean cluster size was used in the analysis. We ran only the half-normal key function with maximum of 2 cosine adjustments) because other detection models appeared unreasonable, given the limited sample size The estimated detection radius was 619m (SE = 1370m). Estimated density of argali was 1.084 argali/km^2 (95% CI: 0.339 – 3.471). Applying these density estimates to the 4,439 km^2 of mapped argali distribution within the aimag resulted in an estimate of 4,812 (95% CI 1,505 - 15,408) argali within Dundgobi.

In post-analysis work however, it was discovered that survey teams probably biased their surveys toward areas more likely to have argali. Based on previous knowledge of the area, biologists at the Mongolian Academy of Sciences consider that there were probably about 2,338 argali in Dundgobi (Appendix E).

5. J. 2. Ibex in Dundgobi

A total of 14 ibex groups, consisting of 75 individuals were seen. Ibex were observed in 6 of the 21 ADUs surveyed. Ibex groups varied in size from 1 to 20 animals ($\bar{x}$ = 5.3, SD = 5.1). Of 35 ibex that could be identified, 16 were classified as adult ewes, 10 as adult rams, 2 as yearlings, and 7 as lambs. Field teams appeared to record yearling and lambs inconsistently, as many observations were made at long distances (> 2 km), making these identifications uncertain.

Cluster size was not a significant factor, so mean cluster size was used in the analysis. We ran only the half-normal key function with maximum of 2 cosine adjustments) because other detection models appeared unreasonable, given the limited sample size. The estimated detection radius was 703m (SE = 65m). Estimated density of ibex was 0.634 individuals/km^2 (95% CI: 0.2889 – 1.392). Applying these density estimates to the 4,439 km^2 of mapped argali distribution within the aimag resulted in an estimate of 2,814 (95% CI 1,278 - 6,179) ibex within Dundgobi.

5. J. 3. Other species in Dundgobi

The survey team encountered groups of Mongolian gazelle on 5 occasions.. Approximate herd sizes were 310, 75, 6, 5, and 35 animals. A group of 6 black-tailed gazelles was also seen. Solitary red foxes were encountered on 4 occasions, and 1 wolf was also seen.

5. J. 4. Discussion: Dundgobi

Argali density, as quantified using distance sampling, was reasonably high in Dundgobi, and argali appear to be distributed in many areas throughout the aimag. Poaching was not identified as a threat to argali, although mining was considered problematic at some, albeit not all, areas of argali distribution. Livestock density was almost invariably considered high. These relatively productive grasslands are probably sources of contention between pastoralists and argali.

5. K. Dornogobi (and Gobi-Sumber)

A total of 128 argali groups, consisting of 839 argali were seen. Argali groups varied in size from 1 to 32 animals ($\bar{x}$ = 6.8, SD = 6.7). Of 793 argali that could be identified, 455 were classified as adult ewes, 219 as adult rams, 40 as yearlings, and 79 as lambs. Field teams appeared to record yearling and lambs inconsistently, as many observations were made at long distances (> 2 km), making these identifications uncertain. The number of lambs recorded was surprisingly low, but it is unclear if this reflects a truly low number or is a reflection of sampling issues.

5. K. i. Southern Dornogobi

Observations were made from a total of 67 fixed points. From the viewshed analyses, we extrapolated to an estimated number of argali, based on a suite of assumptions regarding how far the team could see argali. These calculations suggested from 841 to 3,561 argali within the southern portion of Dornogobi; the mean of the 4 extrapolations was 2,050. No ibex were documented in this area.

5. K. ii. Northern Dornogobi

Argali were counted in an effort to tally as many as possible in this area. Observations points at which argali were not observed were not recorded; thus no extrapolation of these numbers was possible. A total of 324 argali were documented.

5. K. iii. Ikh Nart Nature Reserve

Ibex are known to inhabit the Ikh Nart Nature Reserve, and probably exceed 100 individuals. However, no survey of ibex abundance was conducted as part of this work.

While conducting line transect sampling, observers documented 189 argali in 32 groups in ~ 121 km of transect line. Estimated density of argali, using program DISTANCE was 1.63 argali/km^2 (95% CI: 0.59 – 3.29), which, applied to the study area, yielded a population estimate of 539 (95% CI: 196-1,082).

During mark-resight surveys, observation teams tallied a total of 467 individual argali observed during all sessions (including re-samplings). Mean number of animals seen per survey team/session was 58.1 and varied from 24 to 98. Mean number of animals seen per day (by all 4 teams) was 91.4 and varied from 19 to 223. Eight of the

25 marked animals (7 ♀, 1♂) were resighted (a total of 12 times including resampling of marked animals). In addition, 7 observations were made. Depending on assumptions about the status of some marked animals, abundance estimates were 461 females (95% CI: 278 – 643) and 191 males (95% CI: 81 – 379) (i.e., total argali = 652 (CI = 359-1,022) and 779 females (95% CI: 269 – 1,289) and 268 males (95% CI: 5 – 820), that is, total argali population of 1,047 (CI = 274 – 2,109).

See Appendix F for details.

6. Discussion

On the basis of objective sampling and the methods detailed above, we estimate that there were approximately 17,903 argali in Mongolia as of October 2009, with a lower 95% confidence limit of 9,193 and an upper 95% confidence limit of 43,135. Our point estimate of ibex is 24,371 with a lower 95% confidence limit of 13,840 and an upper 95% confidence limit of 43,873. Might these numbers be biased high or low?

First, for Khovd, Uvs, Zavkhan, and part of Dornogobi aimag, we were unable to do more than report raw counts, either obtained directly or from other reliable surveys. Our initial estimates of argali in these areas are probably biased low (also this may not be the case for the adjustments made later by IOB personnel). Secondly, for Bayankhongor, part of Dornogobi, and Uvurkhangai, we could not correct for imperfect detectability, and therefore extrapolated counts that assumed all individuals within surveyed areas were seen. This too would have tended to bias our estimate low.

Countering this, it is possible that despite efforts to obtain a representative view of argali habitat, some field teams biased their selection of areas to survey toward those with higher density of argali or ibex than characterized the area as a whole. If so, this would have biased our estimate positively. Secondly, mapping of ADU was done by different teams of aimag-level environmental officials. In some cases, these units may have been mapped expansively, over-stating the true area of argali occupancy. If so, our extrapolation of argali density to the entire aimag would have been biased high. (In cases where we discovered that ADUs were mapped incorrectly, i.e., they no longer contained argali, we removed them prior to extrapolation).

It may seem difficult to believe that so many more ibex and argali may exist than were physically observed during the survey. On this, however, it is instructive to consider the case of surveys in Ikh Nart Nature Reserve in Dornogobi (Appendix F), where years of biological research formed a backdrop, and where surveys with by far the highest intensity were conducted. In this relatively small area of ~ 330 km^2 with good access and few visual obstructions, teams of experienced observers conducted both distance sampling and mark-resight sampling. When sampling the area systematically (approximately 120 km of line transect), observers tallied 189 argali, about 35% of the point estimate of 539 animals (from program DISTANCE). When 4 teams of observers attempted to find as many argali as possible, biasing their movement so as to maximize the chance of seeing argali, they tallied at most 223 animals during a single day of survey, or to 21% to 34% the point estimates of 1,047 and 652 produced by mark-resight analyses.

Our interpretation is that ibex outnumber argali in Mongolia. Where we had reliable methods of estimating it, density of ibex generally exceeded density of argali within ADUs. Many of these also contained ibex (although some evidently did not), but ibex are also distributed in many mountain areas of Mongolia that did not contain argali as of 2009. The survey contributed to the mapping of ibex distribution areas within Mongolia, but additional areas with ibex probably exist, and were not surveyed.

There is always uncertainty in estimating the abundance of a wildlife population. That is particularly the case where animals are difficult to find, and live over enormous areas. Thus, we urge readers to view all the numbers reported here as approximate, and to keep confidence intervals in mind. However, we believe that these results are generally accurate and reliable.

In this report, we have also de-emphasized interpretation of herd structure data compared with previous reports (e.g., IOB 2001, Magamedov et al. 2003,Frisina et al. 2007). There are a few reasons for this:

1) Interpretation of productivity ratios such as lamb:ewe ratios is difficult because the same ratio can arise from a number of different causes. Low numbers of lambs relative to ewes most likely arises from low productivity or low early survival, and these

are generally interpreted as negative indicators for the population. It may be tempting to conclude that a population displaying low numbers of lambs relative to ewes is in particular distress. However, an equally plausible interpretation is that high levels of intraspecific competition, possibly arising from locally high densities, are at the root of low productivity or low early survival. Thus, past or current conservation success, resulting in locally high density, could result in low lamb:ewe ratios, and provide a competing hypothesis with the usual interpretation of poor forage or high predation on lambs.

2) In both argali and ibex, yearling females do not reproduce. Thus, understanding productivity during the most recent lambing season (and subsequent period of juvenile survival) requires that a separate age-class, yearlings, be accounted for. If the yearling age-class is ignored (and yearlings are classified either as lambs or adult ewes), indices of production are biased by the size of the (unknown) yearling cohort. Unfortunately, identifying yearlings under typical field conditions is very difficult, and prone to error. Some field workers do not identify yearlings at all (presumably combing them with females aged 2 and above). Others identify yearlings, but may lack certainty about the identification. In general, only the closest observations allow unambiguous identification of yearlings.

3) If the above 2 issues can be solved satisfactorily, there remains the issue that productivity (and early juvenile survival) are often highly correlated with meteorological factors that vary yearly. Without ancillary data on weather conditions prior to, during, and subsequent to parturition, interpreting productivity statistics as indicators of longer-term population status is difficult. Yearly fluctuations in weather conditions that affect production and early juvenile survival are a normal and natural phenomenon that is beyond management intervention.

4) Lambs can be difficult to see, and may be undercounted when doing large-scale surveys in which many animals are seen at great distance.

5) Comparing productivity indices across years requires that they be made similar times of year.

Thus, we in this report, we repeat herd structure information from the field teams, but limit interpretation of them.

Our survey identified a number of positive developments.

1) Numbers of both species were both fairly high. In general, consumptive use is not contraindicated. However, management must occur on local level; the fact that the country, or any one aimag has sufficient numbers to sustain a theoretical level of consumptive use does not necessarily mean that level can be achieved in reality without damage, if not distributed evenly over the area

2) Reports of poaching were not widespread, but restricted to individual areas

3). Some aimags or ADUs showed higher numbers than expected, based on earlier surveys and reports. Conventional wisdom in recent years has been that argali in the Mongolian Altai have declined greatly (IUCN 2008). This report cannot support or refute that contention in general, in part because surveys in Khovd and Uvs did not allow reliable aimag-wide estimates. However, reports from Bayan-Ulgii suggested that argali are doing well, at least in some areas. In northern Uvs, a WWF-sponsored community conservation program shows great promise, and WWF and other NGOs are active throughout the Altai-Sayan area. As suggested by IUCN (2008) and Reading et al. (1997), argali in most Govi regions remain in reasonable densities.

4). Survey teams documented promising local efforts at conservation particularly in Bayan-Ulgii, Uvs, and Dornogobi.

5) Mongolia has continued to gradually strengthen its system of protected areas. Some of these overlap areas of importance for argali and ibex.

Our survey also identified a number of worrisome indicators:

1) Within aimags, population status often appeared to vary among regions. While some areas may continue to have thriving populations, other areas within the same aimag may have lost argali completely. Survey teams documented some previously mapped ADUs that are were evidently completely devoid of argali (although not necessarily ibex). We also noted that ADUs that are particularly large in area (e.g., in Khovd, Uvurkhangai, and Uvs), although they contain argali, apparently have very low densities.

2) Argali and ibex within Mongolia are both reside in a large number of disjunct patches. Some of this is almost certainly entirely natural, reflecting the fact that both are

mountain ungulates that do not find appropriate habitat in large expanses of steppe or desert with no topographic relief. It is possible however, that additional fragmentation is of human origin. Argali, although to a lesser extent ibex, are often capable of traveling long distances, and may be able to maintain genetic and/or demographic linkage despite having a patchy geographic distribution (Harris et al. 2010; R. Reading, unpublished data). Areas of concern regarding long-term isolation and restrictions of necessary gene flow should be investigated in future, using genetic techniques.

3) Most areas reported very low numbers of adult males. This may have resulted from sampling characteristics (males sometimes prefer the most inaccessible habitats, and thus their detection probability is lower than that of females). However, it may also reflect excessive harvest pressure (either legal or illegal), or competition from livestock (if males tend to respond more quickly to inadequacy of forage). The low number of males from composition counts argues for additional conservatism in any off-take quotas

4) Grazing pressure from domestic livestock continues to be a concern. Livestock were reported as present throughout the sampling area, and in some areas, team members believed that pressure from livestock was great enough constitute a limiting factor for argali.

Suggestions for future monitoring

The fact that IOB and WWF biologists had already produced a distribution map for argali made this survey much more successful than it could have been lacking that. These maps are extremely valuable, and we urge continued work on updating and revising the argali map and ensuring that digital versions are correct and consistent. This survey has begun the process of producing similar maps for ibex. That should also be continued.

We recommend that surveys similar to this be repeated periodically, using randomly selected points within randomly selected distribution units. When the ibex distribution map for Mongolia is completed, the can also form the basis for better estimates of ibex abundance nationwide.

We recommend that future assessment work focus more on local monitoring on a yearly basis. Many distribution areas are too small, have too few animals, for any rigorous estimation method to produce reliable results. Instead, we recommend training and equipping local rangers or environmental officials to conduct thorough and repeatable surveys, and to document their efforts using maps (which are now available), GPS units, binoculars, and written reports. This would allow biologists centrally located in Ulaanbaatar to more on training, outreach, facilitation, coordination, documentation and interpretation of results from local level

Local assessment efforts should support and complement efforts to manage and conserve these species at a local level. Although policy and oversight should come from the national level, incentive-based conservation of these mountain ungulates ultimately depends on the active cooperation and involvement of officials at the aimag and soum levels, as well as on the enthusiasm and support of every day Mongolians living on the land.

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Appendix A

Mountain ungulates assessment survey's teams and responsible areas

Province	IoB	WWF	"Altay-Sayan" project	Mongolian Hunting Association	"”Amitan-Asralt NGO	MNET	PA's administration	Local Nature conservation agencies	Local soum representatives	Total
1. Arkhangai/Uverkhangai (1 team)	B.Munkhtsog*			N.Tserengochoo*			1	1	-	4
2. Baynkhongor (2)	G.Tsogtjargal*							1	2	6
3. Bayan-Ulgii (2)	G.Naranbaatar*		Dabkharbayr Buyanzhargal				1	1	1	6
4. Gobi-Altai (2)	Yad.Adiya*	D. Bandi					1	1	1	6
5. Dornogobi, Gobisumber (2)	S.Amgalanbaatar Ganchimeg?				Ts.Tserennorov	A.Bayasgalan*		2	1	6
6. Dundgobi (2)	S. Batdorj				O.Ganbold*			2	2	6
7. Dzavkhan(1)	Yan.Adiya*							1	1	3
8. 0mnogobi (2 **áàã**)	Ts.Munkhzul* G.Sukhchuluun*			N. Batmunkh			1	1	1	6
9. Tuv	L.Amgalan*				Ts.Sanjsuren	B. Dorjgotov		1		3
10. Khovd (2)	Rich Harris Otgoibayar	Munkhtogto			Ch.Buuvei*		1	1	2	7
11. Uvs(1)	B.Lhagvasuren* + 2**						1	1	1	6
Ä¿í	**13**	**2**	**1**	**2**	**4**	**3**	**6**	**12**	**18**	**59**

Appendix B

Field data forms

All forms were translated into Mongolian for field use. English versions are provided here.

Field form for argali observations where line transects are feasible.

Gobi - (not high mountains) Survey **Team Members:** sightability: 1 = excellent, 2 = OK, 3 = bad

Argali Sighting Form **Location:** **Aimag:**

Date: **Distn #**

Transect #	Time	Lat	Long	elev	Animals Observed						distance	animal bearing	moving away?	sightability code
					total	♀	♂	ylg	lamb	UI				

Field form for ibex observations where line transects are feasible.

Gobi - (not high mountains) Survey **Team Members:** sightability: 1 = excellent, 2 = OK, 3 = bad

Ibex Sighting Form **Location:** **Aimag:**

Date: **Distn #**

Transect #	Time	Lat	Long	elev	Animals Observed						distance	animal bearing	moving away?	sightability code
					total	♀	♂	ylg	lamb	UI				

Field form for documenting length and direction of transect

Transect Form **Team Members:**

Date	Transect #	Start Location			End Location		
		UTMn	UTMe	elev	UTMn	UTMe	elev

Field form for argali observations from fixed points (for either point transects or multiple-observer mark-recapture).

Mountain Survey Multiple Observer **Observer (1 name)** sightability: 1 = excellent, 2 = OK, 3 = bad

Argali Sighting **Location:** **Aimag:** behavior: 1) lying; 2) standing 3) moving

Date: **Map Name/Number:** **Distn #**

Point #	Time	Observer Lat	Observer Long	Elev	Mark on map	Animals Observed total	♀	♂	ylg	lamb	UI	sightability code	also seen by:	seen on way to point?	animal behavior

Field form for ibex observations from fixed points (for either point transects or multiple-observer mark-recapture).

Mountain Survey Multiple Observer **Observer (1 name)** sightability: 1 = excellent, 2 = OK, 3 = bad

Ibex **Location:** **Aimag:** behavior: 1) lying; 2) standing 3) moving

Date: **Map Name/Number:** **Distn #**

Point #	Time	Observer Lat	Observer Long	Elev	Mark on map	Animals Observed total	♀	♂	ylg	lamb	UI	sightability code	also seen by:	seen on way to point?	animal behavior

Field form: Summary of form for each ADU

Argali Distribution Area Summary Report

Aimag

Date

Team Members:

Distribution Area: US map list number	Distribution Area: Aimag team number	Distribution Area: Sum (sums)	Distribution Area: Central Latitude	Distribution Area: Central Longitude	Distribution Area: Description of location (e.g. river,mountain)

Total argali seen:

Total ibex seen:

Other species seen:

Estimate of % of area with ibex habitat:
(cliffs, steep slopes, rocky scree) %

Argali

Livestock density near argali habitat:
(low, moderate, high)

Industrial disturbance (e.g., mining) near argali habitat
(low, moderate, high)

Reports of argali poaching?
(none, few, many)

If few or many (above), describe source and reliability:

Ibex

Livestock density near ibex habitat:
(low, moderate, high)

Industrial disturbance (e.g., mining) near argali habitat
(low, moderate, high)

Reports of ibex poaching?
(none, few, many)

If few or many (above), describe source and reliability:

Other notes on this area related to conservation and management of mountain ungulates:

Appendix C. Mongolian-English names

English	Mongolian	Other commonly seen English
Arkhangai	Архангай	Arhangay
Bayankhongor	Баянхонгор	Bayanhongor
Bayan-Ulgii	Баян-Өлгий	Bayan-Olgiy
Dornogobi	Дорноговь	Dornogovi, East Gobi
Dundgobi	Дундговь	Dundgovi, Middle Gobi
Gobi-Altai	Говь-Алтай	Govi-Altai, Govi-Altay
Gobi-Sumber	Говь-Сумбэр	Govi-Sumber
Khentii	Хэнтий	
Khovd	Ховд	Hovd
Khuvsgul	Хөвсгөл	
Sukhbaatar	Сухбаатар	
Tuv	Төв	Tov
Ulaanbaatar	Улаанбаатар	Ulan Batar
Umnu-gobi	Өмнөговь	Omnogobi, Omnogbvi, South Gobi
Uvs	Увс	
Uvurkhangai	Өвөрхангай	Uverkhangai
Zavkhkan	Завхан	Dzavkhan

Appendix D

Participants at March 2009 Workshop on estimating population size of mountain ungulates, Ulaanbaatar, Mongolia

Dr. Richard B. Harris, University of Montana
Ganchimeg Wingard, Argali Research Center and Denver Zoological Foundation
S. Amgalanbaatar, Institute of Biology, Academy of Sciences, Mongolia
A. Bayasgalan, Mongolian Ministry of Nature, Environment and Tourism
L. Amgalan, Institute of Biology, Academy of Sciences, Mongolia
B. Lhagvasuren, Institute of Biology, Academy of Sciences, Mongolia
Ya. Adiya, Institute of Biology, Academy of Sciences, Mongolia
G. Tsogtjargal, Institute of Biology, Academy of Sciences, Mongolia
B. Buveibaatar, Institute of Biology, Academy of Sciences, Mongolia
G. Naranbaatar, Institute of Biology, Academy of Sciences, Mongolia
G. Sukhchuluun, Institute of Biology, Academy of Sciences, Mongolia
Yd. Adiya, Institute of Biology, Academy of Sciences, Mongolia
E. Namshir, Argali Research Center
Ch. Buvei, Argali Research Center
D. Buuyanzhargal, Argali Research Center
Tchleget, Juulchin
R. Adiya, President, Mongolian Hunters Association
Batbold, head, UMENGO Tourism Company
Tegelder, Mongolian National University
Yo. Onon, WWF-Mongolia
B. Chimid-Ochir, WWF-Mongolia
Enkhbilig, Wild Camel Project
S.Dulamtseren, retired, Mongolian Academy of Sciences

Appendix E

Methods for adjusting original argali estimates

Institute of Biology

Mongolian Academy of Sciences

Ulaanbaatar, Mongolia

1. Uvs

The overall argali distribution areas covered of 1,316 km^2 in Uvs aimag. Two survey teams recorded 414 argali in 7 distribution points. From the observation data points, it was estimated that 527.5 km^2 was effectively surveyed. The density was thus estimated to be 0.78 argali/km^2. Applies to an assumed argali distribution area of 1,316 km^2 yielded an estimate of 1,026 argali.

2. Khovd

The overall argali distribution areas covered of 3,172.6 km^2 in Khovd aimag. Two survey teams recorded 183 argali in 10 distribution points. From the observation data points, it was estimated that 251.2 km^2 was effectively surveyed. The density was thus estimated to be 0.72 argali/km^2. Applies to an assumed argali distribution area of 3,172.6 km^2 yielded an estimate of 2,311 argali.

3. Gobi-Altai

The overall argali distribution areas covered of 6,449.7 km^2 in Gobi-Altai aimag. Two survey teams recorded 50 argali of 11 groups in 11 distribution points. From the observation data points, it was estimated that 207.2km^2 was effectively surveyed. The density was thus estimated to be 0.24 argali/km2. Applies to an assumed area of 6,450 km^2 yielded an estimate of 1,556 argali.

4. Dundgobi

The overall argali distribution areas covered of 1,723.5 km^2 in Dundgobi aimag. Two survey teams recorded 293 argali of 58 groups in 46 distribution points. From the observation data points, it was estimated that 216km^2 was effectively surveyed. The density was thus estimated to be 1.36 argali/km^2. Applies to an assumed area of 1,723.5 km^2 yielded an estimate of 2,338 argali.

Appendix F

Details of survey methods and results for Ikh Nart Nature Reserve, Dornogobi aimag

Methods

Distance sampling using line transects.

Within the area (~330 km^2) portion of Ikh Nart that we treat separately here, we placed 12 ca. 10 km long transects systematically at approximately 2 km intervals. We oriented all transects from east-southeast to west-northwest, such that observers traveled at a bearing of approximately 275° while walking. Six teams, each consisting of 2-4 observers, walked 2 transects each on September 21, 2009 (one in early morning, another in late afternoon). Most observers carried binoculars; although they initially made most observations with the naked eye (they used binoculars primarily to clarify group size and the sex/age individual animals). They estimated radial distances from the point of initial observation to the animal group were estimated to the nearest meter using laser rangefinders and bearings to animal groups to the nearest degree using hand-held compasses. Teams marked the location of observations using hand-held GPS units.

Mark-resight sampling using previously radio-tagged individuals

Mark-resight surveys took place during August 9-12, 2009, and again on September 28, 2009. On both occasions, we conducted a thorough radio-tracking survey of the area to confirm the number of marked animals (i.e., those wearing operating radio-collars) within the search area the day before the resighting surveys began. We divided the study area into roughly 4 quadrants, each of which a separate observation team surveyed. During both time periods, the 4 teams of observers (each consisting of 2-4 observers) spent the early morning hours (during which argali are generally more active and easily observed) driving by 4-WD vehicle to high points within their quadrant, and scanning for argali using binoculars or spotting scopes. For each argali encountered, observers attempted to determine visually whether it was wearing a radio-collar. Simultaneously, one team member scanned all of the radio-frequencies of argali known to be alive and in the study area the previous day while orienting the antenna toward the argali (group) they just observed. In 7 cases, teams visually confirmed animals wearing radio-collars, but received no signal, leaving the identity of the animal in doubt. We therefore classified animals as marked and identified, marked but unidentified, or unmarked. Although teams surveyed separate regions of the study area, our design and analysis did not require that animals be sampled without replacement (see below).

Analyses for distance sampling

We calculated perpendicular distances from field measurements of radial distances, bearings to animal groups, and GPS locations along the transect line by using 'Perpendicular Distance Calculator', version 1.2.2. (2005; P. J. Ersts, American Museum of Natural History, http://biodiversityinformatics.amnh.org/open_source/pdc/). These distances, as well as sizes of each argali group formed the raw input into Program DISTANCE (Thomas et al. 2009). We truncated the most extreme 5% of observations (Buckland et al. 1993:106), reducing sample size from 32 to 30. Although we estimated radial distances in the field to the nearest meter and angles to the nearest degree, we binned observations into 200m intervals to account for estimation error and non-random movement of animals. Because we had no basis to suggest that detection functions differed between sexes, and to conserve sample size for robust estimation, we analyzed males and females together. We explored various reasonable detection functions based on the principles of the Program DISTANCE model, the desired shape, robustness, and efficiency criteria (Buckland et al. 1993:42), and standard model fitting procedures. Because AICc and goodness-of-fit tests indicated that all reasonable models enjoyed similar levels of support, we produced model averaged estimates using the bootstrapping capability of program DISTANCE.

Analysis for mark-resight sampling

We used the Poisson log-normal mark-resight model (McClintock et al. 2008) as implemented in Program MARK (Cooch and White 2008) to estimate the abundance of unmarked argali within the study area. This approach is appropriate for sampling without replacement; indeed, it allows collapsing all resighting events into a single "session". It also allows the use of auxiliary data marked animals that cannot be identified to individual. Many fewer males were marked than females, and our previous capture experience suggested that males were more adept at evading capture than females. We thus hypothesized that the proportion of marked animals differed by sex, and elected to consider sexes separately during mark-resight experiments.

Because we conducted a general radio-tracking survey immediately prior to both resighting surveys, we felt comfortable considering the number of marks in the population known. We did, however, face a problem in interpretation when we observed animals wearing collars from which we could not obtain a signal. These instances could have arisen from 2 circumstances: a) the collared animal was among the set of known, marked individuals, but because of operator or receiver error, the signal was not obtained during the resighting, or b) the collar had ceased functioning, and the animal was thus a member of the unknown number of animals collared in previous years who were still alive and present on the study area. In the former case, we took advantage of the Poisson log-normal model's ability to incorporate these data, and coded them as "marked but unidentified". In the latter case, because we lacked a method of estimating the number of living animals wearing inactive radio-collars, we considered them unmarked. We thus proceeded with 2 analyses, one corresponding to each alternate scenario, reporting the results from each and assessing their relative likelihood based on ancillary, non-quantitative factors.

Results

Distance sampling

Observers documented 189 argali in 32 groups while surveying the ~ 121 km of transect line. Twenty-one of the 32 groups were maternal groups, consisting of adult females and their offspring, ten groups consisted of rams only, and 1 group was mixed. We found no support for models in which group size varied with distance or detection function; we thus used mean group size throughout the analyses. Mean argali group size (truncated to 1,000m distance) was 6.03 animals.

Both AICc and goodness-of-fit tests suggested that the negative exponential detection function was the best fit to our data, and this pattern persisted under an array of alternative binning and truncation combinations. However, we rejected the negative exponential as unstable and unreliable; it also fit the data particularly poorly in the critical shoulder region. Among more robust models, the uniform cosine (i.e., Fourier series) was the top AIC model, but half-normal, and hazard function detection functions differed by only 0.21 and 0.38 AICc units respectively (and all had similar GOF statistics). We thus produced a model-averaged estimate via bootstrapping (n = 1,000; which also had the benefit of incorporating model uncertainty in the confidence intervals). This procedure yielded a population density of 1.63 argali/km^2 (95% CI: 0.59 – 3.29), which, applied to the study area, yielded a population estimate of 539 (95% CI: 196-1,082).

Mark-resight sampling

Immediately prior to the August surveys, there were a total of 24 animals wearing radio-collars and present in the study area (19 ♀, 5♂). Two additional adult females were captured and radio-collared in mid-September, but 1 of these evidently left the study area immediately, those producing an increase of only 1 known mark (i.e., (20 ♀, 5♂) for the September resighting survey. For simplicity, we approximated this complexity by assuming n = 25 marked animals throughout. Of the 25, 2 were yearlings (marked as lambs approximately 1 year earlier in autumn 2008), and 4 were lambs (collared in spring 2009).

Observation teams tallied a total of 467 individual argali observed during all sessions (including re-samplings). Mean number of animals seen per survey team/session was 58.1 and varied from 24 to 98. Mean number of animals seen per day (by all 4 teams) was 91.4 and varied from 19 to 223. Eight of the 25 marked animals (7 ♀, 1♂) were resighted (a total of 12 times including resampling of marked animals). In addition, 7 observations were made of collared animals in which individual identification was not possible (6 ♀, 1♂).

In model selection, we considered models in which resighting probability and individual heterogeneity in resighting probability was constant or varied across sexes. Because our interest was in the best estimate of abundance (incorporating model uncertainty), we conducted model averaging and report those results.

Under the assumption that unidentified marked animals were members of the known, marked set, model averaging yielded abundance estimates of 461 females (95% CI: 278 – 643) and 191 males (95% CI: 81 – 379). When considering unidentified marked animals to be unmarked, model averaging yielded abundance estimates (including the number of marked animals) of 779 females (95% CI: 269 – 1,289) and 268 males (95% CI: 5 – 820).