2007 Marco Polo Argali Research in the Big Pamir Mountains of Afghanistan
Year-end Summary.

John Winnie Jr. and Richard Harris

Prepared for the Wildlife Conservation Society.

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Introduction

The Marco Polo sub-species of argali (*Ovis ammon polii*) is an important indicator of ecosystem health in the Pamirs of northeast Afghanistan and adjacent countries. Long prized for both food and ceremonial purposes by locals, as well as by foreign trophy hunters, this species was once very important to local cultures and economies. In the early 1930s, a preserve, Pamir-i-Buzurg, was established by Nadir Shah in the Big Pamir region of Afghanistan's Wakhan Corridor, expressly for trophy argali hunting. Until the Soviet invasion of Afghanistan in 1979, grazing of livestock and hunting were limited in the reserve, and these restrictions apparently lead to a stable population of argali. Just prior to the Soviet invasion, Petocz et al. (1978) estimated the Big Pamir argali population to be approximately 500.

Unfortunately, local protection and management of the species and its habitat disintegrated when the Soviet Union invaded Afghanistan in 1979, resulting in unrestricted hunting as well as expanded grazing by domestic livestock herds in the former argali reserve. Current density, distribution, local habitat preferences, and connectivity of argali populations throughout the Pamirs, are poorly understood. To date, no post-war argali population estimates have been based on repeated, or comprehensive sampling, but most estimates (including our preliminary estimate - see *Preliminary Population Estimate*, below), suggest that since Petocz's 1978 estimate, the argali population in the Big Pamir has fallen by roughly 50%. Furthermore, there are no post-Soviet studies examining seasonal habitat use, overall distribution, and movement patterns of argali in the region.

A primary goal of WCS conservation efforts is to help developing nations weave conservation plans into political, administrative, and physical infrastructure. These efforts are science-based, often necessitating a tremendous amount of effort to gather baseline data on species and regions of

interest. In the case of argali in the Big Pamir, we need to establish: 1) Seasonal habitat use; 2) Overall distribution; 3) Population size, demographics, estimates of recruitment, and; 4) The nature of interactions with domestic livestock, specifically whether there is competition for forage between livestock and argali. With these data in hand, and with data from other WCS researchers, we will be able to make sound management recommendations to the Afghanistan government, facilitating their efforts to re-establish an argali reserve in the Big Pamir, as well as promote a trans-boundary park or preserve in the far northeast Wakhan, Tajikistan, Pakistan and China.

Goals for 2007

Our efforts in 2007 were centered on two field expeditions to the Big Pamir region of the Wakhan Corridor. Our goals were:

1) Identify argali summering and wintering areas.
2) Collect argali fecal pellets for both mark-recapture estimates of population size, and for determining the relationship(s) between the Big Pamir population and surrounding populations in Tajikistan, Pakistan, China, and the Little Pamir (see separate report by Harris and Luikart).
3) Collect argali and domestic livestock pellets for dietary analyses.
4) Determine summer and winter livestock use areas in the Big Pamir.
5) Gather supporting data (particularly GIS data) and research, to aid in habitat and demographic modeling.
6) Build the capacity of local research participants. Particularly, train Sabir to use GPS, log data, and understand correct sampling techniques so that he can operate independently as field technician on future expeditions.

Overview of Methods

The study area is centered on the former Pamir-i-Buzurg preserve in Big Pamirs of Afghanistan's Wakhan Corridor, an area between 37^{o} and 37^{o} 20' latitude, and 73^{o} 30’ and 72^{o} 45’ longitude. All of the drainages we surveyed flow generally northwest to the Pamir River, which forms the border between Tajikistan and Afghanistan. The broad valleys range in elevation from 3650 to 4400 m ASL, with mountain peaks typically between 5200 and 6200 m ASL.

We surveyed drainages on foot, using binoculars and high powered spotting scopes to scan for argali. Upon sighting a group, we classified individuals as to age and sex class: ewe, lamb (young of the year), yearling, adult male, and unknown. Unknown class animals were a mixture of lambs and yearlings, which are often difficult to distinguish at great distances and in tight, moving groups. We also calculated herd position using a combination of GPS and topographic maps produced by the Soviet military. In addition to noting argali locations, we also noted the presence and extent of livestock operations.

We attempted to obtain fecal samples from all argali groups we sighted, unless sampling supplies were limited or we had already heavily sampled the area. To reduce stress to the animals, after noting the position of a group, we either sat and waited for them to move away, or left the area and returned the next day to collect fecal pellets. On several occasions, we surprised animals at close range (< 1km), and they fled the area, so we sampled immediately. To collect fecal pellets, we went to locations where we had seen argali, and searched for moist pellets that had no signs of weathering. These were often adjacent to bedding sites, allowing us to be reasonably sure we were not double-sampling the same individuals (although doubtless, this still occurred). Upon finding fresh fecal pellets, we placed them in a sampling tube containing 25 ml 95% ethanol, only touching the pellets with the spork built in to the underside of the tube's cap, thus avoiding cross-contamination of the samples. We took a

GPS fix of the rough center of area sampled using a hand-held GPS unit. Each sample was then labeled with a code linked to the herd location and date. These samples have since been shipped to the Research Center in Biodiversity and Genetics Resources, Universidade do Porto, in Vairao, Portugal for extraction of DNA and identification of nuclear micro-satellites which will be used to identify individual argali.

We will use the genetic data supplied by the Portugal lab to determine population size using genetic mark-recapture techniques (Lebreton et al. 1992; Gardner and Mangel 1996; Mills et al. 2000; Creel et al. 2003; Lukacs and Burnham 2005), and to determine regional population connectivity between the Big Pamir, and adjacent populations in the Little Pamir, Tajikistan, Pakistan, and China (see Harris and Luikart report for an overview of methods and references). For both of these study components, it is necessary to make identifications down to the individual level, and this requires nuclear DNA. At present, the lab has run preliminary analyses and had excellent success in extracting mitochondrial DNA, which bodes well for their success in extracting nuclear DNA.

Summer 2007 Survey

From 23 June to 12 July, we surveyed the Aba Khan, Manjulak, Nakchirshitk, Shikargah, and the Kund-a-Thur/Asan Katich drainages, as well as the mountain faces along the Pamir River between Gos Khan and Manjulak (Figure 1), and the pass to Sargez. We encountered argali in the upper reaches of the Manjulak, Nakchirshitk, and Shikargah drainages, and estimate that we observed a minimum of 120 unique individuals (Table 1a). Argali tended to be widely scattered, but always at relatively high elevations. In drainages where livestock were present, argali were limited to the upper reaches of the drainages and higher elevations than livestock operations, with the exception that some argali groups were seen near unattended yak herds at high elevations in upper Manjulak and Nakchirshitk drainages, and untended cattle in the Shikargah drainage (Figure 1). During this survey we collected 61 argali fecal pellets for

genetic analyses and these were shipped to the lab in Portugal. We collected an additional 6 fecal samples of argali and 6 from domestic livestock for estimation of diets from micro-histological fragment analyses, and these were shipped to the Wildlife Habitat and Nutrition Laboratory at Washington State University, in Pullman, Washington, USA.

The minimum summer lamb:ewe ratio was 0.93:1 (Table 1a), suggesting that: a) the survey occurred during, or immediately following lambing, and: b) fertility (realized fecundity) for this population was high in 2007. The minimum yearling:ewe ratio was 0.1:1, the maximum 0.55:1, suggesting roughly 45% to 90% lamb mortality over the first year (assuming the 0.93:1 lamb:ewe ratio is representative and approximately constant across years).

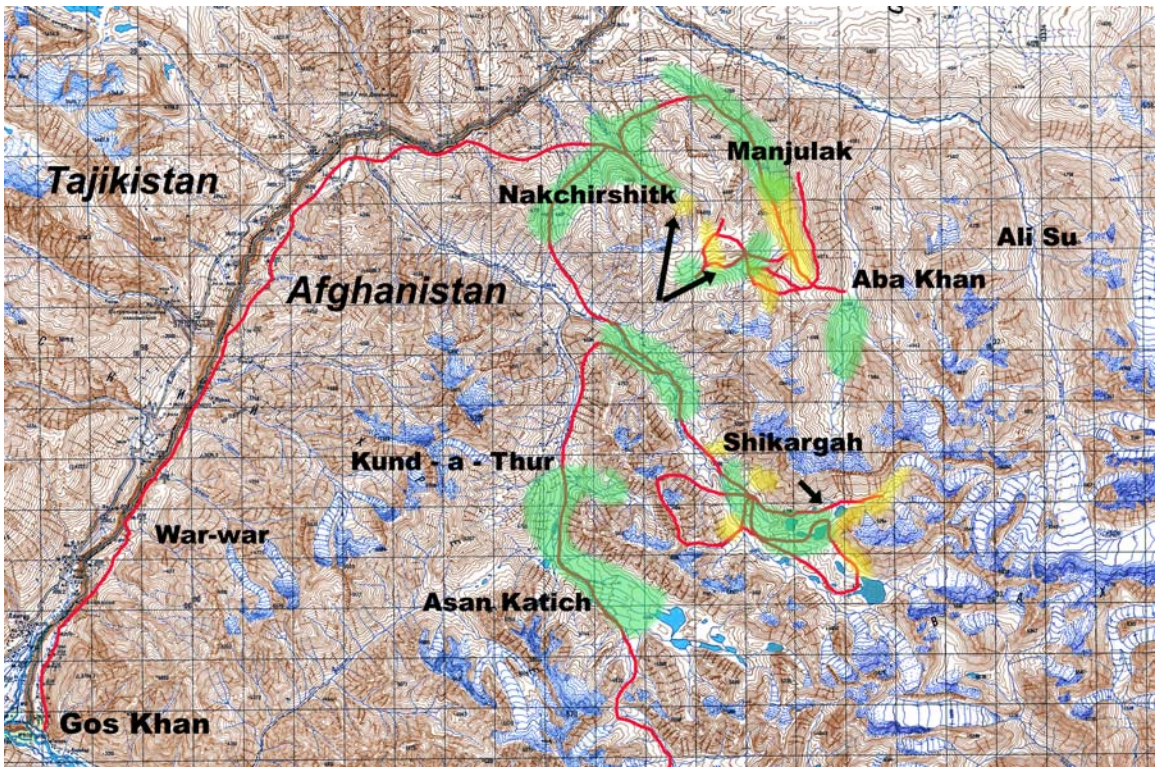

Figure 1. Summer survey route in the Big Pamir of Afghanistan's Wakhan Corridor. Argali locations are shaded in yellow, livestock locations are green. Arrows indicate areas where argali and livestock were seen in close proximity (see text).

Table 1a **Summer 2007**

Date	Time	UTM E (X)	UTM N (Y)	Duplicate?	Females	Lambs	Yrling	Males	Uk/Other	Tot.	Elevation M
6/28/07	12:00	332470	4115900	Yes	0	0	0	4	0	4	4750
6/28/07	12:10	332480	4115800	Yes	1	0	1	0	0	2	4700
6/30/07	6:30	332300	4120000	Yes	13	9	0	0	1	23	4600
6/30/07	6:30	332320	4116400	No	0	0	0	9	0	9	4750
6/30/07	6:30	332300	4116000	No	4	3	0	0	0	7	4800
6/30/07	6:30	332260	4117000	Yes	6	6	0	0	0	12	4650
7/1/07	12:00	331950	4111800	No	5	4	3	0	0	12	5000
7/1/07	12:30	321893	4117820	No	6	6	0	0	0	12	4727
7/1/07	15:00	332380	4111900	No	14	14	0	0	9	37	4450
7/3/07	9:00	332300	4120000	Yes	5	5	0	0	1	11	4600
7/3/07	18:30	321950	4119500	Yes	5	5	0	0	1	11	4600
7/3/07	18:30	321820	4120000	Yes	10	2	0	0	0	12	4600
7/4/07	13:30	322050	4110000	No	0	0	0	4	0	4	4380
7/5/07	8:00	322750	4108719	Yes	0	0	0	7	0	7	4740
7/5/07	8:30	325918	4106087	No	0	0	0	6	0	6	4750
7/5/07	11:30	325918	4106087	No	0	0	0	4	0	4	4750
7/5/07	11:30	325918	4106087	No	0	0	0	9	0	9	4750
7/6/07	9:30	328055	4108921	No	0	0	0	12	0	12	4852
7/7/07		332300	4107000	Yes	0	0	0	4	0	4	4600
7/8/07	10:00	322450	4108419	No	0	0	0	4	4	8	4730
7/9/07	8:00	328000	4108300	Yes	0	0	0	4	0	4	4750
		Totals seen:			**69**	**54**	**4**	**67**	**16**	**210**	
		Total Unique Individuals:			**29**	**27**	**3**	**48**	**13**	**120**	
		Minimum Lamb:Ewe ratio:			**0.93:1**						
		Maximum Lamb:Ewe ratio:			**1:1**	**Mean elevation of unique locations:**					**4722**
		MinimumYearling:Ewe ratio:			**0.1:1**						
		Maximum Yearling:Ewe ratio:			**0.55:1**						

Table 1b **Fall - Winter 2007**

Date	Time	UTM E (X)	UTM N (Y)	Duplicate?	Females	Lambs	Yrling	Males	Uk/Other	Tot.	Elevation
11/17/07	15:55	319486	4121350	No	0	0	0	7	0	7	4592
11/22/07	12:00	322384	4124058	No	80	20	4	4	11	119	4491
11/23/07	10:00	324000	4119000	Yes	3	3	0	0	0	6	4400
11/23/07	11:30	321500	4121000	Yes	0	0	0	5	0	5	4665
11/25/07	10:00	322002	4121938	No	3	0	1	1	0	5	4485
11/27/07	11:30	316404	4116992	No	13	4	0	2	2	21	4356
12/1/07	11:00	317011	4111996	No	3	0	0	0	0	3	4590
12/1/07	11:30	316382	4111615	No	4	0	0	1	0	5	4590
12/4/07	12:15	313207	4118000	No	3	3	0	0	0	6	4380
12/4/07	12:40	312109	4117995	No	0	0	0	1	0	1	4300
12/4/07	12:40	312300	4118500	No	4	1	0	0	2	7	4400
		Totals seen:			**113**	**31**	**5**	**21**	**15**	**185**	
		Total Unique Individuals:			**110**	**28**	**5**	**21**	**15**	**174**	
		Minimum Lamb:Ewe ratio:			**0.25:1**						
		Maximum Lamb:Ewe ratio:			**0.39:1**	**Mean elevation of unique locations:**					**4465**
		MinimumYearling:Ewe ratio:			**0.05:1**						
		Maximum Yearling:Ewe ratio:			**0.18:1**						

Table 1. Argali locations, herd compositions, and elevations for summer (a) and winter (b), 2007.

Most argali observations were obtained at long distances. Argali observed at 1 km or more generally were unaware of us or tolerated our presence. Argali observed at closer distances fled from us, either quickly (if we surprised them at close range) or gradually (usually at distances > 500m). All argali we observed were either in “maternal bands” (i.e., adult females, lambs, yearlings) or all-male groups. We observed play behavior among lambs on a few occasions, but otherwise made no important behavioral observations useful for conservation planning.

In addition to argali, we observed Asiatic ibex (*Capra sibirica*) on 2 occasions (a group of 15 males, and a group material group consisting of 7 adult females, 7 lambs, and 2 yearlings). We observed brown bears (*Ursus arctos*) on 2 occasions: a female with 2 cubs on June 30 and a female with 2 yearlings on July 8. These and other observations are detailed in a separate report by Habib.

Fall - Winter Survey

From 15 November to 7 December, 2007, we surveyed the four major drainages in, and adjacent to, the former Pamir-I-Buzurg reserve in the Big Pamirs: Ali Su, Aba Khan, Shikargah, and Kund-a-Thur/Asan Katich. In addition, we surveyed three smaller drainages: Manjulak, Nakchirshitk, and War-war (Figure 2). We encountered argali in 4 of the drainages, collected 134 argali pellet samples and are reasonably sure we saw 174 unique individuals (Table 1b, Figure 2). We also collected 3 fecal samples from argali for estimating winter diets, and 2 additional samples from livestock.

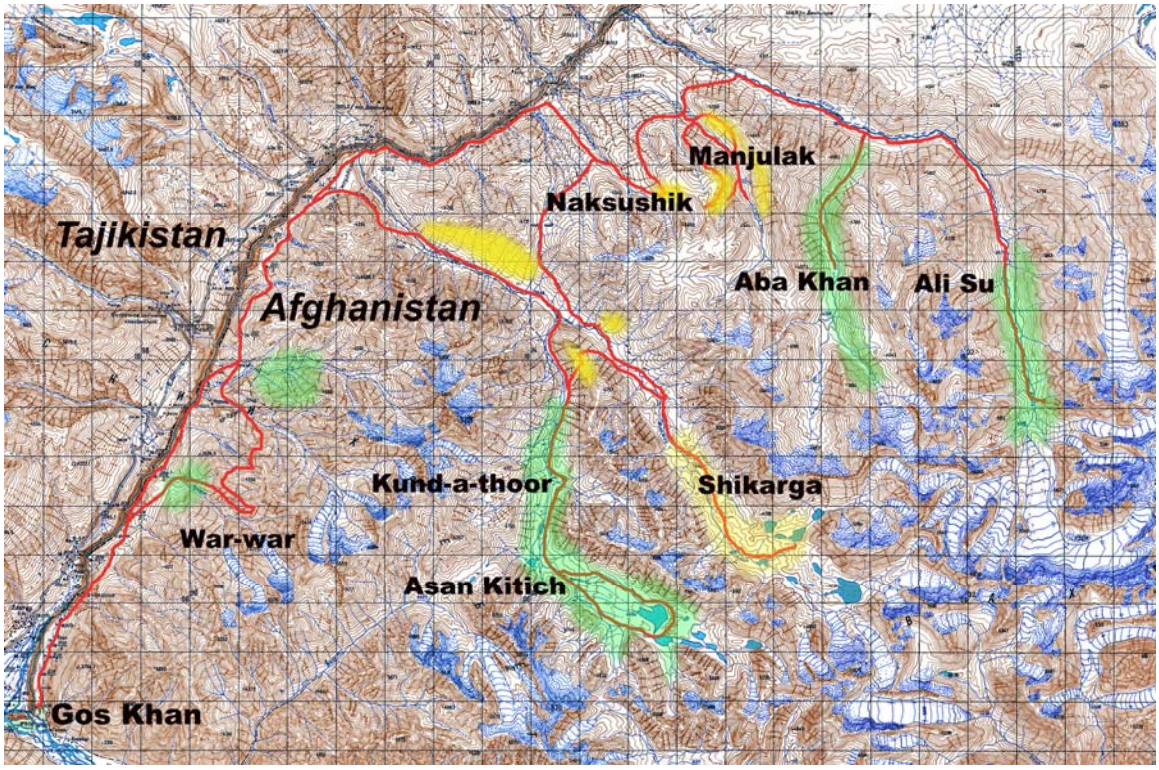

Figure 2. Winter survey route in the Big Pamir of Afghanistan's Wakhan Corridor. Argali locations are shaded in yellow, livestock locations are green. We did not see argali in the upper Shikargah valley, but saw large numbers of fresh tracks and beds, indicating that a herd had recently moved through the area. Note that the survey route does not include upper Aba Khan - the upper reaches of the valley are designated as winter livestock use based on reliable reports of an active operation.

During the winter survey, we sighted no argali and found no recent signs of their presence (hoof prints, bedding sites, feces) in drainages containing herds of livestock. In Manjulak, there were no livestock, and no recent signs of livestock, and here saw our largest herd of argali (119). In neighboring Ali Su and Aba Khan drainages, there were active livestock operations, and we sighted no argali in these drainages. In Shikargah valley, there were no livestock and we saw 4 separate groups of argali and extensive signs of their recent presence (fresh feces, beds and tracks) in the upper reaches of the drainage. By contrast, in neighboring Asan Katich, livestock operations had pulled out the day before we arrived, and in 4 days of extensive surveys, we saw no argali or recent sign. In addition to this, wherever we encountered them, our presence was clearly

disturbing to argali, as all groups and individuals that we sighted (and they in turn saw us) within 2km of us moved rapidly away.

The minimum early winter lamb:ewe ratio was 0.25:1 (Table 1b) and was likely higher (our unknown class of animals is comprised of both yearlings and lambs and was not included in this estimate). This is a reasonably high ratio, indicating fair initial lamb survival. However, our maximum yearling:ewe ratio (definite yearling sightings combined with *all* unknown individuals) was 0.18:1, and this is slightly below the roughly 0.20:1 recruitment ratio generally required by large ungulates for population maintenance or growth (Festa-Bianchet et al. 2003). The minimum yearling:ewe ratio is 0.05:1, and the true value likely falls between our minimum and maximum estimates. If this value is typical, and adult female survival is comparable to those assumed by Festa-Bianchet et al. 2003, the Big Pamir argali population would be declining. Regardless of our assumptions about the composition of unknown individuals, recruitment (i.e., to yearling age) for this population appeared to be low during 2007.

Note that the minimum and maximum lamb:ewe and yearling:ewe ratios fell by approximately 60 and 50 percent, from our summer to winter counts, respectively. If our estimates are correct, this indicates that *both* the young of year and yearling, age classes suffered high mortality through the summer and fall of 2007 (the seasons *prior* to their first and second winters, respectively). Because winter is generally a time of high mortality for both young, and old age classes, we can reasonably expect a further decline in yearlings during their second winter. Furthermore, if our current yearling:ewe, and lamb:ewe ratios are representative of long-term demographics, we can expect from fifty to eighty percent mortality within the 2007 young of the year over the coming year (based on the current differences between minimum and maximum lamb:ewe, and minimum and maximum yearling:ewe ratios in table 1).

All drainages showed signs of heavy, widespread livestock use that must have persisted until after the growing season because there was no evidence of re-growth - there was little forage that had not been grazed or browsed. Grasses were typically cropped to within 2 to 3 cm of the ground, sedges to within 5 to 7 cm of the ground, and most woody species (e.g. *Artemesia* spp.) showed signs of browsing, with most plants not exceeding 15cm in height. We encountered these conditions on valley floors, and on adjacent slopes up to approximately 4850 m (16,000 ft) in elevation, and on three occasions saw unattended yaks at these higher elevations.

We encountered red fox (*Vulpes vulpes*), or their tracks, in all drainages up to 4850 m (16,000 ft). We also encountered Tolai (Cape) hare (*Lepus tolai*) or their tracks in all of the drainages. Wolf (*Canis lupus*) tracks, from pairs or solitary animals, were present in Ali Su, Manjulak, Upper Shikargah, and Asan Katich. We found wolf feces with what appeared to be argali fur in them, near the location where we saw 7 mature rams in Nakchirshitk. We found a freshly dug brown bear (*Ursus arctos*) den in upper Shikargah as well as tracks nearby. Near the junction of Shikarga and Kund-a-thoor/Asan Kittich valleys, we followed fresh brown bear tracks in snow for over a kilometer on 1 December, 2007 (figure 3). We saw Ibex (*Capra sibirica*) in Ali Su, Manjulak, Shikargah, Asan Katich, and War-war drainages. We did not see snow leopard (*Uncia uncia*), or signs of snow leopard, in any drainage.

Figure 3. Brown bear tracks near the junction of Shikargah and Kund-a-Thur valleys on 1 December, 2007. Boot is 32 cm long.

Preliminary Population Estimate

We do not yet have data to make a population estimate using mark-recapture data, but with some arguable assumptions can offer a rough estimate of the late 2007 population. If we assume that we saw 80% of the Big Pamir population of ewes, and that the adult sex ratio is 60:40 (ewes:rams), (Geist 1971; Petocz et al. 1978) using the number of unique ewes we sighted (Table 1b), we can:

a) estimate the number of ewes at 110/.80 = 138;

b) lambs at 138 x .25= 34;

c) yearlings (using the mid-point between the low and high recruitment estimate here) at 138 x .12 = 17;

d) and males at 138 x .4 = 55;

5) for a total of 244.

This is a tentative, point estimate with no way of calculating sampling variance, and if our assumptions about sightablilty (the proportion of the population's ewes we saw), sex ratio, and our estimates of the lamb:ewe and yearling:ewe ratios are incorrect, the estimate could vary substantially up or down. For example, if we assume we saw all of the ewes in the population and hold all other assumptions constant, we obtain a population estimate of 195, and if we assume we saw 60% of the ewes, the estimate jumps to 325. However, in November and December, argali appeared to have been concentrated in a relatively small area that we covered well, sampling intensively both within and outside of the apparent winter range (Figures 2,3). Thus, assuming that we saw a high proportion of the ewes in the population is not unreasonable. Still, until we have more (genetic) data that can be subjected to rigorous analyses, our population estimates should be viewed with caution and some healthy skepticism.

Argali Summer and Winter range

The mean elevation of argali locations in the summer was 4722 m (15,558 ft) and 4465 m (14,734 ft) in the winter (Table 1a &1b). The minimum convex polygon (MCP) enclosing all winter locations was 10.2 km farther west, and 5.5 km farther north than the MCP around summer locations, and there was only slight overlap in the winter and summer ranges (Figure 4). According to our guide, Sabir, and the head of our yak herders, Somet Khan, during November and December 2007, there was less snow than normal in the study area - we encountered little snow over 15 cm deep up to elevations of 4850 m (16,000 ft). If snow pack was indeed below average in 2007, we would expect our estimates of winter range to not represent the long-term average winter habitat use, and for argali to use lower elevations and areas farther to the west (the mountains slope downward towards the west) in years of heavier snow fall.

From our summer observations, it appears that argali may be vertically displaced by livestock operations that push to near the heads of drainages

Displacement appears to be stronger in the winter, with argali avoiding entire drainages that have active livestock operations. In addition, the strong reaction argali had to our presence (leaving drainages upon our arrival, and staying away during our occupation), and summer observations of argali foraging near unattended yaks at higher elevations, suggest that there may be multiple important interactions driving argali habitat use: avoidance of wolves, resource competition from livestock, avoidance of humans; and possibly, summer facilitation by yaks at higher elevations.

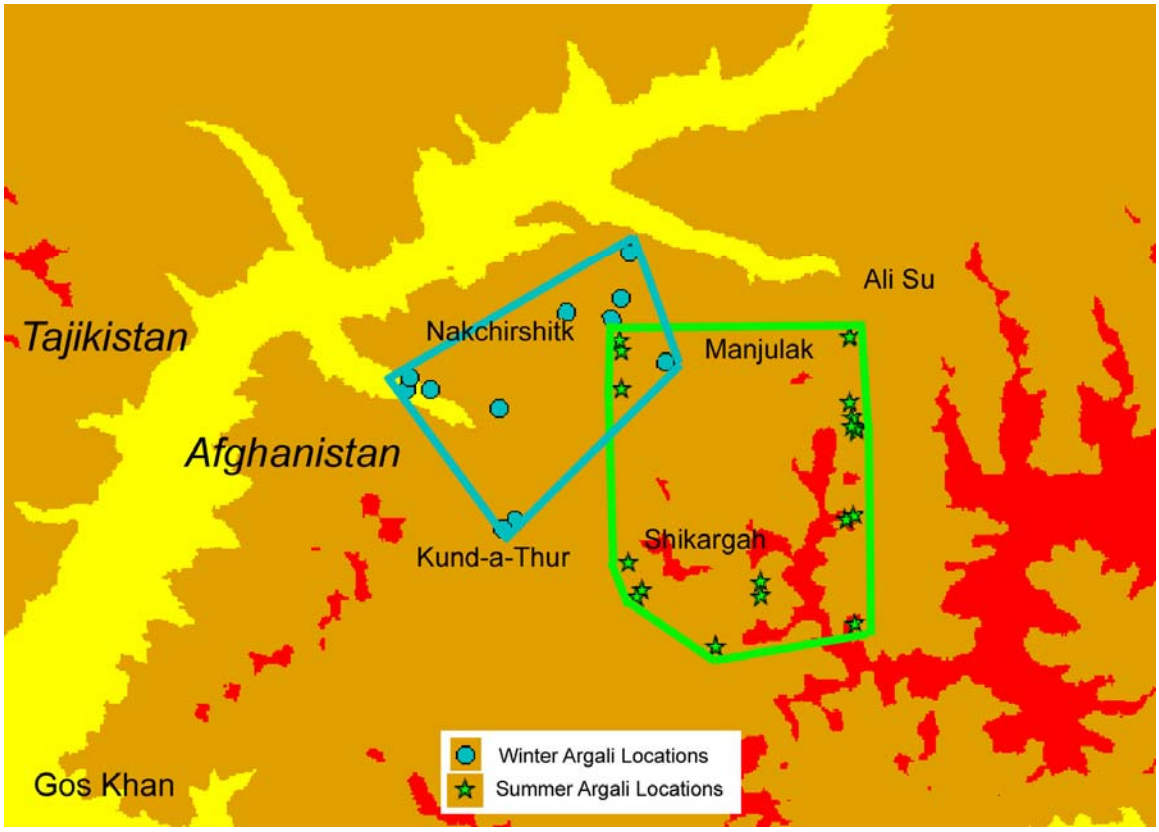

Figure 4. Summer (green) and winter (aqua) argali locations enclosed in Minimum Convex Polygons. Yellow areas are lower elevations, tan are intermediate, and red are highest elevations.

Hypotheses that may explain argali distribution and habitat use

Resource competition and avoidance of humans

Given the heavy levels of grazing and browsing by the broad suite of livestock that we observed, competitive exclusion of argali, particularly by large domestic sheep herds, appears possible. In the summer and fall, argali in the study area are outnumbered by domestic sheep by orders of magnitude. These domestic herds are kept high in the valleys until well after the growing season has ended, precluding the chance for vegetation recovery before the onset of winter. When this is combined with the strong flight response argali have when confronted by humans - even humans at great distances - large tracts of otherwise suitable foraging habitat may be made unavailable to argali while livestock operations are present. Furthermore, due to the lack of late season re-growth, these areas are probably less valuable to argali once livestock operations pull out of the drainages in the early winter.

Facilitation by yaks

The dynamic natures of ungulate - habitat and ungulate - ungulate interactions have been extensively explored in temperate and tropical grass- and range-lands (McNaughton 1984; McNaughton and Georgiadis 1986; Fryxell 1991; Frank and McNaughton 1998; Augustine 2004; Winnie et al. 2008). Some of the relationships identified in these systems may occur in the high, near desert, environment of the Big Pamirs. For example, anecdotal evidence suggests that in the summer, argali often graze in areas also occupied by yaks (which are often at high elevations and unattended by humans and dogs). This tolerance of yaks could be due to the lack of humans, or reflect a form of facilitation identified by McNaughton (1984) on African savannas: large bovids tend to eat taller, coarser materials than smaller grazers, keeping otherwise coarse (when mature) species in early growth stages. In their early growth stages, otherwise tall, coarse and unpalatable species are more palatable to smaller species of grazer. Areas where this is occurring are referred to as

grazing lawns, and they appear to be present in systems as widely diverse as Serengeti and Yellowstone (McNaughton 1984; Frank and McNaughton 1998). The situation in the Big Pamirs is potentially similar because yaks are roughly analogous to the large bovids in McNaughton's studies (African buffalo) and argali are similarly analogous to the mid-sized grazers and browsers in the studies (Hartebeest, Eland, Waterbuck, Grant's Gazelle and Impala). If facilitation is occurring, it offers the possibilities of concessions to, and alternatives for, local herders who stand to face sheep grazing restrictions if the Pamir-i-Buzurg reserve is re-established. Alternatively, argali may simply react to untended domestic yaks in a neutral way, similarly to how they have been documented to behave where wild yaks (*Bos grunniens*) are in close proximity (Harris and Miller 1995)

Summary

Our argali observations in the Big Pamir are generally consistent with observations made by Schaller during his survey of (primarily) the Little Pamir in 2004 (WCS internal report). From our observations, we can reasonably infer that: livestock operations exclude, or partially exclude, argali from drainages (whether this is due to competition with domestic animals or the presence of the humans attending the livestock, or both, is unclear); argali are very shy and will flee drainages altogether when humans are present; female herds may tend to be relatively sedentary (a survey trip 3 weeks before ours located a herd of 120 ewes and lambs in Manjulak drainage, and when we arrived we found a herd of 119 ewes and lambs within 500 m of the same location - presumably the same herd); we can not address whether males travel extensively because we have no movement data across time scales longer than a few hours, nor can we yet address whether argali in the Big Pamir are moving between Afghanistan and Tajikistan. However, once our genetic analyses investigating regional population connectivity are completed, we may be able to address this latter point, as well as whether argali from the Little Pamir are moving between Afghanistan, Tajikistan, China, and Pakistan.

Acknowledgments

We gratefully acknowledgement the assistance of Assadulah Khairzad, Bilal Habib, Zalmai Mohreb, Sabir, and Safdar in the field. Stephane Ostrowski, Donald Bedunah, Inayatollah Farahmand, Qais Sahar, Shafiq Fydaee, Alex Deghan, and Peter Bowles also provided us with much needed advice and assistance.

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Appendix

Capacity Building

Throughout the both 2007 trips to the Big Pamir, we worked with Sabir on sampling techniques and the use of handheld GPS (geographic positioning system). Sabir does not speak or write English, but quickly learned how to read and record GPS locations in a log book, store waypoints in the GPS unit, as well as how to relate a GPS location to a map with a UTM (Universal Transverse Mercator) grid. He also learned the importance of sampling technique, both at the local geographic scale (setting up a sampling grid-search pattern for collecting fecal samples), and at the scale of the individual sample (careful labeling, redundant documentation, and avoiding cross-contamination of samples). In February 2008 Sabir (assisted by our cook, Safdar) will be duplicating our November/December 2007 survey route (Figure 2), gathering fecal samples and recording argali locations, so this training was critical to the success of the upcoming trip. This will be the first time Sabir has been employed to work independently as a field technician, and if successful, will be a significant move up in responsibility and qualifications for him, not to mention substantially increasing his value to WCS and other organizations looking for competent field technicians.