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Argali lamb (*Ovis ammon*) morphometric measurements and survivorship in Mongolia

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Abstract

We examined variables that might affect survivorship of neonatal argali sheep (*Ovis ammon*), including body weight, date of birth, gender, precipitation, and year affects, which often influence neonatal survivorship in other species of sheep. From 2003 to 2008 we hand-captured 75 argali lambs (38♂, 36♀, 1 undetermined) and attached expandable, drop-off radio collars in Ikh Nart Nature Reserve, Mongolia. We collected morphometric and physiological measurements and radio-tracked lambs to obtain data on survivorship and mortality. We found similar morphometric and physiological measurements for male and female lambs, with significant differences only in foreleg length (♀<♂) and respiration rates (♀>♂). Only 44.6% of argali lambs survive their first month of life, but thereafter their mortality rate decreases. Lambs not born in 2006, born in years following years with higher April precipitation, and born later in the year enjoyed significantly higher survival to one month. We found high mortality in the years with severe drought (2005–2006), which depressed overall survivorship. We found no significant effect of any physiological or morphometric variables on lamb survival. Argali lambs die from several causes, with predation (44.6%) and starvation (21.4%) being the most significant.

Keywords: argali; lamb; Mongolia; morphometrics; *Ovis ammon*; survivorship.

Introduction

Recruitment of young animals into a population is obviously vital to the endurance of that population. Several factors influence the survivorship of neonatal young. We undertook this study to examine some of the factors that might affect survivorship of neonatal argali sheep (*Ovis ammon*). In other species of wild and domestic sheep (*Ovis aries*), birth weight, date of birth, gender, precipitation, and year affects often influence neonatal survivorship (Huffman et al. 1985, Festa-Bianchet 1988, Yapi et al. 1990, Gama et al. 1991, Mukasa-Mugerwa et al. 1993, 2000, Festa-Bianchet et al. 1997, Portier et al. 1998, Southey et al. 2001, Mandal et al. 2007, Awan et al. 2008). Many studies found that later birth dates and lamb weights (often correlated) result in higher survivorship. In some cases, heavier lambs survived better (Huffman et al. 1985, Yapi et al. 1990, Mukasa-Mugerwa et al. 1993, 2000, Mandal et al. 2007), while in others both lighter and heavier lambs experienced higher mortality (Casellas et al. 2007, Sawalha et al. 2007). Body weight of lambs may only be important during years of serious resource constraints (Festa-Bianchet et al. 1997). Festa-Bianchet (1988) found that bighorn lambs (*Ovis canadensis*) born earlier in the year survived better than lambs born later, because earlier birth dates correlated with times of higher forage quality. While some researchers found that male lambs experienced higher rates of mortality than female lambs (Huffman et al. 1985, Gama et al. 1991, Mukasa-Mugerwa et al. 2000, Southey et al. 2001, Mandal et al. 2007, Sawalha et al. 2007), others found no difference (Yapi et al. 1990, Awan et al. 2008). Year affects, often correlated with precipitation, also affected survivorship in several studies (Gama et al. 1991, Portier et al. 1998, Enk et al. 2001, Garel et al. 2004, Mandal et al. 2007, Awan et al. 2008). We therefore focused on these variables and how other morphometric variables correlated with gender and body weight.

Understanding factors affecting recruitment in argali sheep is important because the species is considered endangered in Mongolia (Shiirevdamba et al. 1997, Wingard and Odgerel 2001, Clark et al. 2006). In Mongolia, argali inhabit the mountains and rocky outcrops of the southern, central, and western portions of the country, but their range is decreasing and becoming increasingly fragmented (Mallon et al. 1997, Amgalanbaatar and Reading 2000, Reading et al. 2001). Data on argali ecology, threats, and factors influencing survivorship remain limited, but are increasing (Fedosenko and Blank 2005, Reading et al. 2005, Wingard 2005). Poaching continues to be an important source of mortality in Mongolia (Mallon et al. 1997, Reading et al. 1997, 2001, Amgalanbaatar and Reading 2000). Argali also suffer with regard to livestock grazing, as herds of domestic sheep and goats displace argali and likely compete with them for water and forage (Sukhbat and Gruzdev 1986, Mallon et al. 1997, Reading et al. 1997, 1998, 2001, Amgalanbaatar and Reading 2000, Wingard 2005). Other species of livestock are also likely to compete to a lesser extent with argali. Finally, we also found that domestic guard dogs can pose a significant threat to argali (Reading et al. 2005).

From 2003 through to and including 2008, we hand-captured argali lambs during spring in southeastern Mongolia for radio-collaring. In addition to attaching a radio-collar on each lamb, we obtained several morphometric and physiological measurements from the animals we captured. The goals of this study were to better understand the factors affecting neonatal survival and the relationships between different morphometric and physiological characteristics. To the best of our knowledge, this is the first large-scale analysis of lamb morphometrics and survivorship for this threatened species.

Materials and methods

We conducted our research in Ikh Nart Nature Reserve (hereafter Ikh Nart), located in northwestern Dornogobi Aimag, Mongolia (45.723°N, 108.645°E). Ikh Nart was established in 1996 to protect 66,760 ha of rocky outcrops and its wildlife on the northern edge of the Gobi (Myagmarsuren 2000, Reading et al. 2006). The region is a high upland (~1200 m) covered by semi-arid steppe vegetation. The climate is strongly continental and arid, characterized by cold winters (to -40°C), dry, windy springs (to 25 mps), and relatively wet, hot summers (to 43°C). The flora and fauna are representative of the semi-arid regions of Central Asia, with a mix of desert and steppe species (Reading et al. 2006).

The methods used conformed to the ASM (American Society of Mammalogists) guidelines for research on live animals and were approved by the Mongolian Academy of Sciences. We captured argali lambs during spring. Argali ewes typically hide their newborn lambs for ~24–72 h following parturition before joining other ewes and lambs in nursery groups (Schaller 1977, Fedosenko and Blank 2005). We located lambs opportunistically, searching for them from late March until mid-May while conducting other fieldwork or by searching for ewes that displayed behavior indicating they had hidden a lamb. A ewe with a neonatal lamb typically runs a short distance (a few hundred meters) initially, stops, turns and looks back before running further and repeating the process. Usually, such females circle the general area where their lamb is hiding, often watching at 500–750 m while we searched for the lamb. Team members then search the area for the hidden lamb. This process generally took 20–30 min, if successful at all. Once a lamb was located, capture worked best with at least three team members. The team would surround the lamb, with one individual silently and slowly moving forward from behind to grab the animal. Lambs older than ~72 h typically fled once we reached within a dozen or so meters and were too fast and agile to capture.

We hooded captured lambs to minimize stress and held the animals on our laps. We placed ear tags and expandable, drop-off radio telemetry collars (Diefenbach et al. 2003) on captured lambs and collected a number of physiological and morphometric measurements, including temperature (°C); pulse rate: heart beats per minute; respiration rate: breaths per minute; body length (TBL): tip of nose to base of tail; height: top of shoulder to foot placed flat; girth: chest circumference just behind front legs; foreleg: point of elbow to tip of foot; hindleg: point of hock to tip of foot; neck: circumference where radio-collar attached; tail: base to tip; and ear: tip through middle to base. We obtained temperatures with a rectal thermometer; weights (kg) by placing the lamb in a tared cloth sack and suspending it from a scale; and other morphometric measurements (cm) with a metric tape measure. The entire process lasted approximately 15 min.

We radio-tracked collared lambs on the ground for a minimum of 2 weeks every month using hand-held receivers and Yagi antennas. We attempted to locate all collared animals every day, but usually only obtained locations for a few days each month. We equipped collars with a mortality switch and tried to locate animals that died as quickly as possible to determine the cause of death. Where possible, we determined cause of death by animal spoor, method of killing (for predation events), and necropsies of complete or mostly complete carcasses. We examined stomach, intestinal tracks, and the marrow of lone bones whenever possible.

We examined variables for normality using the Shapiro-Wilk test for normality and the Kolmogorov-Smirnov test. We square-root transformed some variables to make them conform to normality. For normally distributed variables, we used t-tests to compare means, with adjustments for separate variances where appropriate. We compared non-normally distributed variables using the Mann-Whitney U-test. We ran stepwise and general linear models and linear regressions to explore the effects of body measurements on body weight, and logistic regression to explore the effects of variables on lamb survival for >1 month. Due to data limitations, we were forced to analyze lamb survival in two stages. We initially considered year affects, birth weight, gender, and date of birth on survival. Since some year affects were significant, we explored precipitation by year, previous year, each month, month in previous years, season, and previous season. We combined results from the two step-wise logistic regressions to attain our final model.

Results

In six field seasons (2003–2008) we captured and measured 75 lambs (38♂, 36♀, 1 undetermined) in Ikh Nart. The lambs we captured represented 74 litters (i.e., a single ewe had twins, both of whom we collared). We captured lambs between March 29 and May 11, with most captures (48.0%) occurring during April 6–15 (Figure 1). We also observed 4 neonatal lambs in the fall while conducting other research; 2 of these animals died within 2 days of us first sighting them. The dams of these lambs clearly cycled and were bred out of season. Parturition appeared to occur over an approximately 4-week period that shifted later in the season over the course of the study (adj. $R^2=0.23$, $F_{1,73}=22.82$, $p<0.001$) (Figure 1). This result appears to result from changing rainfall patterns in Mongolia; later birth dates correlated with higher rainfall during the previous summer and lower rainfall

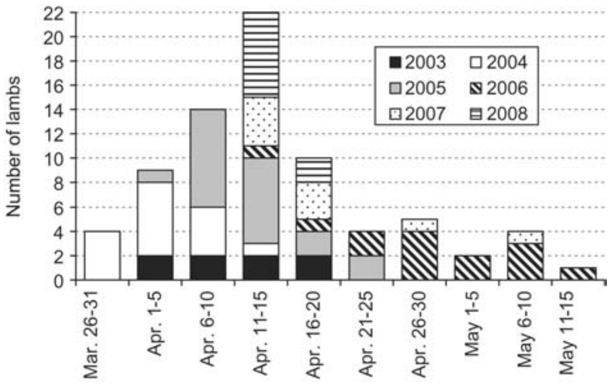

Figure 1 Number of argali lambs (*Ovis ammon*) captured/5-day time period from 2003 to 2008 in Ikh Nart Nature Reserve, Mongolia.

during the previous fall (Table 1). Mean birth date did not vary by gender (t=0.02, df=72, p=0.95). Lambs born later in the season weighed significantly less than lambs born earlier (adj. R^2=0.10, $F_{1,67}$=8.71, p<0.01).

We found similar morphometric measurements for male and female lambs (Table 2). The only significant difference between males and females was foreleg length (t=2.09.5, df=64, p=0.04) (Table 2). All other measurements were similar (p>0.06). Of the three physiological measurements we collected, male and female lambs displayed similar temperature and pulse rates (t=0.70, df=55, p=0.49 and t=0.24, df=51, p=0.81, respectively). However, females had significantly higher respiration rates than males (t=3.39, df=47, p<0.01) (Table 2).

When analyzed separately, all morphometric variables we collected correlated significantly with weight (Table 3). The best multivariate model, however, included five

Table 1 Influence of rainfall on argali (*Ovis ammon*) parturition in Ikh Nart Nature Reserve, Mongolia.

Variable	Cum. adj. R^2	Coefficient	Tolerance	t	p
Precipitation in previous Fall	0.36	-0.053	0.80	-9.96	<0.001
Precipitation in previous Summer	0.53	0.074	0.72	5.85	<0.001
Precipitation in previous Winter	0.66	-0.099	0.77	-1.60	0.11

Adj. R^2=0.66, $F_{3,62}$=42.85, p<0.001.

Table 2 Physiological and morphometric measurements for argali lambs (*Ovis ammon*) captured for a radio-telemetry study in Ikh Nart Nature Reserve, Mongolia, 2003–2007.

Measurement	Males				Females				All animals			
	Mean	SE	Range	n	Mean	SE	Range	n	Mean	SE	Range	n
Weight	4.53	0.16	3.0–6.5	36	4.23	0.11	3.0–5.0	33	4.38	0.10	3.0–6.5	69
TBL	64.65	0.91	55–76	35	64.40	0.91	53–76	34	64.52	0.64	53–76	69
Height	47.54	0.75	40.0–54.5	32	46.74	0.64	37–53	33	47.13	0.49	37.0–54.5	65
Girth	40.20	0.52	33–46	35	39.34	0.61	31.5–49.6	34	39.63	0.37	31.5–49.5	69
Foreleg	20.84	0.24	18–24	32	20.13	0.24	17–23	34	20.47	0.17	17–24	66
Hindleg	23.74	0.26	21.0–26.5	35	23.36	0.24	20–26	36	23.55	0.18	20.0–26.5	71
Neck	19.36	0.39	15–23	33	18.52	0.29	15–22	30	18.96	0.25	15–23	63
Tail	4.77	0.16	3.0–7.0	35	5.16	0.16	3.0–7.5	36	4.97	0.12	3.0–7.5	71
Ear	6.73	0.17	5.0–9.0	35	6.51	0.16	4.0–8.0	36	6.62	0.11	4.0–9.0	71
Hoof length	3.34	0.08	2.6–4.5	33	3.33	0.08	2.2–4.0	34	3.34	0.06	2.2–4.5	65
Temperature	38.89	0.24	36.2–42.5	30	39.13	0.24	35.1–40.8	27	39.01	0.17	35.1–42.5	57
Pulse	89.93	4.93	56–160	28	88.56	5.13	36–140	25	89.28	3.52	36–160	53
Respiration	61.15	4.15	24–102	27	84.00	5.01	32–128	24	71.90	3.69	24–128	51

SE, standard error. Temperatures in °C, pulses in beats/min, and respiration in breaths/min, weight in kg, and all other measurements in cm.

Table 3 Relation between morphometric variables and weight of argali lambs (*Ovis ammon*) in Ikh Nart Nature Reserve, Mongolia.

Variable	Linear regression				Multiple regression				
	Adj. R^2	Coefficient	t	p	Cum. adj. R^2	Coefficient	Tolerance	t	p
Neck girth*	0.35	0.61	5.73	<0.001	0.35	0.30	0.51	2.43	0.02
Hoof length*	0.21	0.47	4.22	<0.001	0.49	0.46	0.49	3.59	0.001
Tail length*	0.06	0.26	2.21	0.03	0.56	-0.35	0.54	-2.91	0.006
Total body length*	0.23	0.49	4.50	<0.001	0.64	0.22	0.55	1.87	0.07
Height*	0.26	0.52	4.71	<0.001	0.70	0.28	0.47	2.17	0.04
Girth	0.38	0.63	6.38	<0.001	0.71	0.14	0.34	0.91	0.737
Ear length	0.17	0.43	3.81	<0.001	0.72	-0.079	0.53	-0.65	0.52
Hind leg length	0.35	0.60	6.03	<0.001	0.72	0.071	0.41	0.51	0.61
Foreleg length	0.32	0.57	5.43	<0.001	0.72	0.018	0.47	0.14	0.89

All values for the multiple regression, except cumulative adjusted R^2 (taken from the step-wise regression), taken from the complete model (i.e., all variables included). Variables with * included in final regression: adj. R^2=0.67, $F_{5,45}$=21.17, p<0.001.

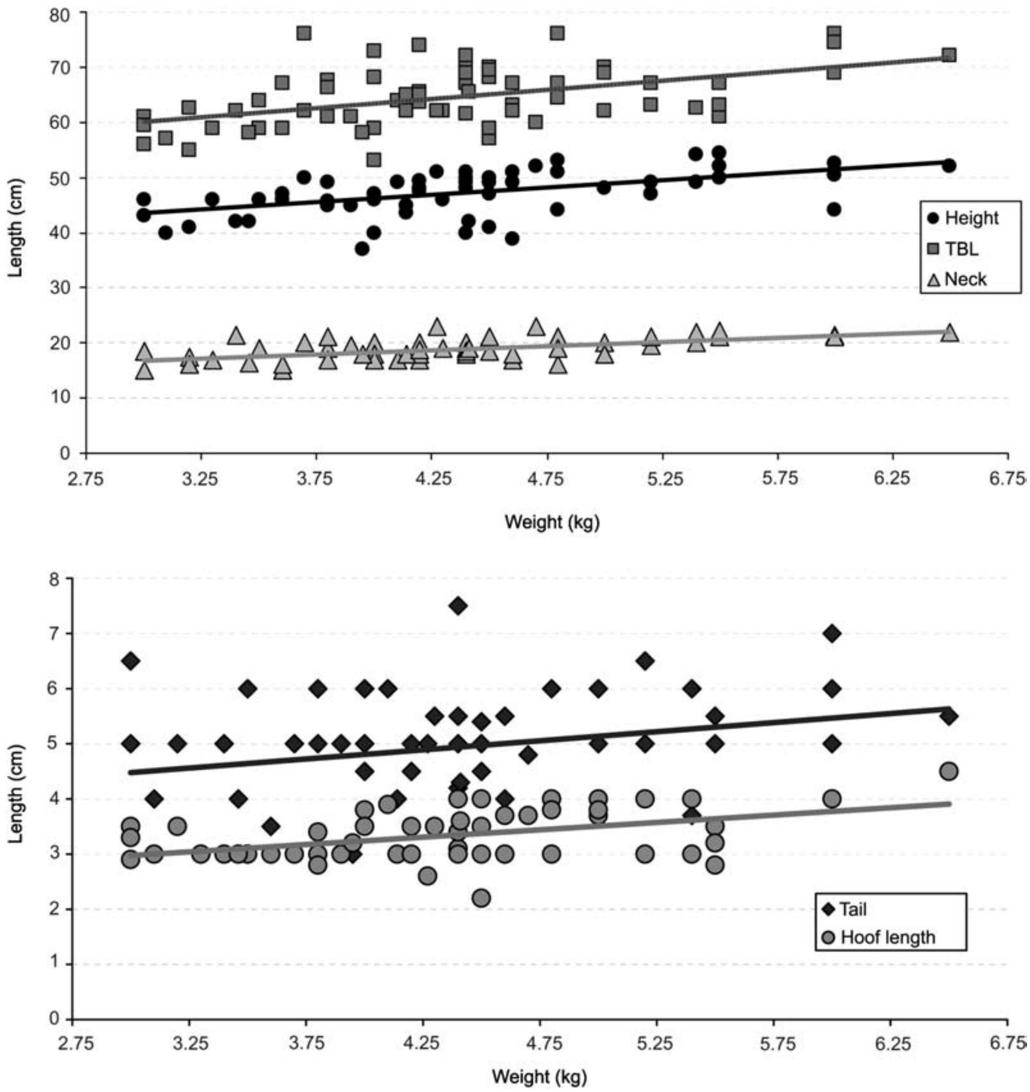

Figure 2 Relationship between argali lamb (*Ovis ammon*) weight and other morphometric measurements. Top: height (adj. R^2=0.26, $F_{1,60}$=22.19, p<0.001), TBL (total body length: adj. R^2=0.23, $F_{1,63}$=20.28, p<0.001), and neck (adj. R^2=0.35, $F_{1,57}$=32.83, p<0.001). Bottom: tail (adj. R^2=0.06, $F_{1,65}$=4.87, p=0.03) and hoof length (adj. R^2=0.21, $F_{1,63}$=17.77, p<0.001).

measurements: neck girth, hoof length, tail length, total body length, and height (Table 3, Figure 2). Together, these variables accounted for 66.9% of the variation in lamb weight (Table 3). The best single predictor of lamb body weight was neck girth, which accounted for 35.4% of the variation in body weight (Table 3, Figure 2).

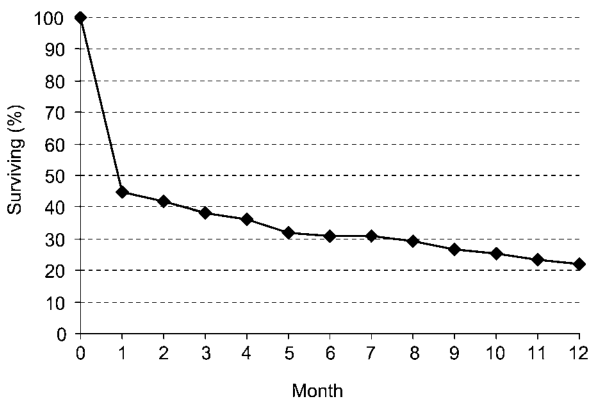

Figure 3 Argali lamb (*Ovis ammon*) 12-month survival rate in Ikh Nart Nature Reserve, Mongolia, 2003–2008.

Few argali lambs survive the first month of life, but thereafter their mortality rate decreases substantially (Figure 3). Overall, 44.6% (n=33 of 74) of lambs survived >1 month, 36.5% (n=27 of 71) survived >3 months, 30.8% survived >6 months (n=21 of 68), and 22.0% survived >1 year (n=13 of 59). Neonatal lamb survival >1 month varied from a low value of 19.0% in 2005 to a high value of 75.0% in 2003 for the first month of life (Figure 4). Our initial model found that some year affects and date of birth influenced survival >1 month, while birth weight and gender did not influence survival >1 month (Table 4). Analyses of precipitation data found that only precipitation in April of the previous year affected lamb survival, so we included this variable in our final model (Table 4). Not being born in 2006 was the most significant factor affecting survival to 1 month; however, precipitation in April of the previous year and date of birth (with animals born later doing better) also yielded significant affects (Table 4). Step-wise logistic regression also included the year 2005 in the final model, finding that not

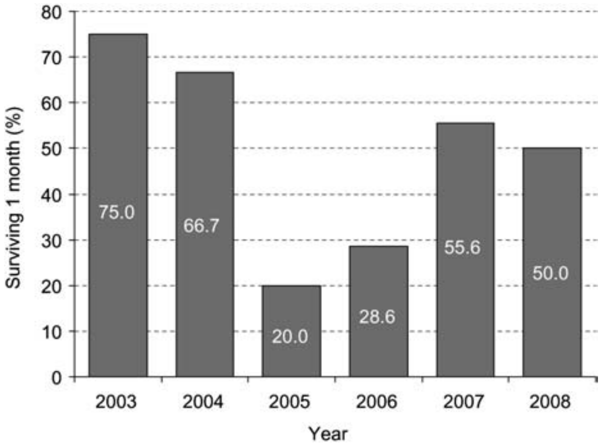

Figure 4 Percentage of argali lambs (*Ovis ammon*) surviving 1 month in Ikh Nart Nature Reserve, Mongolia, 2003–2008.

being born in 2005 improved survival, but this affect was not significant (Table 4).

Argali lambs die from several causes. Predators killed 44.6% of the argali lambs that died in our study, the most significant of all causes (Figure 5). Predators in Ikh Nart included Pallas' cats (*Otocolobus manul*) or manuls (13% of predations), wolves (*Canis lupus*) and dogs (*Canis familiaris*, we could not always distinguish) (20% of predations), red foxes (*Vulpes vulpes*) (8% of predations), unknown felids (12% of predations), a raptor (4% of predations), and unidentified predators (36% of predations). Starvation, especially during the particularly dry years of 2005 and 2006, represented the second leading cause of mortality (21.4%). Disease and apparent accidental deaths (e.g., falls) each accounted for 3.6% of lamb deaths and 1 lamb (1.8%) died due to capture-related issues; we remained too close to our first capture (~250 m) to ensure that the dam returned, but in doing

Table 4 Factors influencing survival of argali lambs (*Ovis ammon*) in Ikh Nart Nature Reserve, Mongolia.

Variable	Cum. adj. R^2	Coefficient	Tolerance	t	p
Initial model					
2005	0.08	-0.24	0.40	1.48	0.23
2006	0.11	-0.49	0.35	3.81	0.06
Date of birth	0.15	0.20	0.33	5.53	0.02
2004	0.19	0.47	0.33	3.35	0.07
2003	0.20	0.23	0.64	0.68	0.41
Weight	0.20	-0.06	0.74	0.57	0.46
Gender	0.21	0.05	0.92	0.14	0.71
2007	0.21	-0.03	0.50	0.02	0.90
Final model: adj. R^2=0.18, $F_{4,69}$=4.69, $p<0.01$					
2006		-0.49	0.53	-2.32	0.02
Precipitation in April of the previous year		0.04	0.42	2.12	0.04
Date of birth		1.37	0.40	2.07	0.04
2005		-0.24	0.57	-1.55	0.13

Values for the initial multiple logistic regression, except cumulative adjusted R^2 (taken from the step-wise regression), taken from the complete model (i.e., all variables included). Analyses on the square root of date of birth.

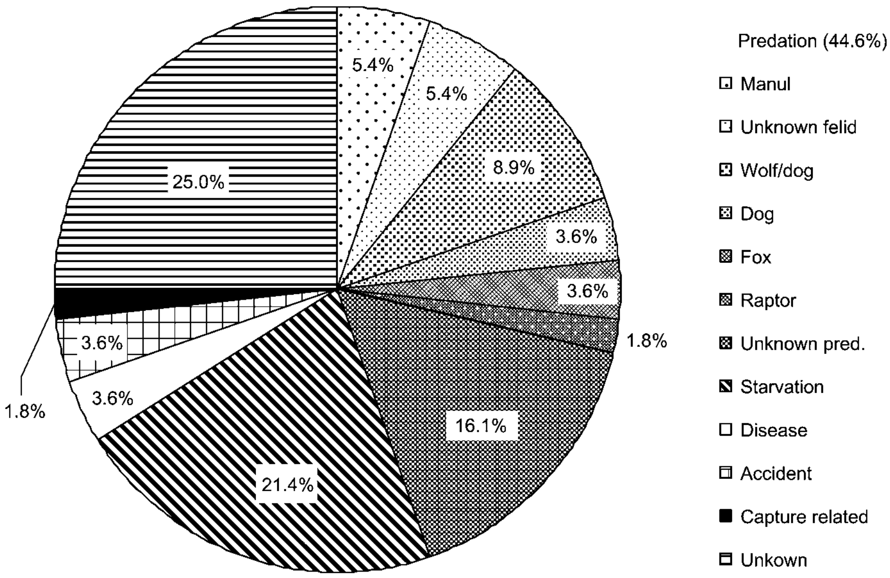

Figure 5 Sources of mortality for argali lambs (*Ovis ammon*) during their first year of life in Ikh Nart Nature Reserve, Mongolia, 2003–2008.

so probably prevented that ewe from returning. Finally, we could not determine the cause of death for 25.0% of the lambs that died.

Discussion

Argali rut and breeding takes place in November and early December in Ikh Nart (Schaller 1998, Fedosenko and Blank 2005, personal observation). Gestation lasts approximately 160–165 days (Fedosenko and Blank 2005). As is typical for *Ovis* (Schaller 1977), ewes separate from other animals as parturition approaches and deliver lambs in isolation. The lambs are hidden for the first few days of life under the careful watch of the dam. As with other wild sheep, and boreal ungulates in general (Festa-Bianchet 1988, Awan et al. 2008), parturition in Ikh Nart argali was highly seasonal and has begun shifting later in the year due to changing precipitation patterns. Festa-Bianchet (1988) found that bighorn lambs born earlier in season survived better, probably because those birth dates corresponded better with times of increased vegetation quality. In our study, argali lambs born slightly later in the season survived better than lambs born earlier. This may be related to the timing of vegetative production, as in Mongolia most precipitation falls between June and August, with very little spring precipitation (Reading et al. 2006). Rainfall patterns are also shifting later in the year (Reading et al. 2006), possibly due to global warming. As a result, vegetation quality improves in summer, well after argali parturition. However, Awan et al. (2008) found no difference in survival between urial (*Ovis vignei*) born early or late in Pakistan, which experiences seasonal rainfall patterns similar to those in Mongolia.

Fedosenko and Blank (2005) summarize the limited data on argali lambs that can be found in the literature. They report that young Gobi argali (*Ovis ammon darwini*) weighed 3.5–4 kg at 10–15 days of age and captive *Ovis ammon collium* newborn argali weighed 3.5–4.5 kg. They provide additional measurements for a small number of Marco Polo sheep (*Ovis ammon poli*) at birth. Males measured 62 cm in total body length; 57.5 cm in height at the shoulder; and 46.6 cm in chest girth at birth. Marco Polo lambs therefore tend to be lighter, but taller in stature and wider in girth than *O. a. darwini* from Ikh Nart. Not surprisingly, several morphological measurements correlated with body weight, but neck girth was the best single predictor. We found no correlation between body weight of neonatal lambs and survival. In contrast, most studies of domestic sheep found that either heavier or medium weight lambs survived better (Huffman et al. 1985, Yapi et al. 1990, Gama et al. 1991, Mukasa-Mugerwa et al. 1993, 2000, Casellas et al. 2007, Mandal et al. 2007), but also see Warren et al. (2001). For wild sheep, Awan et al. (2008) found that heavier urial lambs survived better than lighter lambs, and Festa-Bianchet et al. (1997) found that body mass affected bighorn lamb survival only during years with high resource constraints. In Ikh Nart, body weight remained an unimportant influence on survival even during the drought years of 2005–2006 (R^2=0.00, $F_{1,31}$=0.49, p=0.49).

Despite the even sex ratio at birth, adult populations of argali and other Caprids are heavily skewed toward females (Schaller 1977, Reading et al. 1997, Fedosenko and Blank 2005). The adult population at Ikh Nart was similarly skewed toward females (unpublished data) after an even sex ratio at birth. Despite this eventual trend toward more females in the population, we found similar survivorship among neonatal males and females. No difference in male and female neonatal survival contrasts with some studies of other wild and domestic sheep (Huffman et al. 1985, Gama et al. 1991, Southey et al. 2001, Garel et al. 2004, Mandal et al. 2007, Sawalha et al. 2007), but not others (Yapi et al. 1990, Doloksaribu et al. 2000, Awan et al. 2008).

Similar to our findings, Fedosenko and Blank (2005) report that the highest mortality for argali occurs during the first few months of life; however, they report lower death rates for lambs [11.9–37% for the first 3–4 months for Altai argali (*Ovis ammon ammon*); 42.5–70% for the first year for *Ovis ammon collium*; 35.7–38.5% for *Ovis ammon karelini*; and 67.2% for Marco Polo sheep (*Ovis ammon poli*)]. Schaller (1977) found that mortality among young sheep and goats was high and variable from year to year. We also found high variability between years. During a severe drought in 2005–2006, 81.0% and 71.4% of marked lambs died within their first month, respectively (Figure 4). These high mortality rates depressed overall survivorship in our study. Similarly, Garel et al. (2004) reported the negative impacts of a severe drought on a population of mouflon (*Ovis gmelini*×*Ovis* sp.) in France. Lambs in poorer physical condition may be easier to hand-capture, possibly inflating our mortality rates during these drought years; however, we believe this is unlikely, especially given the survivorship in 2003 and 2004.

As with argali in Ikh Nart, predation represents the main cause of mortality for most neonatal ungulates in environments that retain predators (Linnell et al. 1995). Some bighorn sheep populations suffer from very high levels of predation on neonatal lambs (e.g., Hass 1989), and Awan et al. (2008) report that predation was the main cause of mortality for urial lambs. Similar to the situation in Ikh Nart, Fedosenko and Blank (2005) report that wolves represent the main predators of argali, but that lynx (*Lynx lynx*) and domestic dogs also kill and eat young. Previously (Reading et al. 2003, 2005), we reported that domestic dogs kill young and adult argali, and that red foxes and Pallas' cats kill neonatal lambs. Starvation is the second most important cause of mortality for most neonatal ungulates (Linnell et al. 1995), which is in agreement with our findings for argali in this study.

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