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Dietary overlap between argali sheep and domestic livestock in Mongolia

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DIETARY OVERLAP BETWEEN ARGALI SHEEP AND DOMESTIC LIVESTOCK IN MONGOLIA

by

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Competition for forage between wild ungulates and domestic livestock is poorly understood. Conservation of the endangered argali sheep (*Ovis ammon)* in Mongolia is hindered by inadequate understanding of the impact sympatric domestic sheep and goats, hereafter referred to as "shoats," have on available forage. I studied the food habits of argali and shoats in Ikh Nart Nature Reserve, in Dornogobi Province, Mongolia to evaluate the degree of dietary overlap. I collected 100 fecal samples from argali, and 100 from shoats during all seasons in 2002-2003.

I used fecal analysis as a primary method to estimate botanical composition of their diets. Shrubs were the most selected forage categories, followed by grasses, forbs, and sedges. Argali diets were more varied than shoats for all seasons, with 12 key species comprising a smaller percentage of the diet (58.0% summer, 46.9% fall, 68.6% winter, and 66.4% spring) compared to only 9 key plant species comprising a larger percentage of shoats' diet (70.0% summer, 63.6% fall, 75.3% winter, and 78.0% spring). Dietary overlap between argali and shoats was high and ranged from 93% in summer to 99% in winter at the plant category level; at the key species level overlap ranged from 72% in summer to 95% in winter.

I also compared forage availability between summer and winter by clipping above ground biomass in summer and above snow biomass in winter. Biomass decreased significantly between seasons, from 19g/m^2 to 3.4g/m^2. I collected plant species after direct observations of argali and shoats to determine nutritional quality of forage. These plants were analyzed for crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), dry matter digestibility (DMD), and ash to determine seasonal nutritional values and changes. Both CP and DMD concentrations increased in summer and fall, and decreased in winter and spring. Conversely, NDF, ADF, and ADL contents were lower in summer and fall and increased through winter and spring.

The high degree of dietary overlap and low biomass suggests the potential for competition between argali and shoats. A reduction of livestock would likely improve the situation for argali.

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Finally, I dedicate this thesis to the memory of my mother and father, who understood the power of the knowledge and always inspired me. Unfortunately, neither of them could see this thesis completed; however, I know they believed in me and this gave me strength. Thank you.

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INTRODUCTION

Conservation of argali sheep (*Ovis ammon*) presents a significant challenge to biologists and conservation managers in Mongolia. Although argali are endangered and available data suggest they are declining, the mechanisms causing their decline are poorly understood. However, available data suggest that declines in argali may be attributable in part to competition with domestic livestock for forage. This study aimed to determine food habits of argali, forage availability, and dietary overlap between free-ranging argali sheep and domestic sheep and goats using comparative fecal, forage, and nutritional analysis in Mongolia.

CONSERVATION ISSUE

Argali are the largest mountain sheep in the world, with some males weighing as much as 200 kg and sporting impressive horns that reach over 165 cm in length (Valdez 1982). Argali have relatively long, thin legs and compact bodies built for running speed (Schaller 1977). They prefer rolling hills, plateaus, gentle slopes, rugged mountainous terrain, and areas with rocky outcrops in central Asia, including portions of Mongolia (Sukhbat 1975, Lushchekina 1994). Until recently, 2 subspecies of argali, Altai argali (*O. a. ammon*) and Gobi argali (*O. a. darwini*), were recognized in Mongolia. Over the years, various scientists also classified Gobi argali as *O. a. mongolica, O. a. hodgsoni,* and *O. a. kozlovi*, (Tsalkin 1951, Zhirnov and Ilyinsky 1986, Geist 1971, Reading 1997). However, the results of a recent study on argali population genetics do not support the existence of two subspecies of argali in Mongolia (Tserenbataa et al. 2004). The results from the genetics study are consistent with the supposition that argali movement is widespread and that gene flow between populations in Mongolia is frequent (Tserenbataa et al. 2004).

Threats to argali are not new. Argali have long been a target of local subsistence hunters for meat and in the last decade for trade in medicinal products (the horns are traded in Asia as an aphrodisiac). Foreign sport hunters have coveted their large body and horns and been allowed access since the 1960s. Mongolia permitted the taking of 1,630 males from 1967 to 1989 by trophy hunters (Amgalanbaatar 1993). The Mongolian government recognized the threat to argali and began to manage hunting as early as 1953 (Zhirnov and Ilyinsky 1986, Shagdarsuren et al.1987, Luschekina 1994, Reading et al. 1999, Amgalanbaatar et al. 2003). With increased pressure, Mongolia listed argali in the Mongolian Red Book of Threatened and Endangered Species as threatened in 1987 and now applies criminal sanctions for poaching under the Mongolia Law on Hunting (Shagdarsuren et al. 1987, Wingard and Erdene-Ochir 2004). The Convention on International Trade of Endangered Species of Wild Flora and Fauna (CITES) includes argali in Appendix II (Wingard and Odgerel 2001).

Prior Research and Management Actions

Mongolia has still no official management plan for argali, hunting revenues are not earmarked for conservation of the species, and research remains inadequate to accurately define its status (Amgalanbaatar et al. 2003). In October 2000, the Mongolian Ministry of Nature and Environment (MNE) held a meeting on strategic conservation planning with biologists from the Mongolian Academy of Scientists and World Wide Fund for Nature (WWF) - Mongolia office (MNE and WWF-Mongolia 2000). This plan called for many actions, including developing a central database, standardization of population survey methods, implementing research and monitoring, and enhancing law enforcement and public awareness programs. However, virtually no actions have been taken by the government since that time.

The number of argali that currently inhabit Mongolia is unknown. Past population estimates relied on insufficient, sometimes contradictory data that covered only parts of the species' range (Luschekina 1994). Official government estimates from the Mongolian Academy of Sciences were 50,000 argali in 1975 and 60,000 animals in 1985 (Amgalanbaatar et al. 2003). Earlier estimates of argali numbers varied widely from as few as 10,000 in 1976 (Shanyavskii, 1976) to as many as 40,000 in 1993 (Amgalanbaatar 1993). The 2001 national population survey of argali using unpublished methods estimated that only 13,000 – 15,000 argali remain in Mongolia. Despite the lack of rigorous study, all available data seem to indicate that argali in Mongolia are declining (Reading et al. 1999; Amgalanbaatar et al. 2003).

The mechanisms causing the decline of argali remain unclear. Beyond hunting pressure (legal and illegal), the most likely contributing cause is competition with domestic livestock for forage and habitat (Dzielovskii 1980, Gruzdov and Sukhbat 1982, Zhirnov and Ilyinsky 1986, Shagdarsuren et al. 1987, Amgalanbaatar and McCarthy 1993, Luschekina 1994, Mallon et al. 1997, Reading et al. 1999; Amgalanbaatar and Reading 2000, Shrestha et al. 2004). The increasing number of herding families and livestock, since 1991, coupled with a lack of grazing management, has amplified the magnitude of this problem. The economic crash that followed Mongolia's departure from communism brought with it a wave of "new" herders - some by choice and many out of necessity. Herder numbers more than doubled in just 2 years after reform, jumping from a decades-long average of approximately 130,000 in 1991 to almost 350,000 by 1993 (Reading et al. in press a). With the increase in herders came a corresponding and dramatic increase in livestock numbers, rising 33% from approximately 25 million in 1990 to over 33.5 million in 1999 (Byambatseren 2004, NSO-Mongolia 2004). Cashmere goats were quickly recognized as the most valuable commodity and their numbers increased accordingly, growing 215% over 9 years; horse and cattle also rose sharply, increasing 140% and 135%, respectively, for the same time period, while sheep and camels have either remained relatively constant or declined slightly (Reading et al. in press a). The most recent estimates are likely as much as 25% low due to under reporting by herders to reduce tax liability (Reading et al. in press a). Extreme weather events in consecutive winters (1999-2000, 2000-01) contributed to a large crash in domestic livestock numbers. However, since that time, Mongolia's goat population managed to rebound by 200 % to pre-1999 levels (Reading et al. in press a).

Moreover, Reading et al. (in press a), witnessed a sharp decline in the degree of government oversight and control for this same period. Livestock production within the country was highly regimented and herd movements were restricted to specific areas during the communist era. Under the communists, herders were organized into herding collectives, called "*negdel.*" Herd and territory assignments came from the central government, with each *negdel* occupying a *Soum* (a subdivision of an *Aimag* or province). *Negdel* territories were subdivided into smaller units with these assigned to specialized herding brigades responsible for managing only certain herds. Brigades in turn were divided into several "*Suurin*" (meaning "base" and usually comprising 3 or 4 households) with even narrower responsibility; i.e., management of a small area or one component of herd production (castrated rams, 1 and 2 year-old lambs, rams and male goats, cross-bred sheep, or goat kids separated in autumn). The territorial divisions and specialization of the production process also came with regulation and restriction of livestock movement. Long distance movements, historically practiced, were no longer possible (Reading et al. in press a).

After the fall of communism in 1990, the change in government led to a decrease in legal restrictions as well as a reduction in implementation and enforcement capacity (Wingard and Erdene-Ochir 2004). In sharp contrast to the previous regime, the Mongolian Law on Land promulgated in 1994 returned jurisdiction over grazing regimes to the local level (*Soum* and *Duureg* governors), granting them general authority, but little in the way of guidelines. The Land Law authorized them to determine grazing territories, define "carrying capacity," and limit livestock numbers (Wingard and Odgerel 2001). "Carrying capacity" was simply defined as the "established limit," with no connection to the concept of grassland health. *Bag* governors (the smallest territorial subdivision in the country) were delegated authority to regulate grazing schedules and allocate hayfields for winter fodder. In practice, herding households acquired an unprecedented level of freedom to manage livestock (Bruun 1996). At the same time, government restrictions on movement relaxed, allowing herders to move to and from areas in search of better pasture or access to markets and social services e.g., (schools, hospitals). For example, many families have moved on to land under state protection and reserved for wildlife (Luschekina 1994) because they are considered good grazing areas. At the same time, this new freedom of movement has not led to a return to historical grazing patterns. Instead, the desire to be closer to markets and social services has resulted in the concentration of grazing around urban centers. The loss of support services for herders, particularly organized transport for herder families, has resulted in declining local mobility (Swift and Mearns 1993, Agriteam Canada 1997, Fernandez-Gimenez 1999). In other words, once a herding family has moved to a new area they tend to stay there.

Ultimately, animal numbers and grazing patterns that are not in balance with forage resources will impact rangelands and the animals (both livestock and wildlife) that use these grasslands (Reading et al. in press a). A direct concern for argali conservation efforts is the dramatic and sustained increase in Mongolia's goat population. The impact on shrub communities due to the increase in this population has not been examined, but will likely be significant because of increasing browse use and encroachment on argali population strongholds (Reading et al. in press a).

Research is needed to help understand the decline of argali, specifically the relationship between argali and domestic livestock. Other than the occasional statement by various researchers over the years on argali feeding ecology in Mongolia, only Schaller (1997) examined the question in any detail. Schaller found that Gobi argali are mixed feeders, foraging largely on two common shrubs *Caryopteris mongolica* (43%) and *Artemisia* spp. (17%); other shrubs consumed included *Anabasis brevifolia, Ceratoides* spp., *Amygdalus mongolica, Caragana leocophloea*, and *Zygophyllum xanthoxylon*. Grazing represented a comparatively smaller percentage of their diet (16%) – mainly *Cleistogenes* spp., and *Stipa* spp. Gobi argali browsed on some forbs with an emphasis on *Astragalus junatovii* (13%). Tibetan argali also demonstrated mixed feeding habits (Schaller 1997). However, with few shrubs available, Tibetan argali grazed more and browsed less (Harris and Miller 1995, Schaller 1997). Fedosenko (2000) concluded that food habits of argali in Russia differ by region and altitude. Populations in higher mountain ranges tended to browse little with a diet comprised mainly of graminoides, some sedges (*Kobresia* spp.), and shrubs (*Artemisia* spp.). In medium and lower mountain ranges, shrubs played a more important role.

I initiated a study in Mongolia in 2000 to analyze seasonal food habits of argali and sheep and goats (hereafter "shoats") to assess the nutritional quality of selected forage species, and, most importantly, estimate dietary overlap between argali and shoats. I predicted that shoats and argali would display a high degree of dietary overlap. My null hypothesis was no relationship between the diets of argali and shoats. If shoats and argali diets overlapped substantially, it may indicate that these species compete for forage. To demonstrate competition, however, forage must be limiting for at least part of the year and one species must negatively impact the other. Actually demonstrating the presence or absence and competition lies beyond the scope of this paper.

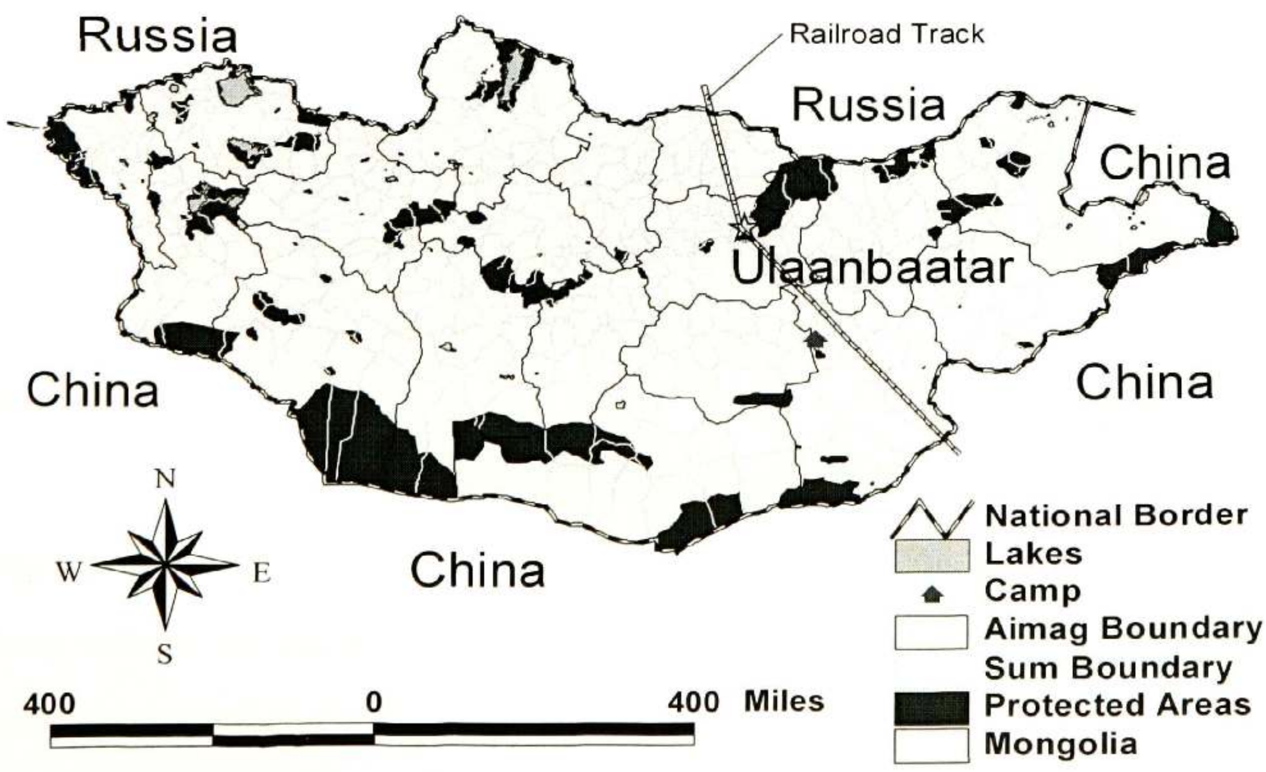
STUDY SITE

I conducted this study in the Ikh Nartiin Chuluu Nature Reserve (Ikh Nart) located approximately 300 km south-southeast of the capital city, Ulaanbaatar, and roughly 50 km from the nearest *Soum* center and transportation route. Ikh Nart encompasses 66,760 ha of open valleys and worn granite outcrops within the Mongolian steppe (Myagmarsuren 2000, Reading et al. in press b). Permanent cold-water springs are available in some of the numerous, shallow valleys draining the reserve. The climate is strongly continental, characterized by cold winters (to –40 °C), dry windy springs (to 25 mps – meters per second), and relatively wet, hot summers (to 35 °C). Precipitation is low and seasonal, with most occurring in the summer (Kenny et al. 2000).

The reserve's flora is representative of the semi-arid regions of Central Asia, with a mix of desert and steppe species. Vegetation is sparse. Xerophytic semi-shrubs, shrubs, scrub vegetation, and turfy grasses dominate, including *Rhamus erythroxylon*, sage (*Artemisia* spp.), wild apricot (*Amygdalus pedunculata*), *Caragana pygmaea*, feathergrasses (*Stipa* spp.), onion grasses (*Allium* spp.), *Koeleria* grasses, and *Cleistogenes squarrosa*. Different plant communities can be found around oases and streams, on rocky outcrops, and other localized areas. Several species occurring within the reserve are classified as "very rare" and "rare" under the Mongolian Law on Plant Protection (Wingard and Odgerel 2001). These include: *Limonium aureum, Calystegia hederacea, Potamogeton natans, Ephedra eguisetina, Asterothamnus central-asiaticus*, and *Vincetoxicum sibiricum.* Plants important to Mongolia's traditional medicine practices include: *Vincetoxicum sibiricum, Bupleurum scorzonerifolium, Caryopteris mongolica, Artemisia frigida, A. mongolica, A. ordossica, A. santolinifolia, Rubia cordifolia, Aquilegia viridiflora, Salsola collina, Panzeria lanata, Calystegia hederacea, Sedum aizoon, Limonium aureum, Chenopodium hybridum, Potentilla bifurca, Thymus gobicus, Erodium Stephanianum, Chamaerhodos erecta, Lappula intermedia, Chenopodium album, Orostachys fimbriata, Cuscuta chinensis, Ulmus pumila, Dracocephalum foetidum, Ephedra equisetin, Clematis fructicosa, Lepidium densiflorum, Melilotus suaveolens,* and *Urtica cannabani.*

Several species of fauna inhabit the reserve. Large mammals include argali, ibex (*Capra sibirica*), goitered gazelle (*Gazella subgutturosa*), Mongolian gazelle (*Procapra gutturosa*), Eurasian lynx (*Lynx lynx*), and gray wolf (*Canis lupus*). Small mammals include: tolai hare (*Lepus tolai*), Daurian pikas (*Ochotona daurica*), and several species of voles, hamsters, gerbils, and jerboas. The reserve's small mammals are preyed upon by Pallas' cats (*Otocolobus manul*), red foxes (*Vulpes vulpes*), corsac foxes (*V. corsac*), badgers (*Meles meles*), and a wide variety of raptors. Raptors are common throughout the reserve including cinereous vultures (*Aegypius monachus*), lesser kestrels (*Falco naumanni*), saker falcons (*Falco cherrug*), and a variety of other raptors including 5 species of eagle (*Aquila* spp.). Besides birds of prey, the most common birds in Ikh Nart are horned larks (*Eremophila alpestris*), ravens (*Corvus corax*), red-billed choughes (*Pyrrhocorax pyrrhocorax*), Daurian partridges (*Perdix dauurica*), several species of wheatears (*Oenanthe* spp.), redstarts (*Pheonicurus* spp.), and wagtails (*Motacilla* spp.). Common reptiles in the park include toad-headed agamas (*Phrynocephalus versicolor*), racerunners (*Eremias* spp.), Central Asian vipers (*Aqkistrodon halys*), and Pallas' colubers (*Elaphe dione*) (Reading et al. in press b).

Figure 1: Location of Study Site in Mongolia



Management of the reserve is legally the responsibility of the local *Soum* government (Dalanjargalan and Airag *Soums*). The Law on Special Protected Areas permits any "traditional household" activity (including grazing livestock) that does not negatively impact the resources for which the reserve has been established (Wingard and Odgerel 2001). The Mongolian government established this reserve in 1996 mainly because of its wildlife resources. No management plan is required under Mongolian Law for the reserve and none exists. Local management occurs incidental to international project activities; *e.g.*, the only ranger for the entire park is paid for by the Argali Research Project.

The reserve is considered good range by herders and they use it extensively, especially in the winter. The resident herder population includes approximately 43 families (180 people). Additional families move to the area during harsh winters, especially during "*dzud*" years (extreme winter weather). Livestock numbers in and around the reserve include an estimated 3,461 sheep, 3,304 goats, 918 horses, 428 cows, and 65 camels (Annual Count of Livestock by Local Soum Governor's Office 2003). Consistent with the country's overall trend, the number of livestock in the study site has been increasing yearly. Data are not available for the numbers of additional herding families and livestock that use the area during extreme winters.

OBJECTIVES

The primary objective of my study was to conduct a detailed investigation into the foraging patterns of argali in Mongolia, as well as gain insights into the existence and extent of dietary overlap between argali and shoats. I examined food habits of argali and domestic livestock, their dietary overlap, forage available to them, and nutritional quality of plant species they selected using comparative fecal, forage, and in-vitro digestion analysis. More specifically, I determined food habits of argali and shoats; the extent of dietary overlap between argali and shoats; forage availability in the study area; and the nutritional quality of selected plant species.

Significance and Application in Mongolia

Currently, little is known about feeding ecology of argali in Mongolia. No thorough studies have been conducted on the food habits of argali or on their dietary overlap with domestic livestock, despite the fact that one of the primary reasons for the argali decline may be competition for forage and displacement by domestic livestock (Reading 1997). Dietary information on large, free-roaming herbivores is an important tool in resource management (Litvaitis et al. 1994). Such information allows us to answer one of the most fundamental questions on resources required by species for their existence. A better understanding of these factors will permit Mongolian conservationists and policy makers to more effectively design and implement recommendations for focused management. Without this kind of study, managers are not in a position to prevent declines in argali numbers and distribution, including, as some scientists predict, the imminent loss of several populations (Reading et al. 2005).

METHODS

Seasonal Dietary Composition

I used fecal analysis as the primary method to determine food composition of argali and shoats. I collected 25 fecal samples from argali and 25 from shoats during each of 4 different seasons: summer (June 2002), autumn (August 2002), winter (January 2003), and spring (April 2003). In Ikh Nart, forage growth (i.e., vegetative "green-up") begins with start of the summer rains in June. I collected samples from up to 15 pellet groups per herd per date of collection, because fecal samples should be representative of the herd (Davitt 1979). I collected 3–6 pellets from each pellet group for a maximum 45 pellets from each herd per date of collection. Where 45 or more pellet groups were easily collected, I took only 1-3 pellets from each pellet group. I replicated this sampling 25 times over a 10-14 day period. I attempted to take samples from different topographic and vegetative areas – valleys, open grassy plateaus, and rugged, rocky terrain. Fresh fecal samples were collected only from observed animals. For purposes of winter collection, pellet groups suspended in snow were considered as good as fresh samples. To be certain my sampling was from domestic livestock, I collected them only from observed livestock.

Fecal samples were dried in an area of good air circulation to prevent molding. After drying, each pellet sample from each herd was stored in a separate brown bag and labeled with the name or size of the herd, date, time, and Global Positioning System (GPS) location. I sent all 200 fecal samples for analysis to the Wildlife Habitat Nutrition Lab of the Department of Natural Resource Sciences, Washington State University in Pullman, Washington. Given travel distances between the study site and laboratory, export occured only twice a year (in the winter and summer seasons).

Relative cover (Korfhage 1974, Davitt 1979) of plant cuticle and epidermal fragments were quantified for 25 randomly located microscope views on each of 8 slides (total 200 views per sample). A 10 x 10 square grid mounted in the eyepiece of the microscope was used to measure area covered by each positively identified fragment observed at 100x magnification (Holechek and Valdez 1985). Measurements of area covered were recorded by plant species, genus, or forage class category, as possible. Percent diet composition was calculated by dividing cover of each plant by total cover observed for all species, then multiplying by 100.

Samples were analyzed by each season. I analyzed data on argali and shoat diets at plant categorical (proportion of major vegetation groups) and key species levels. Plant categorical levels included forbs, shrubs, grasses, sedges, and other. Key plant species levels comprised species representing >5% of the mean diets of argali and shoat in at least 1 season. At both levels of resolution, I analyzed seasonal changes in diet composition and differences between argali and shoats during each season using analysis of variance (ANOVA with equal *n* and with percentage of plant species eaten per sample as the dependent variable and animal species and seasons as fixed factors). Statistical significance was set at the $P < 0.05$ level.

DIETARY OVERLAP

I used the fecal analyses results to assess the level of overlap between argali and livestock diets. I compared argali and shoats' diets at plant categorical (proportion of major vegetation groups) and all plant species levels. At both levels of resolution, the analyses were performed on argali versus shoats combined.

I used Pianka's (1974) index, which estimates the similarity of dietary composition between herbivores using the following equation:

$$O_{ij} = \frac{\left(\sum_{i=1}^{s} P_{ij} * P_{ik}\right)}{\sqrt{\sum_{i=1}^{s} P_{ij}^2 * P_{ik}^2}}$$

I also applied Morisita's (1959) index as modified by Horn (1966) to estimate dietary overlap between herbivorous species:

$$C_\lambda = \frac{\left(2\sum_{i=1}^{s} P_{ij} * P_{ik}\right)}{\left(\sum_{i=1}^{s} P_{ij}^2 + \sum_{i=1}^{s} P_{ik}^2\right)}$$

In these two equations, C_λ and O_{ij} = the overlap between ungulate species *j* and *k*, P_{ij} and P_{ik} = the proportion of species *i* in the diet of ungulates *j* and *k*.

FORAGE AVAILABILITY

I studied forage availability during August (2002) and January (2003) using data on biomass (Daubenmire 1968). I set 100 random Daubenmire plots (1 m x 1 m) to sample vegetation from the approximate herd home range within the study area using previously collected GPS locations of argali occurrence. These argali data consisted of individual animal locations plotted on a 1: 100,000 scale map. I selected sample plot locations within the approximate range of the population using a random number generator and positions located using a standard handheld GPS unit. Within each sample plot, I identified all above ground plants. I determined biomass by removing all vegetation by species in the sample plot to ground level, and then weighed the air dried mass (biomass). If more than 70% of a tussock perennial's base was present in the random plots, I cut all above ground parts of this plant and included it in the sample; if less than 70% was present, I did not cut any parts of the plant and excluded it from the sampling (Shennikov 1964). If any of the random plots were in a shrub community, then I increased the plot from 1m x 1m to 10m x 10m. From the shrubs within the plot, I collected and weighed 10 samples from new growth only.

Forage Use and Availability

I analyzed dietary use versus availability using the vegetation composition data. I determined forage preference using a simple use and availability index. This is the simplest preference index in food habits studies where the percent of the plant species in the diet is divided by the percent of the plant species in the total available forage (Petrides 1975). The index assumes that all vegetation is available and tests whether an herbivore will select from available forage in proportion to its relative abundance. Thus, where use is in proportion to availability the ratio is 1. Ratios >1 support a "preference" (use higher than availability); ratios <1 suggest "avoidance" (use lower than availability). I looked at differences between seasons and between animal species separately.

Nutritional Quality

Finally, I analyzed forage nutritional quality; crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), acid detergent lignin (ADL), and ash. This enabled me to compare species consumed with species present and examine the extent to which each ungulate species selected the most nutritious plant species available. I selected plants for nutritional analysis by observing plant species consumed by argali (using a spotting scope). While conducting direct observations, I recorded the individual plants and plant parts to the extent possible being consumed and collected these plant species and parts from each season for nutritional quality analysis.

I sent collected plant samples to the Department of Animal Sciences at the Colorado State University. ADF, NDF, ADL, and ash content were determined following Van Soest (1970). Nitrogen was determined by the Kjeldahl process; crude protein was estimated by multiplying these Kjeldahl nitrogen percentages by 6.25.

Moreover, I conducted IVDMD (In-Vitro Dry Matter Digestibility), because fecal analysis has limitations due to varying digestibility of plant species in different phenological stages, and for different animal species. IVDMD is a two-stage micro-digestion technique that requires samples from (1) selected plant species and (2) rumen fluid from the species in question. In the first stage of the digestion process (Van Soest 1970), measured amounts of rumen fluid are added to the test tube containing the accurately weighed plant samples. Digestion occurs under anaerobic conditions and a buffer solution is added to maintain a standard pH. The tubes are kept in a water bath at 39° C for 48 hours. This process simulates digestion within the rumen. In the second stage, an acid/pepsin solution is added (to represent digestion in the small intestine) and digestion continues for another 24 hours. At that time, the undigested plant material is filtered out, dried, and weighed. The percent of dry matter digestibility (DMD) is then calculated as follows:

% DMD = 100 – (Residue DM/Sample DM x 100), where DM is dry matter.

My original design called for obtaining rumen fluid from an argali during the hunting season and performing IVDMD tests in the field. This was not possible due to the SARS epidemic that resulted in numerous cancellations of planned trips by foreign hunters. Instead, IVDMD for this study was conducted at the Animal Science Lab at Colorado State University. I collected plant samples in the study area after directly observing the species being eaten; only the 10 most frequently selected plant species from each season were selected. All plant samples were dried, ground to standard particle size, weighed, and placed in a test tube containing rumen fluid from a fistulated heifer. Although this animal is considered a universal donor for feeders of mixed plant categories such as sheep and goats, Blankenship et al. (1982) indicated that caution should be exercised when using inocula from one ruminant species to estimate dry matter digestibility for another species. Therefore, I did not use IVDMD results to correct fecal analysis as originally intended. However, the results are at least an indicator of nutritional quality and therefore useful to the overall discussion.

Throughout the manuscript, all means are reported as ± standard errors.

RESULTS

SEASONAL DIETARY COMPOSITION

Argali - I identified 37 plant species from argali fecal analysis in summer, fall, winter, and spring seasons (Table 1). Shrubs represented the most common category during all seasons: summer ($\bar{x}$ = 43.8 ±2.2%), fall ($\bar{x}$ = 52.1 ±1.9%), winter ($\bar{x}$ = 37.4 ±4.6%), and spring ($\bar{x}$ = 36.0 ±2.0%). The proportion of forbs in the argali diet was lower in winter ($\bar{x}$ = 5.3 ±0.7%), and spring ($\bar{x}$ = 7.6 ±0.86%), than in the summer ($\bar{x}$ = 38.7 ±2.2%), and fall ($\bar{x}$ = 20.9 ±1.4%). Grasses in the argali diet showed the opposite trend – high during winter ($\bar{x}$ = 53.6 ±4.6%)/spring ($\bar{x}$ = 48.3±2.6%) and low during summer ($\bar{x}$ = 12.8 ±2.16%)/fall ($\bar{x}$ = 21.1 ±1.86%). The proportion of sedges in argali diet was consistently low (Table 2, and Figure 2). The highest sedge use occurred in spring ($\bar{x}$ = 7.5 ±0.9%). The plant category "other" included flowers, insects, lichen, and fruit. These food items comprised a low percentage of the diet, with the highest use in summer ($\bar{x}$ = 3.4 ±0.7%) (Figure 2).

With respect to individual species, as many as 37 plant species were found in argali diets, but only 12 species represented ≥ 5% of the mean diet in at least one of the seasons (Table 3). I refer to these as "key species." Overall, these 12 species accounted for 59.9% of the plant fragments found in argali feces in summer, 55.5% in fall, 72.6% in winter, and 76.4% in spring. Key shrubs included *Ajania achilleoides, Artemisia frigida/A. ruthifolia, Caragana pygmaea,* and *Caryopteris mongolica*; key grasses were *Agropyron cristatum, Cleistogenes squarrosa, Festuca /Poa* spp., and *Stipa* spp.; key forbs utilized were *Bassia dasyphylla, Erysimum/Convolvulus* spp., and *Oxytropis* spp.; and *Carex* spp. comprised the key sedges. Together, the key shrubs represented a large portion of argali diet during all 4 seasons (summer = 30.5%, fall = 31.3%, winter = 22.0%, and spring = 27.4%). Of these, *Artemisia frigida* had the highest percentage of occurrence and this percentage remained similar for all seasons (summer = 16.8%, fall = 16.2%, winter = 15.1%, and spring 15.6%). The proportion of key forbs was consistent with the overall trend for forbs, increasing slightly during summer and fall compared to winter and spring seasons. Key grasses showed a reverse trend; they were high during winter/spring and low during summer/fall.

Shoats – I identified 42 plant species from shoat fecal analyses in summer, fall, winter, and spring seasons (Table 4). Shrubs were always the most common category: summer ($\bar{x}$ = 25.2 ±1.9%), fall ($\bar{x}$ = 38.7 ±2.1%), winter ($\bar{x}$ = 39.7 ±1.6%), and spring ($\bar{x}$ = 44.3 ±2.3%) (Table 5, Figure 2). Following the same pattern as argali diets, the second most common plant categories were forbs in summer/fall and grasses in winter/spring (Figure 2). The proportion of sedges was consistently low, with the shoats' highest use of sedges occurring in the spring ($\bar{x}$ = 6.1 ±0.7%). The category "other' represented the smallest portion of the shoats' diet, with the highest consumption in summer ($\bar{x}$ = 3.4 ±1.0%) (Figure 2).

Of the 42 plant species consumed by shoats, only 9 represented 5% or more of the mean diet in at least 1 of the seasons (Table 6). Overall, these 9 species accounted for

67.3% of the plant fragments found in the feces of shoats in summer, 62.0% in fall, 77.9% in winter, and 79.1% in spring. Key plants utilized by shoats included the shrubs *Ajania achilleoides*, *Artemisia frigida/A. ruthifolia,* and *Caragana pygmaea*; the grasses *Agropyron cristatum*, *Festuca/Poa* spp., and *Stipa* spp.; the sedges *Carex* spp.; and the forbs *Erysimum/ Convolvulus* spp. and *Oxytropis* spp. From these key species, forbs in the *Erysimum/ Convolvulus* complex were consumed the most, followed by *Artemisia frigida/A. ruthifolia* and *Agropyron cristatum.* Only 3 key plant species (*Bassia dasyphylla, Caryopteris mongolica*, and *Cleistogenes squarrosa*) found as key species in argali diet were not also key species for shoats.

The overall diet composition of argali and shoats for all seasons was similar with a few exceptions. Both groups used the same plant species with the exception of five (*Corispermum mongolicum*, *Dracocephalum foetidum*, *Saussurea* spp., *Silene jenisseensis,* and *Haplophyllum dahuricum*) used by shoats and not argali. Both argali and shoats also consumed plant categories similarly, with a majority of their diet comprised of shrubs, followed in order by grasses, forbs, and sedges. However, argali and shoats focused on different numbers and types of key species; these key species comprised different proportions of overall diets and key species were used differently depending on the season. Argali diets were more varied than shoats for all seasons, with more key species (12) consistently comprising a smaller percentage of the diet (58.0% summer, 46.9% fall, 68.6% winter, and 66.4% spring) compared to only 9 key species comprising a larger percentage of shoats diet (70.0% summer, 63.6% fall, 75.3% winter, and 78.0% spring). This is consistent with my results on the composition of argali and shoat diets, showing that shoats have a more focused diet.

Some differences in plant use were also noted when I analyzed plant categories between animal species and seasons. Between animal species, I found a significant difference in the use of shrubs ($F = 37.40$, df = 1, $P < 0.001$), as well as the use of grasses ($F = 18.54$, df = 1, $P < 0.001$). These results are consistent with my results on diet composition that showed that shrubs represented a higher percentage of the argali diet in summer and than shoats (summer = 43.8% for argali vs. 25.2% for shoats; fall = 52.1% vs. 38.7%, respectively). Grasses represented a greater portion of shoats' diet for the same seasons (summer = 12.8% for argali vs. 25.4% for shoats; fall = 21.1% vs. 28.7%, respectively). However, I found no significant difference between argali and shoats in the seasonal use of the remaining plant categories: forbs ($F = 2.14$, df =1, $P > 0.15$), sedges ($F = 1.82$, df = 1, $P > 0.18$), and others ($F = 0.73$, df = 1, $P > 0.39$).

DIETARY OVERLAP

Morisita's (MI) and Pianka's (PI) indices confirmed my hypothesis that the argali's diet overlapped considerably with that of shoats (Table 7). Overlap was especially pronounced at the plant category level, which showed high degrees of overlap for all seasons. The highest dietary overlap occurred in winter and spring (MI and PI = 99% for both seasons); followed by fall (MI = 93%, PI = 94%), and then summer (MI and PI = 92%). Mean overlap at the species level (including all identified dietary items) was generally lower, although still relatively high, ranging between seasons from a summer low of MI = 72% and PI = 73% to a spring high of 88% for both indices. Dietary overlap was 85% (MI) to 86% (PI) during fall and 87% (MI) to 88% (PI) during winter. However, key species overlap was generally higher. Summer was still the season with the least overlap (MI = 72% and PI = 74%). The diets of argali and shoats overlapped most during spring (MI and PI = 95%), followed by winter (MI = 90% and PI = 92%), and then fall (MI = 88% and PI = 90%) (Table 7).

Similar to both forage category and species level analyses, key species overlap increased through fall to winter and then to spring. Importantly, however, the key species that argali and shoats focus on eating during winter and spring showed higher overlap than the species level analysis indicated.

FORAGE AVAILABILITY

Forage availability changed significantly between seasons. In summer 2002, I recorded 69 species of plants from 46 genera and 20 families within the 100 randomly sampled plots (Table 8). Species with the highest frequency included: *Stipa* spp. (occurring in 77 of 100 plots, or 77%), *Artemisia frigida* (63%), *Allium* spp. (61%), *Carex* spp. (59%), and *Cleistogenes squarrosa* (46%). Another 47 species had a frequency of 22% or less within the sampled plots. Mean dried biomass during summer was 19.0 g/m^2. The species accounting for most of the available biomass were *Stipa* spp. (3.3 g/m^2), *Artemisia frigida* (4.2 g/m^2), *Allium* spp. (2.4 g/m^2), and *Carex* spp. (3.0 g/m^2), comprising 68% of the total mean biomass (Table 8).

In winter 2003, I recorded only 22 species in the same general areas (Table 9). Species with the highest frequency of occurrence included *Carex* spp. (60%), *Artemisia frigida* (58%), *Stipa* spp. (43%), *Cleistogenes squarrosa* (27%), *Caragana pygmaea* (18%), *Kochia prostrata* (17%), *Agropyron cristatum* (15%), *Artemisia* spp. (9%), and *Allium* spp. (7%). *Allium* spp., and *Cleistogenes squarrosa* decreased substantially from summer to winter (from 61% to 7% and from 46% to 27%, respectively). Shrubs and graminoides comprised most of the forage available during winter. Winter biomass was significantly lower than summer with a mean biomass of 3.9g/m^2. Plant biomass in winter was reduced by over 80% of the amount available in summer. The species providing the most winter biomass were *Carex* spp. (1.4 g/m^2), *Artemisia frigida* (1.1 g/m^2), *Stipa* spp. (0.2 g/m^2), and *Caragana pygmaea* (1.1 g/m^2).

I recorded significant changes in biomass availability for many plant species between summer and winter. For example, *Artemisia frigida* decreased from a summer biomass of 5.1 g/m^2 to a winter biomass of only 1.2 g/m^2 in winter. Similarly, *Stipa* spp. decreased from 3.8 g/m^2 in summer to 1.2 g/m^2 in winter, and *Carex* spp. dropped from 3.3 g/m^2 in summer to 1.4 g/m^2 in winter. These decreases were, however, comparatively less than the decrease in overall biomass or compared to other important species.

FORAGE USE AND AVAILABILITY

I compared summer forage availability to plant use by argali and shoats for 19 plant species. Argali consumed 8 plants (*Artemisia frigida/ruthifolia*, *Ajania achilleoides*, *Agropyron cristatum*, *Bassia dasyphylla*, *Chenopodium aristatum*, *Caragana pygmaea*, *Convolvulus ammanii*, and *Caryopteris mongolica*) more frequently in summer than one would predict based on their availability. Shoats ate 6 species (*Artemisia frigida/ruthifolia*, *Agropyron cristatum*, *Ajania achilleoides*, *Koeleria macrantha*, *Chenopodium aristatum*, and *Bassia dasyphylla)* more frequently in summer than their availability would suggest (Table 10). For both argali and shoats, *Bassia dasyphylla* and *Chenopodium aristatum* were highly preferred. In addition, argali particularly selected *Caragana pygmaea* and *Caryopteris mongolica* as forage, while shoats also selected *Agropyron cristatum* and *Koeleria macrantha*. Alternatively, both argali and shoats strongly avoided (index < 0.2) *Ptilotrichum canescens*, *Ephedra* *equisetina*, *Heteropappus hispidus*, and *Achnatherum splendens*. For argali, *Carex* spp. was also strongly avoided in summer, while shoats also avoided *Convolvulus ammanii*, a plant preferred by argali.

Winter forage availabilty results were compared to use for 11 of the most abundant species *(Artemisia frigida, Stipa* spp., *Carex* spp., *Agropyron cristatum, Achnatherum splendens, Cleistogenes squarrosa, Caragana pygmaea, Koeleria macrantha, Arenaria capillaris, Bassia dasyphylla,* and *Heteropappus hispidus*) (Table 10). In winter, both argali and shoats demonstrated a high preference for *Agropyron cristatum*, *Arenaria capillaris*, and especially *Koeleria macrantha*. Argali also selectively foraged for *Cleistogenes squarrosa*, while shoats selected *Stipa* spp. Both argali and shoats strongly avoided the same species in winter, including *Carex* spp., *Achnatherum splendens*, *Bassia dasyphylla,* and *Heteropappus hispidus* (Table 10). Interestingly, *Bassia dasyphylla* was strongly preferred by both argali and shoats in summer, but completely avoided by both in winter. *Agropyron cristatum* was always preferentially eaten by both argali and shoats.

NUTRITIONAL QUALITY

Nutritional composition for all plant species varied seasonally, corresponding with shifts in plant phenology. Concentrations of crude protein and DMD in argali and shoats diets coincided with the summer growing season for almost all forage species and decreased through fall and winter as other nutritional components, such as NDF, ADF, ADL, and ash, increased (Tables 11, 12, and 13).

Dietary CP changed seasonally and it was greatest in *Allium polyrrhizum* 31.4% in summer and was followed by *Kochia prostrata* (18.6%) and *Stipa gobica* (12.5%)

from all species sampled. In fall, the CP concentrations increased in *A. odorum* (33.0%), followed by *Allium odorum* (24.3%) and *Allium antisopodium* (17.5%). In winter, *Artemisia frigida* had the highest CP concentrations (11.1%), followed by *Allium polyrrhizum* (10.3%) and *Stipa gobica* (9.0%). In spring, *Allium polyrrhizum* again had the highest CP content (16.6%), followed by *Carex duriuscula* (13.6%) and *Allium mongolicum* (13.0%).

Furthermore, with increasing CP concentrations, DMD of forage increased. The most digestible plant from all plants sampled was *Allium antisopodium*, with a spring DMD of 60.5% and a fall DMD of 52.3%. The least digestible plant was *Amygdalus pedunculata*, with a winter DMD of 15.0% and a fall DMD of 16.7%. Digestibility differed greatly even within forage classes. For example, within the forbs, *Clematis fruticosa* had a DMD 35.5 % compared to 60.5% for *Allium antisopodium*. Within the shrubs, DMD for *Amygdalus pedunculata* was 15.0% compared to DMD for *Kochia prostrata* of 58.3%. For grasses, *Stipa gobica* showed the lowest DMD, at 27.2% in winter, compared to 54.1% in summer for *Caryopteris mongolica*. The sedge *Carex duriuscula* had a DMD of 46.2%.

For some species I was able to compare seasonal change in DMD (Table 13). Digestibility did not remain constant for individual species from season to season. The lowest digestibility for most species was recorded during winter. For example, *Amygdalus pedunculata* was 35.5% digestible in summer and only 14.9% in winter. Only *Artemisia* species did not fit this pattern. *Artemisia frigida* had a slightly higher DMD at 41.3% in winter compared to 39.7% in fall and *Artemisia ruthifolia* demonstrated lower DMD in spring (27.5%) than in winter (32.0%). As expected, the highest digestibility usually occurred in spring or summer depending the plant species' phenological development. For example, *Agropyron cristatum* is an early developer that showed 52.1% DMD in spring and dropped to 33.9% DMD by summer. *Caryopteris mongolica* develops later, flowering in July to late August, and had a 40.3% DMD in spring that increased to 54.1% in the summer. Two shrubs recorded the highest digestibility levels in the fall (*Kochia prostrata* and *Spiraea aquilegifolia*). DMD values for *Caryopteris mongolica* varied between 54.1%, 52.2%, and 40.3% for June, August, and April, respectively. DMD values for *Caragana pygmaea* showed 19.7% in August and 19.5% in April. The most constant DMD of all plants analyzed was *Ulmus pumila*, decreasing slightly over three seasons from a high of 28.5% in summer to a low of 24.7% in winter.

NDF and ADF values accounted for the greatest proportion of dietary content in all seasons with some seasonal variations. Dietary NDF accounted for the greatest proportion of dry matter (>25%) in all seasons. Of those species analyzed, for example, *Stipa gobica* had the following NDF contents across seasons (summer = 62.1%, fall = 70.9%, winter = 64.5%, spring = 65.7%) (Table 11 and Table 12). Furthermore, *Caragana pygmaea* had the following NDF values (summer = 59.3%, fall = 61.7%, winter = 63.1%, spring = 63.9%); *Amygdalus pedunculata* (summer = 41.2%, fall = 43.0%, winter = 68.4%, spring = 62.2%); *Caryopteris mongolica* (summer = 32.4%, fall = 37.0%, winter = 58.2%, spring = 56.6%); and *Allium polyrrhizum* (summer = 28.7%, fall = 61.6%, winter = 60.0%, spring = 48.5%). Dietary ADF accounted for the second greatest proportion of dry matter (>23%) in all seasons. *Stipa gobica* had the following ADF contents across seasons (summer = 28.1%, fall = 36.7%, winter = 34.0%, spring =

35.0%); *Caragana pygmaea* (summer = 43.5%, fall = 47.0%, winter = 49.5%, spring = 48.3%); *Amygdalus pedunculata* (summer = 28.0%, fall = 31.5%, winter = 46.4%, spring = 46.0%); *Caryopteris mongolica* (summer = 23.5%, fall = 27.0%, winter = 42.0%, spring = 41.4%); and *Allium polyrrhizum* (summer = 22.0%, fall = 30.5%, winter = 45.5%, spring = 41.5%). Dietary hemicellulose is obtained by subtracting ADF from NDF values (NDF-ADF) and is generally more digestible than cellulose, which is obtained by subtracting ADL from ADF. The percentage of dietary hemicellulose was slightly higher than dietary cellulose for most species. For example, dietary hemicellulose for *Stipa gobica* was in summer 34%, in fall 34.2%, in winter 30.5%, and in spring 30.7%. However, the percentage of dietary cellulose for *Stipa gobica* was only 29.0% in summer, 31.6% in fall, 24.1% in winter, and 31.6% in spring.

Although ADL values varied between plant species on a seasonal basis, in general they were lowest in summer, increasing through fall and winter, and with the highest values in spring. For *Allium polyrrhizum*, ADL was the highest in spring (5.6%) and lowest in winter (4.8%); for shrubs (*Amygdalus pedunculata, Caragana pygmaea*) the highest ADL occurred in winter (9.2% and 14.6% respectively) and lowest in summer (7.4% and 10.2%); and for grasses *(Caryopteris mongolica, Stipa gobica*) the highest ADL was in winter (12.7% and 5.0% respectively) and the lowest in spring (11.9% and 3.4%). There was a reverse relationship between the lignin content and digestion of cellulose. Consequently, I found that both argali and shoats selected the most digestible plants.

Ash was highest for *Allium polyrrhizum* in April (15.9%) and for *Stipa gobica* in August (5.7%). Otherwise, ash content for all species remained between 0.5% to 3.28% (Tables 11 and 12).

DISCUSSION

Range resources in Mongolia may appear infinite at first glance. To the casual observer, the expanses of grassland stretch beyond the imagination and indeed are part of the largest continuous, open grazing system still in existence in the world. However, good grazing land for wildlife and domestic livestock is limited by a number of factors, including available quantity and quality of forage in areas that have sufficient water and escape terrain for wildlife. Forage in this region can generally be described as sparse, water is only available in a few locations, and seasonal precipitation rates are low. Ikh Nart offers comparably better grazing than neighboring areas and has 7 permanent water sources.

SEASONAL DIETARY COMPOSITION

Fecal analysis has limitations due to the varying digestibility of plant species in different phenological stages and for different animal species. Generally, shrubs tend to be overestimated due to their higher fiber content and associated lower digestibility, while readily digested forbs are often underestimated (Holechek and Vavra 1981, Holechek et al. 1982, McInnis et al. 1983). To decrease these possible biases, I tried different methods, such as IVDMD. However, the results of IVDMD were not completely satisfactory for my needs. Direct observations could only be conducted at certain times of the day and could not be done consistently, severely limiting my ability to observe during potentially important feeding times. In addition, IVDMD results were not produced using rumen fluid from argali. Therefore, I did not use the results to correct fecal analysis and the possibility of biases in my results must be considered.

On the other hand, Korfhage (1974) and Fraser and Gordon (1997) maintain that fecal analyses can be appropriate when comparing herbivores and may be especially beneficial in comparing herbivorous species using the same range. Baldi et al. (2004) similarly concluded that microhistological fragment analysis comparing 2 species did not introduce systematic bias into the assessment of diet. Therefore, my dietary comparison results between argali and shoats might be interpreted with less caution than the individual diet results for the species.

Diet composition studies of argali conducted in Mongolia and Russia, differ from the results reported for Tibetan argali. Schaller (1998) and Fedosenko (2000) found that argali are mixed feeders, and at lower elevations in the summer they tend to forage largely on shrubs, followed by graminoides and forbs. However, diet composition studies on Tibetan argali (*Ovis ammon hodgsonii*), showed summer diets dominated by forbs and grasses (Harris and Miller 1995; Miller and Schaller 1995; Shrestha et al. 2005).

While some of these studies differed from each other, the reasons for these differences are likely due to the timing of the study and elevation (Shresta et al. 2005), both of which affect forage availability. My summer (conducted in June) and fall (conducted in August) studies of argali diet showed a trend similar to those reported by Schaller (1998) and Fedosenko (2000): they were dominated by shrubs. However, it may be that my summer study results are closer to Shresta et al. (2005) when factoring in the digestibility of forbs and the similar percentage of forbs (38.7%) and shrubs (43.8%)

in the diet. Higher forb digestibility may have resulted in my underestimating the proportion of forbs in the diet and therefore created a bias in favor of shrub content. In this study, I directly observed argali and shoats feeding on several forbs, including *Allium mongolicum*, *A. polyrrhizum*, *A. antisopodium*, *Clematis fruticosa*, and *Serratula centauroides*, although these species did not show up in my fecal analysis results (pers. obs.).

The results from my study of shoats' diet in summer were similar to a study in Omnogobi, Southern Mongolia (Campos-Arceiz et al. 2004, Mandakh et al. 2005), which found that shoat diets were dominated by forbs, with shrubs and grasses each comprising 25% of the diet. This differs from Cincotta et al. (1991) and Harris and Miller (1995) who reported a summer shoat diet dominated by graminoides. Harris and Miller (1995) also reported that domestic sheep diets varied significantly depending on vegetation communities in local areas and were likely influenced by herding practices that potentially limit the variability of their diet. Mongolian nomadic herding practices have the potential to similarly limit shoat diet variability as evidenced by more focused diet composition with 9 key species comprising a majority of their diet (70.0%) compared to 12 key species for argali in the same area making up only 58.0% of their total diet.

DIETARY OVERLAP

Not surprisingly, argali and shoats exhibited a degree of high overlap at the plant category level (93% to 99%), as well at the key species level (72% to 95%). High overlap at the category level was expected because this is a general analysis consisting of combinations of species and genera and therefore did not account for possible differences in selection at the species and key species level. The lower degree of overlap at the species level indicates that there were important differences in plant selection between argali and shoats, as illustrated by my fecal analysis results that showed some difference in the use of key species. Thus, overlap indices confirm that some key species are selected differently by argali and shoats depending on the season, with the lowest dietary overlap observed in summer. Lower dietary overlap in summer might be explained by better forage availability (greater biomass and more species) relative to other seasons. Also, overlap was highest in the winter and spring, and this is the very important because that is when the resources are most limiting. Thus, the potential for competition is greatest.

However, overlap is still high and is a strong indicator of the potential for actual competition between argali and shoats in Ikh Nart. Although high overlap by itself does not prove that there is competition (Liu et al. 2004), it does indicate a high potential for it (Schoener 1983). Considering the low forage availability coupled with a high dietary overlap, the co-grazing of argali and shoats suggests competition exists, rather than an equitable allocation of abundant resources (Jiang et al. 2002). Hence, the increase in the livestock population could lead to overgrazing and food shortages for wildlife in Ikh Nart.

FORAGE AVAILABILITY

Mean plant biomass of summer was higher than other seasons primarily due to weather patterns. Mongolia has a very short growing season from June to August, which coincides with a summer monsoonal rain pattern during which over 90% of the precipitation occurs. Not surprisingly, summer biomass values are more than 80% higher than winter values. Importantly, however, my results may be skewed in favor of summer values as a result of my sampling technique. Winter samples were cut from above the snow level, which averaged 15 cm throughout the sampling area. Although Ikh Nart is a designated wildlife reserve, traditional grazing practices and recent changes in demographics have combined to strongly impact the rangeland by heavy livestock grazing. In addition, the region has always been characterized by limited forage availability during the dormant season, which lasts from October to April. This is especially true in late winter and spring when mean biomass falls to 3.9 g/m^2 compared to 19.0 g/m^2 in summer.

The biomass available for argali in Ikh Nart is much lower than reported by Jiang et al. (2002) in Inner Mongolia. Their study found that the largest moderately grazed areas could provide a mean biomass of 30 g/m^2 and lightly grazed areas could provide approximately 100 g/m^2 during spring and summer. However, Ikh Nart is more arid and vegetation is poorer than the areas studied in Inner Mongolia (Campos-Arceis et al. (2004). On the northern edge of the Gobi Desert, Ikh Nart's vegetation is representative of the semi-arid regions of Central Asia that are substantially less productive than neighboring grasslands.

Grass height decreases with grazing intensity, and the short grasses in Ikh Nart provide little available food during winter. The situation is intensified by snow cover and the presence of more herders in winter in Ikh Nart. Harris and Miller (1995) asked whether winter forage availability is negatively impacted by summer livestock grazing? This is likely in Ikh Nart, but has not yet been specifically studied. However, this study shows that mean biomass decreases in winter in Ikh Nart by almost 90% from 19.0g/m^2 to just 3.4g/m^2. Starvation of argali during harsh winters is common (pers. obs.).

Forage Use and Availability

Forage selection and preference by wildlife is influenced by numerous factors. As a result, many methods have been developed to calculate and analyze use and availability of forage resources (Kruger 1972, New et al. 1974, Johnson 1980, Hobbs and Bowden 1982). In this study, I used the simplest preference index (Petrides 1975), because this was the only one my data permitted. More complex methodologies require fecal results in counts as opposed to percentages (as my results were produced) or a different study design that uses radio collars to track habitat use for each species. Still, the simple preference index remains a useful tool in understanding basic selection habits of argali and shoats.

Nutritional Quality

I included plant species in my nutritional quality analysis based on direct observations. Because of this, several important forage species were not analyzed for their nutritional values. I analyzed only 23 species when fecal analyses indicated at least 37 species were in the diet. Of the 23 species included in the nutritional analysis, only 8 were also found in fecal analysis results. These limitations notwithstanding, the results are valuable in that they suggest overall trends between species and across seasons, and provide specific information for the plant species analyzed.

Most forbs had higher percentages of crude protein than most shrubs and graminoides through all seasons. My results were consistent with Darambazar et al. (2003), who found that forbs had higher CP than graminoides (11% compared with 6%) and with Krausman et al. (1989), who found forbs contained more nutrients than grass. However, it differed from Cincotta et al. (1991), who reported that forbs had lower nutritive quality than graminoides. Furthermore, crude protein contents decreased in winter and spring for all forage classes. My findings that protein concentrations in argali and shoats diets comprised 4% - 6%, which seemed barely to meet the levels suggested by Van Soest (1982) as being the critical level (4%-9%) required by ungulates.

Forbs were the most digestible plants, and they were followed by shrubs and grasses, contrary to Dailey et al. (1984), that forbs are less digestible and more lignified. My results showed that DMD was generally higher for forbs than grasses and ADL was comparatively low. This is consistent with Darambazar et al. (2003), who found that DMD of forbs was higher than shrubs and grasses (58.4% for forbs, 49.0% for shrubs, and 42.0% for grasses). Furthermore, Long et al. (1999) and Shrestha et al. (2005) reported that forbs provide higher quality forage than shrubs and grasses.

Allium polyrrhizum ADL was 5.6% in summer, 5.9% in fall, 4.8% in winter, and 20.9% in spring. This compares to ADL levels in *Caryopteris mongolica* of 8.45% in summer, 9.2% in fall, 12.7% in winter, and 11.1% in spring. *Allium* spp. were also the most digestible plants compared to all other plants during all seasons.

Furthermore, my original intention was to use digestibility analysis to adjust my fecal analysis results, based on differences among the various forage species and parts consumed. I conducted IVDMD analysis using heifer rumen fluid, although Blankenship et al. (1982) stated that caution should be exercised when using inocula from one ruminant species to estimate DMD for another species. Therefore, I did not to use these results to correct my fecal analysis findings. Still, the IVDMD results are important because at least they indicate approximate and relative digestibility of various plant species at Ikh Nart.

MANAGEMENT IMPLICATIONS

The most pressing concern for argali management in Ikh Nart is the potential competition between argali and shoats. Unlike many other areas in the country, poaching of argali does not appear to be a significant problem in the reserve (Wingard 2005, in press), although prior to an initiation of argali research, poaching was relatively common in Ikh Nart as well (pers. obs.). This problem is especially critical considering the low forage availability and high degree of dietary overlap. Recent grassland deterioration appears to have been caused by intensive grazing due to increasing numbers of livestock in Ikh Nart. Grassland degradation coupled with severe winter weather events often makes grazing by argali difficult, resulting in death or their migrations to other areas (Luschekina 1994).

Either reduction or elimination of livestock grazing will not be easy and likely several management options and approaches will be necessary to affect real change from the current situation. Herders in the area are almost entirely dependent on their livestock and therefore the range resource. As presently managed, pastoralists receive few obvious and tangible benefits from the existence of the reserve and therefore have little incentive to either reduce stocking rates or limit access to available pasture.

Central to the development any successful management regime will be a fuller understanding of the needs of wildlife in the reserve, not just argali. Although relatively small, the reserve is home to several species, many of which are becoming or are already conservation priorities as grazing and other human uses of the reserve increase, including primarily poaching and illegal mining. Species of note include Siberian ibex, Mongolian gazelle, Eurasian badger, red fox, corsac fox, Pallas's cat, cinereous vultures, and lesser kestrels. Many of these species are included on CITES Appendices, receive some protected designation under Mongolian law (Wingard and Odgerel, 2001), and provide a resource for wildlife viewing. Without effective management of the reserve, many of these species may experience significant declines. This is especially true for the argali population, which is declining throughout its range (Reading et al. 2005).

If management is to succeed in creating a viable option for both locals and wildlife, a collaborative model will have to be developed. By 'collaborative management' I mean developing a partnership in which primary and secondary stakeholders agree to share the management functions, benefits, and responsibilities for the reserve among themselves. To create a broad base of support, careful attention will have to be given to participatory processes involving management partners selected according to the following criteria:

- existing rights to land or natural resources;
- continuity of relationship (e.g., residents versus temporary pastoralist visitors and tourists);
- unique knowledge and skills for the management of the resources at stake;
- losses and damage incurred in the management process;
- historical and cultural relations with the resources at stake;
- degree of economic and social reliance on such resources;
- degree of effort and interest in management;
- equitable access to resources and the distribution of benefits from their use;
- compatibility of the interests and activities of the stakeholder with national conservation and development policies;

- present or potential impact of the activities of the stakeholder on the resource base.

At a minimum, management partners must include local government authorities, local community members, the Mongolian Ministry of Nature and Environment, and non-profit research and conservation organizations, like the Argali Research Center and Mongolian Conservation Coalition, both Mongolian NGOs.

Specific objectives of an initial management effort should include: 1) developing and implementing a model for the participatory assessment of resource management needs within nature reserves; 2) creating collaborative management planning processes; and 3) establishing a network of national and international professionals for its sustainable management. Of primary importance will be the drafting of a rangeland management plan for the reserve that specifically identifies the resource condition, pressures, and intended objectives.

LITERATURE CITED

Agriteam Canada. 1997. Study of Extensive Livestock Production Systems TA No.2606-MON. Report submitted to the Asian Development Bank, Agriteam Canada Consulting Ltd, Calgary, Alberta.

Amgalanbaatar, S. 1993. Argali population inventory and conservation measures in selected areas of Mongolia. Research Papers of the Forestry and Hunting Institute. (In Mongolian).

Amgalanbaatar, S., and T. McCarthy. 1993. Hovd/Khokh Serhiin Reserve Trip Report. Unpublished Report. Mongolia Biodiversity Project, Ulaanbaatar, Mongolia

Amgalanbaatar, S., and R. P. Reading. 2000. Altai Argali Sheep (*Ovis Ammon*) Pages 5-9 *in* Endangered Animals: A Reference Guide to Conflicting Issues. Greenwood Press. Westport, CT.

Amgalanbaatar, S., and R. P. Reading. 2003. Argali Conservation and Research Activities in Mongolia. Pages 14-16 *in*: Mongolia: Biodiversity at a Crossroads, Biodiversity at a Crossroads. Biodiversity Briefings from Northern Asia 2(1)

Annual Count of Livestock by Local Soum Governor's Office. 2003. Report of the Dalanjargalan Soum, Dornogobi Aimag, Mongolia.

Baldi, R., A. Pelliza-Sbriller, D. Elston, S. Albon. 2004. High potential for competition between guanacos and sheep in Patagonia. Journal of Wildlife Management 68:924-938

Blankenship, L. H., L. Varner, and G. Lynch. 1982. In-vitro digestibility of South Texas range plants using inoculum from four ruminant species. Journal of Range Management 35(5).

Byambatseren, T. 2004. NSO (National Statistical Office) – Mongolia. 2004. Mongolian Statistical Yearbook 2003.

Bruun, O. 1996. The herding household: Economy and organization. Pages 65-89 *in*: Bruun, O. and O. Odgaard (eds), Mongolia in Transition. Nordic Institute of Asian Studies, Studies in Asian topics. No. 22. Curzon Press, Ltd., Richmond Surrey, Great Britain.

Campos-Arceiz, A., S.Takatsuki, and B. Lhagvasuren. 2004. Food overlap between Mongolian gazelle and livestock in Omnogobi, southern Mongolia. Ecological Research 19:455-460

Cincotta, P., Van Soest, J. Roberstson, C. Beall, and C. Goldstein. 1991. Foraging Ecology of Livestock on the Tibetan ChangTang: A Comparison of Three Adjacent Grazing Areas. Arctic and Alpine Research 23:149-161

Dailey, T.V., N.T. Hobbs, and T. Woodard. 1984. Experimental comparisons of diet selection by mountain goats and mountain sheep in Colorado. Journal of Wildlife Management 48:799-806.

Darambazar, E., T. DelCurto, C.Ackerman, G.Pulsipher, and D. Damiran. 2003. Proceedings Western Section, American Society of Animal Science. Volume 54

Davitt, B. B. 1979. Elk summer diet composition and quality on the Colockum Multiple Use Research Unit, Central Washington. M.S. Thesis, Washington State University, Pullman, WA. 127pp.

Daubenmire, R. F. 1958. A canopy-coverage method of vegetational analysis. Northwest Science 53:43-64.

Dzielovskii, R., J. Krupka, and Bayandelger. 1980. Argali and Siberian Ibex populations in the Khuhsyrh reserve in Mongolian Altai. Acta Theoriologica 25(16): 213-219.

Frazer, M. D and I.J. Gordon. 1997. Organic Matter Intake, diet digestibility, and feeding behaviors of goats, red deer, and South American camelids feeding on three contrasting Scottish vegetation communities. Journal of Applied Ecology 34:687-698

Fedosenko, A. K. 2000. Study of Argali in Russia and bordering Countries. Central Control, 2000, Moscow, Russia

Fernandez-Gimenz, M. 1999. Sustaining the steppes: A geographical history of pastoral land use in Mongolia. The Geographical Review 89: 316-342.

Geist, K. 1971. Mountain sheep. The University of Chicago Press, Ltd., London

Gruzdov, V., and Kh. Sukhbat. 1982. Mountain Ungulates of Mongolia. Hunting and Hunting Farms, 9:41-43 (In Russian)

Harris, R B., and D. J. Miller. 1995. Overlap in summer habitats and diets of Tibetan Plateau ungulates. Mammalia 59: 197-212

Hobbs, N. T., and T. Bowden. 1982. Confidence intervals on food preference indices. Journal of Wildlife Management 46:505-507

Holecheck, J.L., and M. Vavra. 1981. The effect of slide and frequency observation numbers on the precision of microhistological analysis. Journal of Range Management 34:337-338.

Holechek, J.L., M. Vavra, and R.D. Pieper. 1982. Botanical composition determination of range herbivore diets: a review. Journal of Range Management 35:309-315

Holecheck, J.L., and R. Valdez. 1985. Magnification and shrub stemmy material influences on fecal analysis accuracy. Journal of Range Management 38:350-352.

Horn, H. 1966. Measurements of overlap in comparative ecological studies. American Naturalist 100:424-429

Jiang, Z., S. Takatsuki, J.Li, W.Wang, Z.Gao, and J.Ma. 2002. Seasonal Variations in Foods digestion of Mongolian Gazelles in China. Journal of Wildlife Management 66(1):40-47

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Kenny, D., R. P. Reading, S. Amgalanbaatar, and G. Wingard. 2001. The feasibility of immobilizing and radiocollaring free-ranging argali sheep (*Ovis ammon*) in Mongolia. Proceedings of the AZA Western Regional Conference, 22-25. March 2001, Cheyenne Mountain Zoo, Colorado Springs, CO. (Abstract)

Korfhage, R.C. 1974. Summer food habits of elk in the Blue Mountains of northeastern Oregon based on fecal analysis. M. S. thesis. Washington State University, Pullman, WA.

Krausman, P. R., B. Leopold, R. Seegmiller, and S. Torres. 1989. Relationships between desert bighorn sheep and habitat in western Arizona. Wildlife Monograph 102:59-62

Krueger, W. 1972. Evaluating animal forage preferences. Journal of Range Management 25:471-475

Litvaitis, J. A., K.Titus, and E. Anderson. 1994. Measuring vertebrate use of terrestrial habitats and foods. Pages 254-274 *in* T. Bookhout, ed., Research and management techniques for wildlife and habitats. Washington, D.C.: The Wildlife Society.

Liu, B., and Z.Jiang. 2004. Dietary Overlap between Prezewalski's Gazelle and Domestic Sheep in the Qinghai Lake Region and Implications for Rangeland Management. Journal of Wildlife Management 68:241-246

Long, R.J., S. Apori, F. Castro, and E. Orskov. 1999. Feed value of native forages of the Tibetan Plateau of China. Animal Feed Science and Technology 80:101-113

Luschekina, A. 1994. The status of argali in Kyrgyzstan, Tajikistan, and Mongolia. Unpublished report to the U.S. Fish & Wildlife Service, Washington, D.C. 44 pp.

Mallon, D. P., S. Dulamtseren, A. Bold, R. P. Reading, and S. Amgalanbaatar. 1997. Mongolia. Pages 193-201 *in* Wild Sheep and Goats and Their Relatives: Status Survey and Conservation Action Plan for Caprinae, D. M. Shackleton (ed.) and the IUCN/SSC Caprinae Specialist Group. IUCN, Gland Switzerland.

Mandakh, B., G. Wingard, and R. Reading. 2005. Winter pasture conditions and forage use by argali (*Ovis ammon*) in Gobi Gurvan Saikhan National Park. Erforschung Biologischer Ressourcen der Mongolei (Halle/Saale) 9: 71-76.

McInnis, M. L., M. Vavra, and W.C. Krueger. 1983. A Comparison of Four Methods Used to Determine the Diets of Large Herbivores. Journal of Range Management 36(3):303-306

Miller, D. J., and G. B. Schaller. 1995. Ranging Dynamics in the Chang Tang Wildlife Reserve, Tibet. In Proceedings of the International Symposium Karakorum, Hindukush and Himalaya: Dynamics of Change, Islamabad, Pakistan.

Morisita, M. 1959. Measuring of interspecific association and similarity between communities. Memoirs of the Faculty Science, Kyushu Univ., Series E (Biology) 3:65-80

Myagmarsuren, D. 2000. Unpublished report to the Mongolian Ministry of Nature and Environment on the Protected Area Network of Mongolia. Ulaanbaatar, Mongolia.

Neu, C.W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization – availability data. Journal of Wildlife Management 38(3):541-545.

Pianka E. 1974. Niche overlap and diffuse competition. Proceedings of National Academy of Sciences 71:2141-2145

Petrides G. 1975. Principal food versus preferred foods and their relation to stocking rates and range condition. Biological Conservation 7:161-169

Reading, R. P. 1997. Wild camels in Mongolia. International Zoo News 44(7):422-423

Reading, R. P., M. Jonhstad, S. Amgalanbaatar, Z. Batjargal, and H. Mix. 1999. Expanding Mongolia's system of Protected Areas. Natural Areas Journal 19(3):211-222

Reading, R. P., S. Amgalanbaatar, G. J. Wingard, D. Kenny, and A. DeNicola. 2005. Ecology of argali in Ikh Nartiin Chuluu, Dornogobi Aimag. Erforschung Biologischer Ressourcen der Mongolei (Halle/Saale) 9: 77-89.

Reading, R. P., D. J. Bedunah and S. Amgalanbaatar. In press a. Conserving biodiversity on Mongolian rangelands: Implications for Protected Area Development and Pastoral Uses *in*: Rangelands of Central Asia: Transformations, Issues and Future Challenges, D. J. Bedunah (ed.).

Reading, R. P., D. Kenny, G. Wingard, B. Mandakh, and B. Steinhauer-Burkart. In press b. Ikh Nartiin Chuluu Nature Reserve: Argali Stronghold. Nature-Guide No. 4, Mongolia. ECO Nature Edition Steinhauer-Burkart OHG, Oberaula, Germany.

Shagdarsuren, O, S. Jigj, D. Tsendjav, S. Dulamtseren, A. Bold, Kh. Monkhbayar, A. Dulmaa, G. Erdenejav, Kh. Ulziisaikhan, U. Ligaa, Ts. Sanchir. 1987. Red Book of the Mongolian People's Republic. Mongolian State Publishing House. Ulaanbaatar, Mongolia (in Mongolian)

Shanyavskii, A. 1976. Development of Forestry and Hunting Farms. Mongolian Ministry of Forestry, Ulaanbaatar, Mongolia. (In Russian)

Shennikov, A. P. 1964. Geobotanical Research. Moscow, pp.447.

Shrestha, R., P.Wegge, A. Koirala. 2005. Summer Diets of Wild and Domestic Ungulates in Nepal Himalaya. Journal of Zoology 226:111-119

Schaller, G. B. 1977. Mountain monarchs: Wild sheep and goats of the Himalaya. Chicago: University of Chicago Press, Chicago, Illinois.

Schaller, G. B. 1998. Wildlife of the Tibetan Steppe. Chicago: University of Chicago Press, Illinois.

Schoener T. 1983. Field experiments on interspecific competition. American Naturalist 122:240-285

Sukhbat, Kh. 1975. Census of mountain ungulates in the Mongolian and Gobi Altai. Pages 165-167 *in* Problems of Game Management and Nature Conservation. Irkutsk Agriculture Institute. Irkutsk, Russian Federation.

Swift, J., and R. Mearns. 1993. Mongolian pastoralism on the threshold of the twenty-first century. Nomadic Peoples 33: 3-7.

Thomas, D. L., and E. J. Taylor. 1990. Study designs and tests for comparing resource use and availability. Journal of Wildlife Management 54:322-330.

Tsalkin, V. I. 1951. Wild Mountain Sheep of Europe and Asia. Moscow Association for Nature Research, Moscow, Soviet Union. (in Russian)

Tserenbataa, T, R. R. Ramey II, A. Ryder, T.W. Quinn, and R. P. Reading. 2004. A population genetic comparison of argali sheep (*Ovis ammon*) in Mongolia using the ND5 gene of mitochondrial DNA; implications for conservation. Molecular Biology 13:1333-1339

Valdez, R. 1982. The wild sheep of the world. Mesa, NM: Wild Sheep and Goat International.

Van Soest, P. J. 1970. Basis for relationship between nutritive value and chemical indentifiable fractions *in*: Natl. Conf. Forage Quality Evaluation and Utilization. Nebraska Center for Continuing Education, Lincoln.

Van Soest, P. J. 1982. Nutritional ecology of the ruminant. O&B Books, Inc., Corvallis, Oregon.

Wingard, J. R., and P. Odgerel. 2001. Compendium of Environmental Law and Practice in Mongolia. GTZ Commercial and Civil Law Reform Project and GTZ Nature Conservation and Buffer Zone Development Project. Ulaanbaatar, Mongolia.

Wingard, J. R., and Erdene-Ochir, B. 2004. Strengthening of Environmental Management in Mongolia: Institutional and Regulatory Analysis. World Bank Report, Ministry of Nature and Environment, Ulaanbaatar, Mongolia.

Wingard, J. R. 2005 (in press.) Silent Steppe: the Illegal Wildlife Trade Crisis in Mongolia. Wildlife Conservation Society and World Bank Project Report.

Zhirnov, L. V., and V. O. Ilyinsky. 1986. The Great Gobi Reserve – a Refuge for Rare animals of the Central Asian Desert. USSR/UNEP Project, Programme for Publication and Informaiton Support, Centre for International Projects, GKNT, 129 pp., Moscow, Soviet Union.

TABLES

Table 1: Percent diet composition as determined by fecal analysis of argali collected during summer, fall, winter, and spring in Ikh Nart, Mongolia, 2002-2003.

Plant species	Season							
	Summer n=25		Fall n=25		Winter n=25		Spring n=25	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Forbs:								
Allium polyrrhizum	0.20	2.00	0.00	*	0.00	*	0.00	*
Aquilegia viridiflora	0.00	*	0.05	0.00	0.00	*	0.00	*
Arenaria capillaris	2.30	1.63	0.05	0.00	1.23	0.36	0.04	0.00
Astragalus spp.	0.76	0.81	0.00	*	0.23	0.13	0.00	*
Bassia dasyphylla	6.40	0.94	0.90	0.16	0.83	0.17	1.33	0.25
Bupleurum spp.	0.47	0.34	1.26	0.31	0.74	0.26	0.27	0.29
Chamaerhodos erecta	2.84	0.61	0.93	0.20	0.47	0.41	0.34	0.21
Chenopodium aristatum	2.32	0.40	1.88	0.36	0.26	0.12	0.89	0.24
Erysimum/Convolvulus spp.	5.26	0.78	5.56	1.01	0.52	0.51	0.10	0.02
Heteropappus hispidus	0.19	0.26	0.13	0.09	0.02	0.00	0.08	0.07
Lappula intermedia	3.37	0.69	4.76	0.60	0.74	0.35	0.02	0.00
Melandrum spp.	0.18	0.00	0.00	*	0.00	*	0.00	*
Oxytropis spp.	8.34	0.78	2.40	0.25	1.80	3.19	1.20	0.27
Peucedanum bungeana	0.00	*	0.00	*	0.02	0.00	0.00	*
Potentilla spp.	1.41	0.50	0.26	0.18	0.04	0.00	0.07	0.00
Rheum undulatum	0.14	0.45	0.24	0.28	0.06	0.00	0.00	*
Stellera dichotoma	0.10	0.15	0.00	*	0.06	0.00	0.00	*
Thymus gobicus	0.00	*	0.00	*	0.05	0.00	0.00	*
Urtica cannabina	0.00	*	0.00	*	0.12	0.00	0.00	*
Vicia spp.	0.47	0.31	0.05	0.00	0.00	*	0.00	*
Unknown Forbs	3.92	0.30	2.44	1.45	1.65	0.26	0.87	0.21
Shrubs:								
Leaf, Rhus like hair	6.57	0.72	11.69	1.11	2.12	0.58	0.93	0.21
Ajania achilleoides	1.90	0.41	1.86	0.22	4.04	0.54	10.02	0.87
Amygdalus pedunculata	1.16	0.66	1.13	0.27	0.15	0.14	0.43	0.52
Artemisia frigida/A. ruthifolia	16.83	2.09	16.26	1.56	15.09	1.63	15.58	1.20
Caragana pygmaea	7.12	1.11	6.90	0.77	2.56	0.52	1.76	0.42
Caryopteris mongolica	4.65	0.53	6.24	0.68	0.30	0.20	0.06	0.15
Ephedra equisetina	0.35	0.86	0.14	0.15	11.58	1.24	13.63	1.38
Ptilotrichum canescens	0.17	0.08	0.12	0.05	0.23	0.07	0.25	0.20
Unknown Shrub leaf	5.05	0.61	7.72	0.58	3.57	0.48	1.68	0.28
Grasses:								
Achnatherum splendens	0.56	1.13	0.60	0.35	0.16	0.00	0.00	*
Agropyron cristatum	3.36	0.61	2.76	0.75	16.94	1.32	18.16	1.95
Cleistogenes squarrosa	1.29	0.58	3.08	0.44	6.00	0.74	4.59	0.62
Elymus chinensis	0.00	*	0.05	0.00	0.00	*	0.00	*
Festuca/Poa spp.	0.00	*	0.00	*	8.91	0.74	7.67	0.53
Koeleria macrantha	0.22	0.10	0.84	0.21	1.24	0.24	1.99	0.40
Poa spp.	1.16	0.76	3.76	0.53	0.00		0.00	*
Stipa spp.	3.41	0.81	6.05	0.72	11.41	1.09	9.80	1.06
Unknown Grasses	2.76	0.41	3.96	0.55	2.55	0.39	1.80	0.33
Sedges:								
Carex spp.	1.34	0.90	3.47	0.48	4.20	0.62	6.11	0.68
Other:								
Flower	0.00	*	0.02	0.00	0.00	*	0.00	*
Seed/Nut	2.70	0.64	1.80	0.58	0.02	0.00	0.02	0.00
Thorn	0.58	0.27	0.60	0.66	0.09	0.11	0.23	0.17
Lichen	0.00	*	0.00	*	0.00	*	0.04	0.00
Insect	0.15	1.00	0.05	0.00	0.00	*	0.05	0.00
Total:	100.00	*	100.00	*	100.00	*	100.00	*

* - SE were not calculated

Table 2: Percent diet composition at categorical levels as determined by fecal analysis of argali collected during summer, fall, winter, and spring in Ikh Nart, Mongolia, 2002-2003.

Plant categories	Season							
	Summer		Fall		Winter		Spring	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Total Forbs	38.7	2.2	20.9	1.4	5.3	0.6	7.6	0.8
Total Shrub	43.8	2.2	52.1	1.9	37.4	4.6	35.9	2.0
Total Grass	12.7	1.6	21.1	1.9	53.6	4.7	48.3	2.6
Total Sedge	1.3	0.5	3.5	0.5	2.7	0.5	7.5	1.0
Total Other	3.4	0.7	2.5	0.5	1.0	0.3	0.6	0.2
Total	100.00		100.00		100.00		100.00	

Table 3: Key plant species selected by argali during summer, fall, winter, and spring in Ikh Nart, Mongolia, 2002-2003

Plants	Summer (%)	Fall (%)	Winter (%)	Spring (%)
Artemisia frigida/ruthifolia	16.83	16.26	15.09	15.58
Oxytropis spp.	8.34	2.40	1.80	1.20
Caragana pygmaea	7.12	6.90	2.56	1.76
Bassia dasyphylla	6.40	0.90	0.83	1.33
Erysimum/Convolvulus spp.	5.26	5.56	0.52	0.10
Caryopteris mongolica	4.65	6.24	0.30	0.06
Agropyron cristatum	3.36	2.76	16.94	18.16
Ajania achilleoides	1.90	1.86	4.04	10.02
Stipa spp.	3.41	6.05	11.41	9.80
Festuca/Poa spp.	0.00	0.00	8.91	7.67
Carex spp.	1.34	3.47	4.20	6.11
Cleistogenes squarrosa	1.29	3.08	6.00	4.59
Total (%)	59.90	55.48	72.60	76.38

Table 4: Percent diet composition of shoats as determined by fecal analysis collected during summer, fall, winter, and spring in Ikh Nart, Mongolia, 2002-2003

Plant species	Season							
	Summer n=25		Fall n=25		Winter n=25		Spring n=25	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Forbs:								
Allium polyrrhizum	0.00	*	0.11	0.00	0.00	*	0.13	0.15
Aquilegia viridiflora	0.10	0.00	0.00	*	0.00	*	0.00	*
Arenaria capillaris	0.35	0.20	0.52	0.00	0.35	1.04	2.03	0.49
Astragalus spp.	1.20	0.40	0.67	0.46	0.05	0.06	0.49	0.21
Bassia dasyphylla	2.92	0.53	1.09	0.16	0.28	0.09	0.77	0.27
Bupleurum spp.	0.26	0.50	0.81	0.31	0.48	0.46	0.50	0.20
Chamaerhodos erecta	1.13	0.86	2.15	1.35	0.00	*	0.29	0.56
Chenopodium aristatum	1.11	0.18	0.83	0.15	0.47	0.27	0.44	0.27
Corispermum mongolicum	0.07	0.00	0.00	*	0.00	*	0.00	*
Dracocephalum foetidum	0.00	*	0.11	0.00	0.00	*	0.00	*
Erysimum/Convolvulus spp	22.22	3.16	10.76	1.98	0.10	0.19	0.24	0.18
Heteropappus hispidus	0.22	0.28	0.27	0.54	0.00	*	0.02	0.00
Lappula intermedia	1.04	0.34	0.66	0.37	0.26	0.36	0.02	0.00
Melandrum spp.	0.18	0.48	0.08	0.55	0.00	*	0.00	
Oxytropis spp.	6.35	0.55	2.94	0.39	2.09	0.57	0.93	0.66
Peucedanum bungeana	0.00	*	0.00	*	0.16	0.21	0.00	*
Potentilla spp.	1.82	0.37	1.12	0.71	0.11	0.45	0.01	0.00
Rheum undulatum	0.30	1.05	0.14	0.20	0.00	*	0.00	*
Saussurea spp.	0.05	0.00	0.00	*	0.00	*	0.00	*
Silene jenisseensis	0.16	0.64	0.34	1.45	0.00	*	0.00	*
Stellera dichotoma	0.00	*	0.05	0.15	0.00	*	0.00	*
Thymus gobica	0.00	*	0.00	*	0.00	*	0.02	0.00
Urtica cannabina	0.02	0.00	0.00	*	0.00	*	0.00	*
Vicia spp.	0.23	0.11	0.08	0.00	0.00	*	0.00	*
Unknown Forbs	2.73	1.67	3.39	0.41	0.95	0.19	1.67	0.28
Shrubs:								
Leaf Rhus like hair	2.10	0.66	3.45	0.78	1.45	1.96	0.37	0.39
Ajania achilleoides	2.83	0.43	3.82	1.10	4.79	0.89	6.48	0.45
Amygdalus pedunculata	0.58	0.67	1.04	0.40	1.54	0.72	0.37	0.50
Artemisia frigida/ruthifolia	13.58	1.38	14.03	1.28	21.42	2.34	23.30	1.69
Caragana pygmaea	2.34	0.83	7.79	0.93	3.48	1.07	2.64	0.33
Caryopteris mongolica	0.72	0.28	2.34	0.51	0.56	1.80	0.13	1.00
Ephedra equisetina	0.29	0.40	0.56	0.18	0.72	0.84	0.87	0.34
Haplophyllum dahuricum	0.08	0.00	0.06	0.00	0.00	*	0.00	*
Ptilotrichum canescens	0.15	0.09	0.09	0.09	0.04	0.00	0.14	0.17
Unknown Shrub leaf	2.50	0.42	5.50	0.82	3.39	0.86	1.68	0.26

Table 4: Continued

Plant species	Season							
	Summer n=25		Fall n=25		Winter n=25		Spring n=25	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Grasses:								
Achnatherum splendens	0.80	0.46	0.47	0.66	2.61	0.49	1.58	0.29
Agropyron cristatum	7.42	0.99	9.11	1.22	13.72	1.16	14.89	1.48
Cleistogenes squarrosa	1.96	0.94	2.02	0.51	1.36	0.37	4.77	0.51
Elymus chinensis	0.05	0.00	0.00		1.12	0.38	0.58	0.33
Festuca/Poa spp.	2.50	0.60	0.20	0.00	7.19	0.82	8.12	0.69
Koeleria macrantha	0.69	0.48	0.86	0.36	2.03	0.27	1.33	029
Poa spp.	2.21	0.59	2.94	0.43	0.49	0.00	0.00	*
Stipa spp.	6.44	0.97	8.89	0.92	22.41	3.42	15.02	1.28
Unknown Grasses	3.32	0.33	4.16	0.40	2.68	0.43	2.05	0.29
Sedges:								
Carex spp.	3.59	0.84	4.46	0.91	2.70	0.52	7.48	0.97
Other:								
Seed/Nut	2.76	1.33	1.36	0.63	0.18	0.67	0.23	0.30
Thorn	0.55	0.09	0.69	0.26	0.68	0.32	0.32	0.51
Insect	0.08	0.60	0.00	*	0.14	0.75	0.10	0.18
Total	100.00	*	100.00	*	100.00	*	100.00	*

* - SE were not calculated

Table 5: Percent diet composition of shoats at categorical levels as determined by fecal analysis collected during summer, fall, winter, and spring in Ikh Nart, Mongolia, 2002-2003

Plant categories	Season							
	Summer		Fall		Winter		Spring	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Total Forbs	42.46	3.22	26.14	2.10	8.84	1.87	5.21	0.59
Total Shrub	25.17	1.82	38.69	2.10	39.63	1.59	44.33	2.33
Total Grass	25.39	2.31	28.66	2.47	47.22	2.24	44.02	2.59
Total Sedge	3.59	0.78	4.46	0.87	4.20	0.62	6.11	0.68
Total Other	3.39	0.93	2.04	0.46	0.11	0.05	0.33	0.13
Total	100.00		100.00		100.00		100.00	

Table 6: Key plant species selected by shoats in summer, fall, winter, and spring in Ikh Nart, Mongolia, 2002-2003

Plants	Summer (%)	Fall (%)	Winter (%)	Spring (%)
Erysimum/Convolvulus spp.	22.22	10.76	0.08	0.24
Artemisia frigida/ruthifolia	13.58	14.03	21.42	23.30
Oxytropis spp.	6.35	2.94	2.09	0.93
Ajania achilleoides	2.83	3.82	4.79	6.48
Caragana pygmaea	2.34	7.79	3.48	2.64
Stipa spp.	6.44	8.89	22.41	15.02
Agropyron cristatum	7.42	9.11	13.72	14.89
Festuca/Poa spp.	2.50	0.20	7.19	8.12
Carex spp.	3.59	4.46	2.70	7.48
Total (%)	67.27	62.0	77.88	79.10

Table 7: Dietary overlap of argali and shoats diets using Morisita's and Pianka's similarity indices

Seasons	Mean Forage Category Overlap		Mean Species Overlap		Mean Key Species Overlap	
	Morisita's	Pianka's	Morisita's	Pianka's	Morisita's	Pianka's
Summer, 02	92%	92%	72%	73%	72%	74%
Fall, 02	93%	94%	87%	88%	88%	90%
Winter, 03	99%	99%	85%	86%	90%	92%
Spring, 03	99%	99%	88%	88%	95%	95%

Table 8: Plant species summer biomass (g/m^2) as determined by random vegetation sampling in Ikh Nart, Mongolia, 2002

Species	Sum	# Plots w/	Means	SD	SE
Artemisia frigida	266.3	63	4.2	5.0	0.6
Artemisia spp.	122.2	10	12.2	12.4	3.9
Artemisia dracunculus	33	2	16.5	14.0	9.9
Stipa spp.	255.9	77	3.3	3.5	0.4
Kochia prostrata	42.5	19	2.2	1.3	0.3
Carex spp.	174.9	59	3.0	2.1	0.3
Allium spp.	144.7	61	2.4	3.2	0.4
Agropyron cristatum	35.7	19	1.9	2.1	0.5
Achnatherum splendens	166	7	23.7	18.1	6.9
Cleistogenes squarrosa	48.2	46	1.0	0.9	0.1
Caragana pygmaea	61.9	21	2.9	2.6	0.6
Ajania achiloides	32.8	11	3.0	1.5	0.5
Koeleria machrantha	4.4	5	0.9	0.5	0.2
Gypsophila desertorum	24.8	19	1.3	0.8	0.2
Haplophyllum dahuricum	17	11	1.5	1.3	0.4
Chenopodium aristatum	8.7	7	1.2	1.0	0.4
Cymbaria dahurica	2.8	15	0.2	0.1	0.0
Bassia dasyphylla	21.5	9	2.4	1.7	0.6
Peganum nigellastrum	6.2	2	3.1	3.5	2.5
Scorzonera spp.	6.5	5	1.3	1.1	0.5
Convolvulus ammanii	68.7	20	3.4	3.0	0.7
Limonium spp.	4.1	5	0.8	0.8	0.3
Salsola pestifera	98.2	16	6.1	9.4	2.4
Salsola passerina	2.1	1	2.1	*	*
Orostachys fimbriata	5.3	6	0.9	1.6	0.7
Erysimum altaicum	0.3	1	0.3	*	*
Elymus pabaonus	70.5	4	17.6	11.2	5.6
Asparagus dahuricus	6.5	6	1.1	0.9	0.4
Stelleria dichotoma	0.2	1	0.2	*	*
Vincetoxicum sibiricum	1.6	2	0.8	1	0.7
Potentilla bifurca	0.5	1	0.5	*	*
Heteropappus hispidus	29.0	22	1.3	1.1	0.2
Sibbialdanthe adpressa	5.2	3	1.7	1.2	0.7
Puccinella Hauptiana	0.5	1	0.5	*	*
Reaumuria soongorica	1.5	1	1.5	*	*
Astragalus miniatus	2.3	4	0.6	0.7	0.3
Tribulus terrestris	2.3	2	1.2	1.2	0.9

Table 8: Continued

Species	Sum	# Plots w/	Means	SD	SE
Dontostemon integrifolius	0.1	1	0.1	*	*
Caryoptris mongolica	25.1	10	2.5	1.6	0.5
Eragrostis minor	1.8	1	1.8	*	*
Iris tenuifolia	4.5	3	1.5	0.6	0.3
Ephedra sinica	87.8	4	22.0	28.3	14.2
Melandrum apricum	0.3	1	0.3	*	*
Leptoferum fumaroides	0.4	1	0.4	*	*
Setaria viridis	0.5	1	0.5	*	*
Ptilotrichum canescens	0.2	2	0.1	0.0	0.0
Total	1,895.50	100	19	14.6	1.5

Table 9: Plant species winter biomass (g/m^2) as determined by random vegetation sampling in Ikh Nart, Mongolia, 2003

Species	Sum	# Plots w/	Mean	SD	SE
Artemisia frigida	66.6	58	1.1	0.68	0.09
Artemisia spp.	10.6	9	1.2	1.41	0.47
Stipa spp.	50.7	43	1.2	1.03	0.16
Kochia prostrata	12.1	17	0.7	0.49	0.12
Carex spp.	85.7	60	1.4	1.22	0.16
Allium spp.	2.6	7	0.4	0.39	0.15
Agropyron cristatum	15.7	15	1.0	1.02	0.26
Achnatherum splendens	65.5	7	9.4	6.05	2.29
Cleistogenes squarrosa	8.1	27	0.3	0.40	0.08
Caragana pygmaea	18.9	18	1.1	1.39	0.33
Ajania achiloides	1.1	2	0.6	0.07	0.05
Koeleria machrantha	0.6	1	0.6	*	*
Gypsophila desertorum	0.5	2	0.3	0.21	0.15
Arenaria capillaris	1.0	2	0.5	0.57	0.4
Setaria viridis	1.1	5	0.2	0.13	0.06
Cymbaria dahurica	0.2	2	0.1	0.00	0.00
Bassia dasyphylla	0.1	1	0.1	*	*
Scorzonera spp.	1.2	2	0.6	0.57	0.40
Reaumuria songorica	0.2	2	0.1	0.00	0.00
Crepis spp	0.5	2	0.3	0.07	0.05
Salsola pestifera	1.3	3	0.4	0.49	0.28
Heteropappus hisidus	0.4	2	0.2	0.00	0.00
Total	354.8	90	3.9	3.35	0.35

Table 10: Use and availability indices for selected plant species in summer and winter for argali and shoats in Ikh Nart, Mongolia, 2002-2003

Plants species	Summer Argali	Winter Argali	Summer Shoats	Winter Shoats
Artemisia frigida/ruthifolia	1.4	0.8	1.1	1.1
Stipa spp.	0.3	0.8	0.5	1.6
Carex spp.	0.1	0.2	0.4	0.1
Agropyron cristatum	1.8	3.8	3.9	3.1
Achnatherum splendens	0.1	0.0	0.1	0.1
Cleistogenes squarrosa	0.5	2.6	0.8	0.6
Caragana pygmaea	2.2	0.5	0.7	0.7
Koeleria macrantha	1.0	6.0	3.5	10.0
Arenaria capillaris	-	4.0	-	1.3
Bassia dasyphylla	5.8	0.0	2.6	0.0
Heteropappus hispidus	0.1	0.0	0.1	0.0
Ajania fruticosa	1.1	-	1.6	-
Chenopodium aristatum	4.6	-	2.2	-
Convolvulus ammanii	1.4	-	0.0	-
Caryopteris mongolica	3.5	-	0.5	-
Ephedra equisetina	0.1	-	0.1	-
Ptilotrichum canescens	0.0	-	0.0	-

Table 11: Chemical nutritional analysis of selected plants by argali, shoats during summer and fall in Ikh Nart, Mongolia, 2002- 2003

	Season I – Summer						Season II – Fall					
Plant Species	N%	CP%	NDF%	ADF%	ADL%	Ash	N%	CP%	NDF%	ADF%	ADL%	Ash
Forbs:												
Allium polyrrhizum	5.03	31.44	28.76	21.63	5.57	1.03	2.00	12.47	61.62	30.52	5.94	1.57
Allium odorum	*	*	*	*	*	*	5.27	32.97	24.92	19.34	3.34	1.08
Allium mongolicum	*	*	*	*	*	*	3.88	24.28	36.09	26.83	4.28	0.62
Allium anisopodium	*	*	*	*	*	*	2.80	17.52	46.17	35.55	7.46	0.87
Asparagus gobicus	1.75	10.94	58.00	39.85	7.50	0.73	*	*	*	*	*	*
Clematis fruticosa	1.87	11.71	52.17	38.54	11.42	0.43	1.44	9.00	56.40	41.69	11.04	0.46
Serratula centauroides	1.67	10.43	54.52	36.86	8.74	0.79	*	*	*	*	*	*
Shrubs:												
Artemisia frigida	*	*	*	*	*	*	2.28	14.25	48.62	33.83	10.74	1.57
Artemisia ruthifolia	*	*	*	*	*	*	*	*	*	*	*	*
Artemisia sp.	*	*	*	*	*	*	*	*	*	*	*	*
Amygdalus pedunculata	1.64	10.25	41.18	27.86	7.43	0.82	1.50	9.00	43.01	31.53	13.31	0.54
Caragana pygmaea	1.60	9.98	59.32	43.15	10.23	1.02	1.41	8.79	61.71	46.90	14.62	0.78
Haplophyllum dahuricum	*	*	*	*	*	*	1.28	7.99	52.90	38.17	8.61	0.52
Kochia prostrata	2.97	18.55	45.39	26.97	3.87	0.63	1.73	10.83	41.96	26.33	4.74	1.79
Spiraea aquilegifolia	1.40	8.76	45.38	26.06	6.18	40.75	1.15	7.17	51.16	32.76	11.60	0.89
Grasses:												
Agropyron cristatum	2.00	11.34	64.37	33.53	4.20	1.45	*	*	*	*	*	*
Caryopteris mongolica	1.86	11.60	32.41	23.46	8.45	1.83	1.99	12.44	37.04	26.91	9.16	1.21
Cleistogenes squarrosa	*	*	*	*	*	*	1.78	11.12	67.12	30.09	1.18	1.12
Stipa gobica	2.00	12.51	62.14	28.08	4.00	1.15	1.82	11.38	70.91	36.67	-2.12	5.76
Stipa krylovii	*	*	*	*	*	*	2.70	16.87	45.33	32.70	7.69	0.50
Stipa glareosa	*	*	*	*	*	*	*	*	*	*	*	*
Sedges:												
Carex duriuscula	*	*	*	*	*	*	*	*	*	*	*	*
Other:												
Ulmus pumila	1.81	11.34	55.27	38.35	8.03	0.31	1.35	8.45	78.44	47.15	14.30	1.03

* - plants were not available or not selected at the given season

Table 12: Chemical nutritional analysis of selected plants by argali, domestic sheep, and goats during winter and spring in Ikh Nart, Mongolia, 2002- 2003

Plant Species	Season III – Winter						Season IV – Spring					
	N%	CP %	NDF%	ADF%	ADL%	Ash	N%	CP %	NDF%	ADF %	ADL %	Ash
Forbs:												
Allium polyrrhizum	1.65	10.33	60.06	45.44	4.81	3.28	2.66	16.64	48.47	41.53	20.92	15.92
Allium odorum	*	*	*	*	*	*	*	*	*	*	*	*
Allium mongolicum	*	*	*	*	*	*	*	*	*	*	*	*
Allium anisopodium	*	*	*	*	*	*	2.00	12.52	51.61	39.33	10.90	2.93
Asparagus gobicus	*	*	*	*	*	*	*	*	*	*	*	*
Clematis fruticosa	*	*	*	*	*	*	*	*	*	*	*	*
Serratula centauroides	1.20	7.52	61.42	39.73	5.98	1.18	*	*	*	*	*	*
Kochia prostrata	*	*	*	*	*	*	1.14	7.14	54.81	34.95	9.66	2.20
Shrubs:												
Artemisia frigida	1.77	11.07	49.77	36.81	10.67	2.36	1.49	9.34	54.80	41.16	13.03	2.55
Artemisia ruthifolia	0.77	4.84	63.86	49.49	13.83	0.62	0.78	4.87	63.27	49.57	18.05	0.44
Artemisia sp.	0.63	3.93	73.04	57.37	17.75	1.35	*	*	*	*	*	*
Amygdalus pedunculata	0.67	4.21	68.37	46.39	9.24	0.60	0.75	4.67	62.22	45.95	15.44	0.48
Caragana pygmaea	1.39	8.67	63.13	49.52	14.64	0.96	1.27	7.91	63.95	48.30	15.81	0.70
Haplophyllum dahuricum	*	*	*	*	*	*	*	*	*	*	*	*
Spiraea aquilegifolia	0.90	5.63	65.66	42.01	12.73	0.69	*	*	*	*	*	*
Agropyron cristatum	0.77	4.83	66.71	38.52	3.68	0.79	1.79	11.16	59.59	44.61	4.08	2.37
Grasses:												
Caryopteris mongolica	1.00	6.28	58.17	41.69	12.66	1.26	1.22	7.63	56.59	41.40	11.09	0.83
Cleistogenes squarrosa	*	*	*	*	*	*	1.07	6.68	65.71	35.16	2.15	1.22
Stipa gobica	1.43	8.97	64.46	33.99	4.98	1.42	0.96	6.01	65.69	34.99	3.40	1.50
Stipa krylovii	0.57	3.55	67.40	37.25	3.02	0.72	1.12	6.98	67.54	34.56	3.03	0.58
Stipa glareosa	*	*	*	*	*	*	1.15	7.17	64.26	33.73	12.98	0.81
Sedges:												
Carex duriuscula	*	*	*	*	*	*	2.18	13.60	61.99	32.80	3.83	2.49
Other:												
Ulmus pumila	1.00	6.25	70.71	51.37	10.27	0.64	*	*	*	*	*	*

* - plants were not available or not selected at the given season

Table 13: Percentage IVDMD of selected plant species during summer, fall, winter, and spring in Ikh Nart, Mongolia, 2002-2003

	IVDMD by seasons			
Plants	Summer	Fall	Winter	Spring
Forbs:				
Allium mongolicum	*	35.5	*	*
Allium polyrrhizum	*	*	*	48.9
Allium antisopodium	*	52.3	*	60.5
Clematis fruticosa	35.7	*	*	*
Serratula centauroides	37.7	*	*	*
Shrubs:				
Artemisia ruthifolia	*	*	32.0	27.5
Artemisia frigida	*	39.7	41.3	*
Artemisia sp.	*	*	16.9	*
Amygdalus pedunculata	35.5	16.7	15.0	*
Caragana pygmaea	*	19.7	*	19.5
Haplophyllum dahuricum	*	39.3	*	*
Caryopteris mongolica	54.1	52.2	*	40.3
Kochia prostrata	50.6	58.3	*	30.1
Spiraea aquilegifolia	32.1	38.7	25.4	*
Grasses:				
Stipa gobica	32.6	*	27.2	35.2
Stipa glareosa	*	*	*	31.2
Stipa krilovii	*	30.8	*	47.1
Agropyron cristatum	33.9	*	*	52.2
Cleistogenes squarrosa	32.1	*	*	40.8
Sedges:				
Carex duriuscula	*	*	*	46.2
Other:				
Ulmus pumila	28.5	25.6	24.8	*

Figure 2: Dietary composition of argali and shoats diet in summer, fall, winter, and spring in Ikh Nart, Mongolia 2002-2003