ECOLOGY AND CONSERVATION OF SNOW LEOPARDS, GOBI BROWN BEARS, AND WILD BACTRIAN CAMELS IN MONGOLIA

A Dissertation Presented

By

THOMAS MICHAEL MCCARTHY

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DEDICATION

To my sons Keegan and Kyle,

our times together in the field brought me the greatest joy,
our long separations the most pain,
your concern and understanding the deepest pride;
this is for you.

In loving memory of my father, who missed seeing the completion of this work by two days.
I will miss you Dad.

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Numerous individuals have been instrumental in making this work possible. I sincerely thank my advisor Todd K. Fuller for his guidance, encouragement, and especially his friendship throughout the length of this study. Todd kept the University believing that there really was a student working somewhere in the Mongolia, despite my rare appearances on campus.

I am very grateful to George B. Schaller for providing the opportunity to work in Mongolia and for being instrumental in gaining funding through the years. I thank wildlife filmmaker and friend Joel Bennett for first introducing me to George. I will long value the insights and ideas both of these men shared while sitting around a yak-dung fire in our Altai mountain ger the winter we initiated the study.

J. Tserendeleg, conservationist and Vice-President of the Mongolian Association for Conservation of Nature and Environment, provided vital logistic support, links with government, contacts in the field, and in general, made the project possible from a practical Mongolian standpoint.

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B. Munkhtsog was my Mongolian counterpart on the snow leopard research and also played an important role in conservation planning. B. Mijiddorj of the Great Gobi National Park cooperated on both the wild camel and Gobi brown bear studies. I can not thank them enough for the years of hard work they put in, and the friendship they gave.

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In addition to funding, Julian Matthews of Discoveryinitiatives provided field volunteers for the snow leopard, Gobi bear and wild camel surveys. Martin Harper led a team of Discoveryinitiatives volunteers on snow leopard surveys in the Khovsgol region which provided all our data from that area.

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Pete Zahler has experienced and understands the difficulties of research in Central Asia. Via e-mail he provided unending wisdom, or when that failed, wit, that kept me going through field trips and while wrenching meaning from my data.

Finally, I am indebted to my wife and field-partner Priscilla Allen. Though she joined me and the project half-way through, her devotion and support sustained me during the most difficult periods; from 24-hour snow leopard activity monitoring on a mountainside at -30° C, to editing the last paragraphs of this dissertation. Her questioning of my methods and analyses kept me thinking. More frequent than her questions were her words of encouragement. For all of this, I express my thanks and love.

ABSTRACT

ECOLOGY AND CONSERVATION OF SNOW LEOPARDS,

GOBI BROWN BEARS, AND WILD BACTRIAN CAMELS IN MONGOLIA

FEBRUARY 2000

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Snow leopard ecology, distribution and abundance in Mongolia were studied between 1993 and 1999. I placed VHF and satellite radio-collars on 4 snow leopards, 2 males and 2 females, to determine home ranges, habitat use, movements, and activity. Home ranges of snow leopards in Mongolia were substantially larger than reported elsewhere. Males ranged over 61 - 142 km^2 and female 58 to 1,590 km^2. Cats had crepuscular activity patterns with daily movements averaging 5.1 km. Intraspecific distances averaged 1.3 km for males to 7.8 km for males. Leopards selected moderately to very-broken habitat with slopes > 20°, in areas containing ibex. Leopard distribution and abundance was determined using sign surveys. Leopard range in Mongolia is approximately 103,000 km^2 but cats are not uniformly distributed within that range. High-density areas include the eastern and central Transaltai Gobi and the northern Altai ranges. Relative leopard densities compared well with relative ibex densities on a regional basis.

A snow leopard conservation plan was drafted for Mongolia that identifies problems and threats, and provides an action plan.

Wild Bactrian camels occur in the Great Gobi National Park (GGNP) and are thought to be declining due to low recruitment. I surveyed camels by jeep and at oases, observing 142 (4.2% young) and 183 (5.3% young) in 1997 and 1998. Current range was estimated at 33,300 km^2. Some winter and calving ranges were recently abandoned. Track sizes and tooth ages from skulls were used to assess demographics. A deterministic model was produced that predicts camel extinction within 25 to 50 years under current recruitment rates and population estimates.

Gobi brown bears are endemic to Mongolia and may number less than 35. Three population isolates may occur. I collected genetic material from bears at oases using hair traps. Microsatellite analyses of nuclear DNA determined sixteen unique genotypes, only two of which occurred at more than one oases. Genetic diversity was very low with expected heterozygosity = 0.32, and alleles per locus = 2.3. Mitochondrial DNA sequences were compared to other clades of brown bear and found to fall outside of all known lineages.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The opportunity to study snow leopards in Great Gobi region of Mongolia was presented to me in 1991, and it came about as the result of a serendipitous set of circumstances rather than something I had actively sought. However, the image evoked by words like "snow leopard" and "Great Gobi" lead to ready acceptance of the otherwise unexpected offer. My experience as a wildlife biologist in Alaska had prepared me in most respects for the physical realities of working in Mongolia, but I underestimated the logistic obstacles that lay ahead, anticipating 3 years in the field to complete the planned study. Seven years later, I present here the results of what became a study of more than just snow leopards.

In 1992, when I first traveled to Mongolia with George Schaller of the Wildlife Conservation Society to assess feasibility of the snow leopard study, the country had just emerged from nearly seventy years of communism and had entered a period of economic and political uncertainty. Mongolia was financially incapable of maintaining more than minimal wildlife research or management activities, yet it was during the same year that they announced a goal of placing fully one third of the country into protected status. A keen national interest in maintaining Mongolia's unique natural heritage allowed them to look beyond their immediate economic constraints. The atmosphere was ideal for the cooperative project I was about to initiate and it had strong backing within the country.

Support came from both the Mongolian Association for Conservation of Nature and Environment (MACNE) the nation's leading environmental NGO, and the Ministry of Nature and Environment (MNE). However, my intended study area was far removed from these Ulaanbaatar-based entities and to be successful I would also require local cooperators. Since the days of Roy Chapman Andrews no more than a handful of westerns had visited the southwest of Mongolia were the Altai mountains meet the Great Gobi, and my presence there needed to be explained to the local people, nomadic herders, among whom I would live and work. The Great Gobi National Park (GGNP) had worked cooperatively with Schaller in the past and offered to provide me with the necessary field support. With their assistance I selected a location with a suspected high-density snow leopard population where I would use radio-telemetry to study several aspects of the cats' ecology. From this base I would also travel the length of potential snow leopard habitat in the country to determine range extent and relative abundance. MACNE provided a long-term biological counterpart, B. Munkhtsog, and the project was initiated in early 1993.

As part of the cooperative agreement with the GGNP, I offered to work with staff on other wildlife issues to the extent that time allowed. It quickly became apparent that there was a strong need among staff for training in basic wildlife research and management practices. Through classroom and practical field training we worked to improve staff capabilities. It was through this close association that I became familiar with the pressing research and conservation concerns for at least two other rare species endemic to the Gobi; the Gobi brown bear and the wild Bactrian camel. Bear and camel research proposals submitted by the Park failed to gain financial support from environmental aid agencies. I then approached WCS seeking added support for basic research on both the camel and the bear. They had initiated snow leopard, Gobi bear, and wild camel studies in the late 1980s, but saw all of the projects go dormant for lack of local leadership, so they readily approved my proposal. Additional grants were secured, but time, more than money, was the immediate constraint. By bringing Canadian biologist Elizabeth Hofer to the snow leopard project team, I was able to take on the additional bear and camel studies.

Snow leopards, brown bears, and wild camels represent a seemingly diverse set of study animals for a single dissertation. Yet the three share the same Gobi ecosystem, and many of the same threats in terms of small isolated or fragmented populations susceptible to human encroachment. They may share a similar fate as well, if conservation measures based on sound biological information are not undertaken in the near future. Snow leopards are found outside the Gobi but some of their highest densities within Mongolia occur there. A Gobi devoid of camels, bears and leopards would be a great loss to the people of Mongolia, and the world. The studies I undertook were designed to meet the most immediate information needs for these three species.

As diverse as the study animals, the methodologies required to answer specific research questions were also wide-ranging. I initiated the study of snow leopards using rudimentary ground based-telemetry and counts of leopard tracks. By the end of the study we were employing nuclear genetics for bear research and satellite technology to track snow leopards. By their nature, the resultant collection of papers is, as one of my committee members said, "somewhat eclectic". However, I believe they address a common theme of moving toward conservation of Mongolia's most threatened large mammals.

This dissertation consists of 6 chapters, including 4 manuscripts prepared for submittal to appropriate scientific journals, a conservation plan for snow leopards in Mongolia, and a short concluding chapter.

CHAPTER 1

DISTRIBUTION, ABUNDANCE, AND CONSERVATION OF SNOW LEOPARDS IN MONGOLIA

The range of the snow leopard (*Uncia uncia*) is restricted to the mountainous regions of Central Asia with core areas in the Altai, Tien Shan, Kun Lun, Pamir, Hindu Kush, Karakoram, and Himalaya ranges (Jackson and Hunter 1996). It is known to occur in twelve countries, including Afghanistan, Pakistan, India, Nepal, China, Bhutan, Mongolia, Russia, Tajikistan, Uzbekistan, Kazakhstan, and Kyrgykistan (Fox 1989). Knowledge of its distribution and status within these ranges is considered fragmentary at best. Although widespread, the snow leopard is listed as endangered in the International Union for the Conservation of Nature and Natural Resources (IUCN) Red Data Book and in Appendix I of the Convention on International Trade in Endangered Species (CITES).

Threats to the species are considered numerous and immediate. Despite receiving official protection throughout its range, the snow leopard is still hunted illegally for its bones, which are valued for traditional medicines, and for its pelt (Fox 1989). Intrusion and overgrazing by domestic stock and uncontrolled meat hunting have reduced populations of the leopard's natural prey, principally wild sheep and goats (Schaller et al. 1988). As prey populations decline, snow leopards may increase their use of domestic livestock with resultant retribution killing by herders in response to actual or suspected predation (Schaller et al. 1988,Schaller et al. 1994). Habitat fragmentation may reduce population densities to levels where genetic variability is diminished and long-term population viability threatened (Harris and Allendorf 1989, Soule and Simberloff 1986). This is especially true for large mammals such as snow leopards whose spatial requirements are large, and population densities low (Seidensticker 1986). Establishment and management of protected areas for these cats has often been haphazard and undertaken without the benefit of adequate scientific information (Khan 1994) and required snow leopard research has been impeded by the inherent difficulties of studying an elusive and secretive animal in extremely rugged, remote terrain. Political barriers have also restricted access to many areas known or suspected to support snow leopard populations. Thus, despite the occurrence of snow leopards in at least 45 protected areas encompassing more than 7% of their range (Jackson and Hunter 1996:10, Hunter and Jackson 1997), our ability to ensure their long-term survival is hampered by a lack of basic biological information. With an estimated wild population of between 3,500 and 7,000, snow leopards are not thought to be in imminent danger of extinction (Fox 1989), but for management and conservation efforts to be effective, an improved base of information on snow leopard ecology, distribution, and abundance is essential. Much of the previous work on this cat has been conducted in what may be prime habitat, hence, comparative studies are needed in areas where prey abundance and human disturbance are less favorable (Fox 1989). Mongolia, on both the geographic and ecological fringe of snow leopard range, is such a location and was elected as the site for this research.

As a political buffer between the China and the Soviet Union, this central Asian nation was closed to the western world since the 1920's when it joined the ranks of Soviet satellites. In 1989 Mongolia opted for a free-market economy and democratic government, an event that led to rapid change and yielded a period of economic and political crisis (Anon. 1994:3) from which it is still slowly recovering (Anon. 1997:13). The loss of the USSR as a trading partner was felt at many levels by Mongolian people. Lack of commodities forced severe rationing during the early years of reform and many non-essential government activities, including biological research, were curtailed. Across Central Asia, economic crisis must now be added to overgrazing, deforestation, and poor agricultural practices as threatening the existence of both wildlife and the unique human cultures of Central Asia's mountains (Int. Snow Leopard Trust, unpubl. handbook). The potential exists for developing countries such as Mongolia to look toward short term gains from extractive industry as an answer to current fiscal problems. Mineral and petroleum exploration has recently increased in Mongolia as joint ventures with western industries are pursued (Anon. 1996:23, Anon. 1997b). In the early 1990s Mongolia had limited means to conduct the research and surveys necessary to identify critical wildlife habitats in need of protection in the face of resource development pressure (Anon. 1996:58).

The status of snow leopards in Mongolia had been only superficially dealt with prior to 1989 (Bannikov 1954, Bold and Dorzhzunduy 1976, Mallon 1984, Zhirnov and Ilyinsky 1986, O'Gara 1988). The approximate distribution in Mongolia was known but little information on snow leopard abundance was available. Dash et al. (1977), suggested that snow leopards generally occur in areas where ibex (*Capra ibex*) are present, and that the goat is a principal component of the cats diet. Mallon (1984) concluded that snow leopards are widely distributed in the mountains of western Mongolia but are not common and have likely declined in numbers during this century. They were thought to occur in the Altai Mountains, the Khangai Mountains, the Hanhoohy Uul and Harkhyra ranges, and in isolated mountainous sections of the Trans-Altai Gobi (Mallon 1984,Schaller et al. 1994) with a total range probably less than 90,000 km^2.

Population estimates for snow leopards in Mongolia have ranged from a few hundred (Thornback and Holloway 1976) to more than 4,000 (Marechal, in Green 1988). Schaller et al. (1994) believed that about 1,000 existed with an overall density of 1.10 cats per 100 km^2 of occupied habitat. While density estimates as high as 5 cats per 100 km^2 have been suggested for areas of prime habitat in Nepal (Jackson and Ahlborn 1988), the overall Mongolian estimate compared more favorably with the estimate of 0.98 per 100 km^2 in the Tien Shan region of Kirgizia (Koshkarev 1989) and 0.66 per 100 km^2 in Ladakh (Mallon 1984).

Snow leopards lacked complete protection outside of preserves until early 1992 when a trophy hunting program was discontinued, and Mongolia did not become a signatory to CITES until 1995. Although snow leopards occur in at least 10 protected areas within Mongolia, conflict with domestic livestock is widespread (Schaller et al. 1994, P. Allen, unpubl. data). Prior to privatization in the early 1990s, livestock were communally owned and managed and penalties placed on herders for losing stock to predators were greater than the fines for killing snow leopards (J. Tserendeleg, Mongolia, pers. commun.). Today most livestock is privately owned and economics may still dictate that killing depredating cats is preferable to suffering personal stock losses (Schaller et al. 1994). However, records of losses to predators and resultant retribution kills of snow leopard are no longer being systematically kept and a clear picture of current human-snow leopard interactions is not available.

I sought to address information needs for snow leopard conservation in Mongolia through a two-part project. I discuss here a study of the limits and characteristics of snow leopard range in Mongolia, relative leopard abundance, protected area coverage, and basic information on human-snow leopard interactions. An investigation of snow leopard ecology based in the Saksai River area of Gobi-Altai constituted the second aspect of the overall project (Chapter 2).

Estimates of relative abundance have been generated by counts of tracks and feces for a number of species (Connor et al. 1983, Kirchhoff 1992, Roughton and Sweeney 1982, Van Dyke et al. 1986). Bold and Dorzhzunduy (1976) used unique pug marks in snow to estimate leopard numbers in a small area of

Mongolia. However, the lack of persistent snow or other tracking media makes pug marks ephemeral and not well suited for estimating abundance of snow leopards over large areas. Snow leopards, however, do leave other marks in the form of scrapes, claw rakes, scent sprays, and feces that are long-lasting (Rieger 1978, Ahlborn and Jackson 1988). A standardized methodology for surveying snow leopard sign and reporting the data has been developed by the International Snow Leopard Trust and is now used by researchers and managers in many snow leopard countries (Jackson and Hunter 1996). Together, these field protocols and information network are known as the Snow Leopard Information Management System (SLIMS). I used the SLIMS field techniques in cooperation with Mongolian scientists who are ISLT network affiliates.

<u>Methods</u>

Surveys

Sign surveys were conducted in sample areas throughout known or potential snow leopard range in Mongolia to determine relative leopard abundance in habitats of varying natural attributes and human activity. Most surveys took place where leopards were known to occur, based on best available information from provincial and local government agencies and from local herders. Several areas with habitat characteristics consistent with leopard requirements, but where cat presence was doubtful or unknown were also surveyed.

When snow leopard presence was known, or confirmed after cursory field visits, transect routes were plotted on available maps. Government held 1:100,000 topographic maps were preferred, but these remain State secrets and difficult to access, so 1:500,000 charts were more frequently used to select survey blocks. Transects were laid out at a rate of about 1 km in length per 10 km^2 of survey area. Each transect was between 0.3 and 2.0 km in length ($\bar{x} = 790$ m) and most were along landforms where snow leopard sign is likely to be found, such as ridgelines, sharply defined valley bottoms, cliff edges, or stream banks (Jackson and Hunter 1996). A smaller number of transects ran through less optimum marking habitat such as hillsides or other smooth terrain without pronounced landform edges. To minimize within-transect variability, transects were short and rarely crossed habitat boundaries. Transects were walked by a pair of observers and all sign recorded as to type and number. At each site where snow leopard sign was found, habitat attributes within a 20 m radius were determined including elevation, slope, aspect, vegetative cover, dominant topographic feature, landform ruggedness, land use, and distance to cliff. Of these attributes, landform ruggedness was the most subjective. Other variables were measured or evident. Ruggedness categories included rolling, slightly-, moderately- and very-broken, and cliff. To ensure consistency and comparability, the various observers involved over the course of the work received up to a week of field training to gain proficiency in applying the classification system as detailed in the SLIMS manual (Jackson and Hunter 1996). The distance from sign-sites to the nearest cliff is not an attribute required in the SLIMS protocol, but one that was evaluated in this study. Cliffs in this case were defined as being surfaces of 50° or steeper over an area of at least 5 m width and height.

On each transect a number of random sites (6 to 8 per km) were selected and all habitat attributes were recorded to allow comparisons with sign sites. Random sites were selected using a random number table where the numbers were distances in meters along the transect. The attributes of sign sites and random sites were used to compare use and availability. A selectivity value was assigned ranging from '-' indicating that snow leopards marked sites with these attributes less frequently than they occur ($p=0.05$), to '+', indicating they marked these site types more frequently than would be expected by chance alone. A selectivity value of '0' indicated marking use in proportion to availability.

Sign density, expressed in sign/km of transect was calculated for each transect, for each survey area, and on a regional basis. To test for differences in mean density between sites and regions, transect data were rank-transformed and a Kruskal-Wallis one-way analysis of variance test employed. The rank transformation method was used due to the number of high-end outliers in the data (see corridor sites below) that would have diminished the power of a standard ANOVA F-test. Substrate type (rock, gravel, vegetation, snow) may influence sign deposition rates and longevity. However, in this study substrates were thought to occur in similar proportions across all regions. Sign persistence can be influenced by several factors such as weather and disturbance by livestock. Summer rains and snow melt can cause flooding in valleys and remove sign. Livestock use of higher valleys increases in summer and leopard sign may be obliterated (Fox and Chundawat 1997). Sign deposition may be greatest during the January and February breeding season (Ahlborn and Jackson 1988). For all of these reasons transects conducted in winter may yield higher sign densities than those from the same sites in summer, reducing comparability between sites if not collected in similar seasons. Because surveys in this study were conducted year-round, the data were tested for seasonal differences using a two-sample t-test.

The frequency with which leopards used sites of various habitat attributes was compared to the availability of such sites using a Chi-square goodness-of-fit test. Sign placement was considered an indicator of habitat use by leopards. Selectivity values for habitat variables were determined using the binomial distribution function with a 95% confidence level.

Snow leopard range is discontinuous, particularly in the Transaltai Gobi were the Altai mountain range becomes broken and bisected by open steppe and desert. Local residents believe that snow leopard sign can be found in even the smaller isolated massifs of 3-5 km^2. Suspecting that some interchange or dispersal of snow leopards occurs between ranges, we identified several such massifs situated between larger occupied ranges. Considered too small to harbor a resident cat or cats and lacking resident ungulate prey, they might serve as waypoints of cover or resting habitat to cats crossing open lowlands. Surveys were conducted on candidate "corridor" massifs ranging in size from 3 to 35 km^2.

Prey surveys for large ungulates were conducted at many, but not all of the sign survey sites. Fixed-point counts from ridgeline vantage points were conducted using the methods detailed by Jackson and Hunter (1996:73-76). Survey blocks were delineated on maps and observation sites identified. A survey intensity of 10-20% of the study area was usually selected for surveys. Counts were conducted in early morning or evening with pairs of observers using binoculars and high-powered spotting scopes. Each block was scanned and all ungulates counted and assigned to sex and age class when possible. Age classes included kid/lamb, sub-adult, and adult. For ibex, adult males were further divided into small, medium and large based on horn size, as adapted from Schaller's classification system (1977:104). Small males had horns up to about 35 cm and were usually 2 to 4 year-olds, medium male's horns ranged from 35 to 75 cm and they were 4 to 7 years old, large males had horns longer than about 75 cm and were upwards of 7 years in age. Opportunistic ungulate observations made along snow leopard sign transects provided supplemental data to fixed point counts and the same data were collected as to sex and age. Local herders were also questioned about wildlife numbers. Differences in survey techniques, intensity, and season, along with the need to include anecdotal information where field counts were not possible, precluded direct comparisons of prey numbers between most sites or regions. A regional index to large ungulate relative abundance was derived from these mixed data.

Herder Interviews

Interviews were conducted with semi-nomadic herders in 4 aimags (provinces), Gobi-Altai, Khovd, Uvs, and Bayan Olgi, in 1997 and 1998 to gain information on livestock and wildlife in local areas. Households (gers) were visited by a bi-lingual team that often included one westerner and one Mongolian researcher. Occasionally herders were encountered in the field with their livestock and interviews were conducted there. A standardized questionnaire was followed, although responses were often free-form and any information the interviewee offered was recorded. To avoid bias when possible, herders being asked about their attitudes on snow leopards and other predators, were not made aware of the project's snow leopard research and conservation interests, to avoid bias when possible. One-hundred-five herding households in 4 aimags were questioned about the numbers and type of stock held, losses to predators by stock type, their past personal history of hunting predators, their feelings about regulations on killing predators, and their impression of trends in local wildlife numbers. The Uvs and Khovd aimag surveys were grouped for analyses as they are from similar ecological areas in the Altai mountains. The Gobi-Altai interviews are from the Transaltai Gobi, a desert ecosystem where wild and domestic faunal composition is quite different from the mountain steppe of the northern aimags. While Bayan Olgi is within the mountain-steppe zone and ecologically similar to Khovd and Uvs, it is viewed separately because of sociological differences. Bayan Olgi is populated primarily by people of Kazakh origin.

Results

Surveys

Between 1993 and 1998 sign surveys were conducted in 73 study blocks throughout snow leopard range in Mongolia (Figure 1-1). Cumulatively, 328 transects were walked covering 254 km in length, and 4205 pieces of sign were counted. Scrapes were by far the most common sign type with 2675 observed (63.6%), followed by 1256 feces (29.9%), 166 scent sprays (3.9%), 75 pug marks (1.8%), and 33 claw rakes (0.8%).

Snow leopards differentially target habitat features for marking (Table 1-1). Overall, saddles along sharply defined ridgelines receive the most marks. More than half of all scrapes and feces were found in these small depressions or breaks in the ridges. Marking medium for scrapes in the form of small gravel or sand was generally more likely to be found in these saddles than elsewhere on rocky ridges. Scent sprays were much less commonly found on ridgeline transects, but were most often seen along valley bottoms. The target of most scent sprays were the bases of cliffs where rock faces were perpendicular or overhanging. When large boulders were found in otherwise u-shaped or broad flat valleys, they would receive substantial marking pressure. Such boulders were usually more than 1 m high and again, had a perpendicular or overhanging face. When scrapes or feces were found in valley bottoms, they were almost always associated with cliff bases or large boulders.

Sign sites were not found in habitats of varying attributes in proportion to occurrence (Table 1-2). The attributes of 1,234 sites, including 564 sign sites and 670 random sites were used to compare use and availability. Seven attributes were tested using Chi square goodness-of-fit: elevation, slope, distance to cliff, terrain ruggedness, primary topographic feature, habitat type (vegetative cover), and grazing use. For all of the habitat variables tested, only grazing regime (Chi square = 1.31 $df=2$ $p=0.4$) failed to show significant difference between use and availability. Marking activity indicated a selection for habitats with elevations between 2500 and 3500 meters, very broken or cliffy terrain, along ridgelines, and in areas of shrub cover. Early in the study slope was measured at the exact site of the sign deposition, which was frequently nearly level ground even when located along steep ridgelines or near cliffs. Data from those transects were deleted from the analyses. Slopes reported here represent the steepest slope within a 5 meter radius of the sign site, and indicate that leopards selected to mark in areas with adjacent slopes in excess of 60° and avoided areas with slopes between 20 and 40°.

Leopard sign indicated a strong affinity for sites less than 5 meters ($p < 0.0001$) or 10 meters ($p=0.008$) from cliffs, but were found in areas 10-30 m from cliffs in proportion to occurrence. Sites greater than 30 m from cliffs were generally avoided for marking purposes.

Snow leopard sign density per km of transect was not equal across snow leopard range and regional differences are apparent (Figures 1-2 and 1-3). The eastern Transaltai Gobi had a higher mean density of snow leopard sign/km of transect ($\bar{x}=38.5$) when compared to all other regions ($F=8.29$ $df = 8, 212$, $p< 0.0001$), and when compared to the central Transaltai Gobi and the northern Altai alone ($F=9.32$, $df = 2, 145$, $p=0.0002$). Mean sign densities in the central Transaltai Gobi (17.6/km), northern Altai (18.8/km), and Great Gobi Park (13.2/km) were similar (F=1.014, df=2,138, p=0.37). The lowest sign density was observed in the Zuungarian Gobi ($\bar{x}$ = 1.92/km), but was statistically similar (F=0.44, df = 3,36, p=0.73) to mean densities in the Central Altai, (8.52/km) Khangai (5.9/km), and Bayan Olgi (5.6/km).

Variation in mean sign density between summer and winter was not apparent when all regions were considered as a whole (p=0.522). No difference could be detected between winter sign density ($\bar{x}$ = 35.9/km) and summer density ($\bar{x}$ = 33.1/km) within the Saksai River study area (p=0.81), where 42 transects were sampled, despite seasonally distinct levels of grazing activity and frequent spring flash flooding.

Thirteen isolated massifs were found to contain high densities of snow leopard sign. The massifs were often less than 2000 m in elevation ($\bar{x}$ = 2,415 m) and often no more than 100 m above surrounding terrain. Cats had to cross from 20 to 65 km of open steppe or desert to reach them. Sign density in these 'corridor" sites averaged 102.2 pieces/km of transect, or more than double the high mean density of eastern Transaltai Gobi. Sign type in corridors tended toward feces (56.4%) as opposed to scrapes as in non-corridor sign sites (67.6%). Six corridor sites were identified in the central Transaltai Gobi, 4 in the eastern Transaltai Gobi, and 3 in the northern Altai. In one case in the northern Altai the corridor site was not an isolated massif, but a tall butte at the extreme end of a low ridgeline. It was, however, separated by about 10 km from occupied snow leopard habitat and was the last high point of land between that and the next occupied mountain range to the north, some 35 km distant.

Current Range

Sign survey and herder interview results were used to derive a map of current snow leopard distribution in Mongolia (Figure 1-4) with a total range estimate of approximately 103,000 km^2.

Ibex were present in every survey site where snow leopard sign was found with the exception of the isolated massif corridor sites. The highest direct counts came in the northwest portion of the Altai where densities were calculated at 165/100 km^2 in portions of Altai Tavaan Bogd National Park of Bayan Olgi. In Uvs, 415 ibex per 100 km^2 were estimated for Tsagaan Shuvuut Strict Protected Area (SPA), and 585/100 km^2 on the western side of Turgen Mountain SPA. In the eastern Transaltai Gobi ibex were similarly high at 450/100 km^2 in the Tost Uul area and within Gurvhan Saikhan National Park. Central Transaltai Gobi sites in Bigger and Tsogt districts produced 270 ibex per 100 km^2 and 150/100 km^2 respectively. Few ibex were observed on surveys in Zuungarian Gobi sites and density estimates ranged from 20-40/ 100 km^2. Harper (1995) estimated an ibex density 60-70/100 km^2 in the mountains west of Lake Khovsgol. Direct counts were not comparable from other sites.

A subjective relative ibex density value was arrived at for each region using current survey results, past survey records available from government, anecdotal information and range maps (Figure 1-5) For example, survey sites in both the Eastern Transaltai Gobi and the Northern Altai had ibex densities in excess of 400/100 km^2, local herders felt that ibex numbers were uniformly strong over much of the area, and range maps for the species indicated they are widespread with a substantial portion of the area providing good habitat in both regions. These regions were assigned a 'very high' index value. The central Transaltai Gobi sites had densities that were relatively high, 125-270, but showed substantial variability. Local people and officials suggested that the southern flank of the range was much less productive than the north. Regional maps indicated a somewhat broken and discontinuous range for the species.. This area was assigned a 'high' index value. A 'low' index value was given to the Zuungarian Gobi where ibex range is very limited and, where ibex do occur surveys found no more than 40 head in 100 km^2. Other regions were subjectively assigned index values in a similar manner. To compare leopard relative abundance with ibex density indices, regional leopard sign density was transformed to a relative scale with the highest density, 38.5 sign/km of transect in the Eastern Transaltai Gobi, set to 1.

Human - Snow Leopard Interactions

Herder interviews indicated that the mean herd size for all domestic stock was 319 animals per household (Table 1-3) and varied from 274 in Bayan Olgi, to 394 in Uvs and Khovd. Herd composition was similar in the mountain-steppe sites at approximately 80% small stock (sheep and goats), and 20 % large stock (horses, yak, cows, and camels). In the Gobi large stock comprised a smaller percentage of the herd, and tended to be composed of more camels, and fewer yaks and cows. The Gobi herds also tended to have more goats than sheep, as opposed to an even mix of small stock in the mountain-steppe.

Losses to snow leopard between 1995 and 1998 averaged 57 head of stock per year cumulatively for the 105 herders interviewed, or about 0.45 head per household per year. Forty-six families actually lost stock, for an average of 1.2 head per loss. Overall, 70% of snow leopard kills were large stock. Of the large stock taken, 53% were horses and 36% yaks. The reported loss to wolves was roughly 3-times the loss to leopards (168) during the same period. Wolves more frequently took small stock (56%), and the kill was composed of more sheep (63%) than goats (37%). Of the large stock taken by wolves, horses were again the most frequent prey (48%), followed by yaks (23%) and camels (24%). For both wolves and snow leopards, horses were taken from all age classes, while camel and yak losses were most commonly young of the year. In US dollar terms, snow leopard losses averaged $21 over all families, or $47 for households that actually experienced loss. Wolf related losses averaged $31 overall, or $50 per actual loss. While a $50 loss could be 6 – 10% of annual income (Anon.1997:13), the percentage of the herd lost is more meaningful, given that herd size is the common measure of wealth in rural Mongolia.

The attitudes of herders who responded were strongly anti-wolf. Overall, 91% felt that wolves should be hunted without restriction and often said that a return to government sanctioned hunts would be best. No one suggested protection for wolves. Far fewer herders felt that snow leopards should be hunted openly (14%) and many (45%) felt snow leopards should be completely protected. About 40% thought that snow leopards should be hunted with strict limits, or only for those animals that were problem depredators on livestock. Snow leopard numbers were most commonly thought to be increasing (58%), but not to the extent that wolves were perceived to be (99%). Trends in ibex and argali (*Ovis ammon*) numbers were less clear to herders, and only in the Gobi were both species' downward trends widely agreed upon.

Discussion

Snow Leopard Distribution and Relative Abundance

Occupied snow leopard range in Mongolia (Figure 1-4), as determined in this study, varies from what has been reported previously, most notably in the Khangai, Khovsgol and Bayan Olgi regions. Surveys and interviews conducted in the Khangai indicate that current leopard distribution there is much reduced from that previously reported by most researchers (Schaller et al. 1994, Mallon 1985). In Ovorhangai aimag on the eastern end of the Khangai Range, we found no indication that the cat still occurs there during several days of discussions and cursory surveys. The situation in Arhangai aimag is little different with snow leopards thought to occur only in the southernmost reaches of the aimag along the borders with Bayanhongor. Even there, locals were skeptical that it was more than a rarity, except in the western parts of the province. Within Zavhan aimag a small amount of snow leopards sign was found in Otgontenger SPA, and it is likely rare or nonexistent anywhere west of that in the aimag. Hence, rather than occurring throughout much of the potential range within the Khangai mountains, leopards appear to be restricted to a rather narrow band extending from Otgontenger Peak in the west at about 97° E longitude, along the crest of the range to about 100° E longitude. Total range in the Khangai does not likely exceed 1800 to 2000 km^2, within which occupied habitat is patchy and fragmented. This contradicts the most recent reports by Mongolian biologists that suggest the leopard is widespread in the Khangai region, albeit in low numbers (Amarsana, Unpublished data).

Schaller et al. (1994) also questioned the occurrence of the cat in the Khovsgol lake region. Since no confirmed sightings have occurred there in at least 30 years, and perhaps as much as 50 years, the lack of sign on more than 50 km of transects there was not unexpected. No snow leopards likely occur in the Khovsgol region today, with the possible exception of the remote northern border along the Russian Sayan Mountains. No surveys have been conducted on the Mongolia side, but the cats occurrence in low numbers on the Russian side has been documented (Koshkarev 1994).

Various authors have placed much of Bayan Olgi within snow leopard range (Mallon 1984, Mallon 1985, Green 1988, Schaller et al. 1994, Hunter and Jackson 1997, Amarsana Unpublished data). While the aimag is one of the most mountainous in Mongolia, the portion along the western border with China below about 48° N latitude is high, but for the most part smooth, lacking the precipitous broken terrain preferred by snow leopards. Herders in this aimag uniformly felt that snow leopards only occurred along the Altai range which forms the aimag's eastern border with Khovd, and in the far northwest part of the aimag. Surveys provided no reason to doubt that.

Most authors do not place the eastern-most distribution of snow leopards beyond about Dalanzadgad in Omnogobi aimag (104°50' E). Schaller et al.(1994), however, suggest leopards may occur in isolated peaks up to 120 km further east. I did not survey beyond 104° 20'E, but if they are present, it is in a few small areas in low numbers. The southern-most occupied range is apparently the Tsagaan Bogd massif in the Great Gobi SPA. Throughout the Gobi snow leopards occur in similar isolated mountains and may well range farther south and into China. Particularly in the southwest corner of the Great Gobi near Atas and Ingis Mountains where the Chinese Tien Shan is within visual range and potential corridor massifs lay in-between. Surveys close to the border to confirm this were not allowed by the Mongolian border patrol for security reasons.

A total range estimate of approximately 103,000 km^2 is reasonable for Mongolia and is not substantially different from previous estimates of 90,000 to 130,000 for occupied range (Schaller et al. 1994, Mallon 1984). Recently a GIS-based model of potential snow leopard range across Asia was put forward by Hunter and Jackson (1997). The 'potential' snow leopard range in Mongolia predicted by that model was more than 277,000 km^2. This model was elevationally driven, but also considered crude estimates of slope, human habitation, and other disturbance factors. While such a model indicates potential range and is useful for designing investigations of snow leopard presence, absence or abundance, it does not provide a valid picture of snow leopard range use in Mongolia.

This study sampled numerous sites in suspected snow leopard range to document occurrence, but a predictive model of snow leopard distribution could be useful in filling remaining information gaps for conservation planning. Models such as the one above might be improved if habitat parameters snow leopards have shown sensitivity to were considered (Jackson and Ahlborn 1984). Elevation, distance to cliff, slope, landform ruggedness, and vegetation type were found to influence leopard habitat use in this study. However, for these attributes, other than elevation, no GIS databases at a useful resolution presently exist for Mongolia. Livestock grazing intensity is more easily mapped, but appears to be of limited use in predicting snow leopard distribution. No correlation was apparent between grazing regime and snow leopard sign density. Herders often remark that snow leopards show little fear of humans and will approach established human dwelling sites to prey on livestock. Leopard pug marks were frequently found following human tracks during surveys. It seems likely that humans and livestock are so ubiquitous in snow leopard range as not to influence distribution on a large scale. This is not to say that secondary impacts of grazing, particularly reductions in wild prey through competition, do not negatively influence snow leopard range use.

Snow leopard sign density on a regional basis exhibited similar trends to that of ibex relative abundance (Figure 1-5). On a large scale ibex density may then have limited predictive value, but on a local scale the relationship is less obvious. In Yamaat Valley of western Turgen Mountain SPA in Uvs aimag, recent surveys found an ibex density of 584 per 100 km^2. Leopard sign was also relatively dense at 41/km of transect. Tost Uul, some 1,500 km away in the Eastern Transaltai Gobi supports ibex at a density 68% of that in Yamaat, and comparably, snow leopard sign was about 60% as common. However, in Tsagaan Shuvuut, just 100 km north of Yamaat, ibex occur at a rate of 415/km^2, or 71 % that of Yamaat, but leopard sign density was only 34% as dense. In the Saksai River research site in Gobi-Altai, ibex density is estimated at 25% of what Yamaat was, but leopard sign was 80% as dense. Although snow leopards in Mongolia prey primarily on ibex (Schaller et al. 1994, McCarthy, unpublished data) and no occupied snow leopard range in the country has been found to be lacking ibex, ibex density does not appear to be a particularly good predictor of snow leopard sign density. Biomass of all available prey, including livestock and small mammals, may prove a better predictor, but such a value is not easily obtained. In areas where snow leopard density is low, even a few losses to poaching could have a large impact and skew leopard-prey ratios, further obfuscating any predictive relationships.

Sign density on transects may be a function of more than cat density. Fox and Chundawat (1997) expressed concern about comparing sign densities without considering differential sign longevity and how it is influenced by seasonal changes in livestock disturbance, weather, flooding, and animal behavior. However, we found no difference between summer and winter sign density in the data set as a whole, or within the heavily sampled Saksai River site. Sex and age ratios of resident cats may also be a confounding factor. Non-breeding leopards (*Panthera pardus*) in Africa rarely if ever advertised their presence by marking (Bailey 1993:268). In Nepal, however, surveys of scrapes predicted 87% of snow leopard use of an area (Ahlborn and Jackson 1988). Corridor sites with extreme high sign density could confound density comparisons, but these should be detectable in the data and omitted or, as in this study, dealt with by statistically appropriate means such as rank transformation. Sign density as a predictor of leopard density has several potential sources of error, but if limitations are recognized and addressed, it may provide the best available and easily applied method for assessing relative snow leopard densities rangewide.

SLIMS surveys are not designed to yield actual density or total numbers of leopards, rather they provide a relative measure for temporal and spatial comparisons. Still, an estimate of total numbers of snow leopards in Mongolia is of interest. Looking at areas in Mongolia where leopard numbers have been calculated such as Tost Uul (Bold and Dorzhzunduy 1976), Uerte Valley (Schaller et al. 1994) and Saksai River (McCarthy unpub. data) leopard density ranges from about 1 to 4 cats per100 km^2 in good to excellent habitat. In less optimum or marginal range, where sign density is much reduced, a leopard density of 0.25 to 1 per 100 km^2 might be a reasonable estimate. Rangewide in Mongolia a density of 1 to 1.5 leopards per 100 km^2 could then be assumed, or a total population of 800 to 1,500.

Protected Area Coverage

Within Mongolia snow leopard populations are highly fragmented, and, if we accept that sign is at least a general indicator of leopard density, highly variable. Protection of even large tracts within their range does not assure that the most productive or important areas will be secure from degradation, a fact not adequately considered in recent reserve augmentation in Mongolia. Gobi Gurvhan Saikhan in the eastern Transaltai Gobi where snow leopard and ibex densities may be the highest in the country was established in 1993, but was designated a Conservation Park, a less stringent category of protection than that of Strict Protected Area. More importantly, the adjacent Tost Uul and Nemegt Uul ranges were not included, and they may be the most productive snow leopard sites in all of Mongolia (this study, Bold and Dorzhzunduy 1976). Similarly, in the central Transaltai Gobi, Burkhan Buudai was established in 1996 as a small Nature Reserve centered on a sacred mountain. It is also the site of the highest density ibex and snow leopard range identified in that region, but at 529 km^2 it is far too small to protect more than a fraction of that population.

The existing reserves, despite not protecting all of the most productive snow leopard sites, play an important role in maintaining snow leopards in Mongolia. Today at least 10 protected areas harbor snow leopards, including Great Gobi 'A' and 'B', Khokh Serkh, Otgontenger, Tsagaan Shuvuut, and Turgen Uul, all of which are Strict Protected Areas and offer the most stringent restrictions on disturbance (Shiirevdamba 1998:79). Additionally, Gobi Gurvan Saikhan and Altai Tavaan Bogd are two National Conservation Parks totaling some 28,080 km^2 both off which were established since 1993 and placed into protection a substantial amount of known and potential snow leopard habitat. Nature Reserves and Natural Monuments offer reduced levels of protection to wildlife (Shiirevdamba 1998:79), but restrict some human uses. Two Nature Reserves, Burkhan Buudai and Alag Khairkhan, and one Natural Monument, Eej Uul, totaling 1,110 km^2 are entirely within snow leopard range in the central Transaltai Gobi. Cumulatively, protected areas that contain snow leopards cover some 85,320 km^2, of which approximately 18,382 km^2 is known snow leopard range. Thus, only about 18% of the total 103,000 km^2 of leopard range in Mongolia fall under some form of protected status.

Not all reserves in Mongolia have functioned to protect the species contained therein. Khokh Serkh may be such an example. Situated in the central Altai range this reserve was established in 1977 particularly to protect argali, ibex and snow leopards. Surveys in 1990 (Schaller et al. 1994) and again in 1993 (this study) produced no sign of leopards. Although Schaller et al. did observe 14 ibex and 19 argali, I found none during two week-long surveys. Khokh Serkh was open to foreign hunting until 1994. In all reserves except the Great Gobi, human use in the form of livestock grazing continues, although several SPAs are moving to limit or reduce grazing pressure.

There remain many prime snow leopard areas that are unprotected. These include the above mentioned Tost and Nemegt Mountains in the Gobi, and the eastern mountains in Khovd som (rural administrative unit) of central Uvs aimag which could be covered with a southwestward extension of Turgen Mountain SPA. The central Transaltai Gobi, where sign surveys indicate several relatively high density cat populations, is lacking completely in reserve coverage except for the small Burkhan Buudai Nature Reserve. That site and the Saksai River drainage on the southern flank of the Altai range should be considered candidates for protection. In Uvs aimag surveys indicate that the Hanhoohy Range harbors a relatively high density of cats. This area is now under consideration for protected status. More research is needed in the northern Bayan Olgi and Uvs aimags along the Russian border where snow leopard range and abundance has yet to be defined.

Corridor sites may be providing for genetic interchange between Mongolia's highly fragmented snow leopard populations and should be considered in conservation planning. Only two of the identified corridor sites were within protected areas and one was in a buffer zone. Whether it is feasible or desirable to afford all such sites protected status is questionable given that many are little more than small massifs in otherwise open steppe and desert. When reserves contain high density populations, such as Turgen Mountain where a corridor site was identified between it and an adjacent population, buffer zone regulations could be extended to the corridor and adequately restrict human use.

Conservation Outlook

The 1990s have seen several actions taken in Mongolia that benefit snow leopard conservation. Among these were the discontinuation of legal sport hunting for the cat in 1992, acceding to CITES, a complete revision of the national hunting and land laws that favor conservation in general, and the addition of numerous new protected areas, many in snow leopard range. This is not to say that the long-term presence of snow leopards is assured and concerns remain.

Grazing intensity in Mongolia continues to increase, in part due to changes in economic conditions brought on by the switch to a market economy and the end of collectives, and also due to a population growth rate of 1.5% (Bajiikhuu et al. 1998:27). As grazing increases, competition between livestock and wildlife will also increase. Many areas have reached or exceeded grazing capacity, a fact not lost on herders. Nevertheless, when asked where their children's stock will graze, a common reply was "the next valley over". However, I have been in the next valley over, and it too is full. Mongolia is one of the world's least populous countries at 1.5 people/km^2 (Bajiikhuu et al. 1998:27), but given the sparse and fragile nature of its high altitude steppe ecosystem, from a pastoral perspective it may well be overcrowded. A herder of 60 years I spoke with in the central Altai lamented the loss of argali and ibex from his homeland as we looked out over more than 5,000 head of livestock on the surrounding hills. Wild ungulates may face a difficult future if current grazing trends continue.

As wild prey is reduced, or simply as domestic stock becomes more available for snow leopards, depredation will increase with retribution killing likely to follow. However, the results of herder interviews are encouraging for the near-term. Contrary to the contention of Schaller et al. (1994) that public attitudes toward snow leopards were negative, snow leopards are held in esteem by most herders, and the relatively few losses to the cat were taken as a fact of life. While losses to a single household are occasionally substantial, depredation losses overall are rarely more than 0.5% of the herd for any family. At such modest rates, nearly half of all herders can apparently afford to feel that complete protection for the cat is appropriate. This may change if crowding and loss of wild prey result in greater depredation losses.

Currently only about 18% of snow leopard range in Mongolia is under some form of protected status. However, in several protected areas the various land use designations associated with the reserves (core or pristine areas, and buffer zones) have yet to be fully defined and restrictions on use enforced. Hence, people and livestock remain a component of even Strict Protected Area (SPA) ecosystems and conflicts with snow leopards exist. Our surveys also indicate there are many high density snow leopard populations and potentially important dispersal corridors that fall outside of the protected area system. Not all such areas warrant inclusion in the protected area system, but should be identified as important snow leopard range and managed accordingly. A zonal management system across snow leopard range, both within reserves and outside, that encourages people to voluntarily limit their use of important snow leopard habitat would be beneficial. Such a system could have zones or tiers based on the importance of the area to snow leopard conservation. The most restrictive tier might include the core and pristine areas of SPAs and National Parks. Within this tier leopards would receive complete protection and no economic incentives, such as compensation for livestock losses to predators, would be provided. The second tier would include other areas within and outside the reserve system that have been identified through research as harboring high density leopard populations or are used as dispersal corridors. Again, this tier would offer complete protection for leopards including even known depredating cats. Within this zone economic incentives would be provided to herders in exchange for some limits on grazing and tolerance of depredation. Economic incentives could take the form of improved access to markets for herder's products (wool, hides, meat) or handicrafts, or improved veterinary care. The least restrictive tier would cover less productive lands within snow leopard range. Within this tier there would be no limitations on grazing for the purpose of leopard or prey conservation, and depredating cats could be removed by government officials.

Compensation programs for livestock losses to predators can be abused, require a constant input of capital, do not encourage responsible herding practices, and hence, are of limited value in any economic incentive program. As an alternative, a pilot economic incentive program for leopard conservation was established in 4 areas of important snow leopard habitat in 1998 (Allen and McCarthy, in press). The program is known as Irbis Enterprises, irbis being the Mongolian word for snow leopard. It was developed in response to this study's herder interviews that identified a lack of access to markets. In each pilot site, two in Gobi-Altai and two in Uvs aimag, herder cooperatives have been formed and families contracted to produce handicrafts from sheep, camel and cashmere wool. The products are then transported to the capital, Ulaanbaatar, and sold on the tourist market as "snow leopard friendly" goods. Herders gain substantial cash income and in turn agree to tolerate some leopard depredation on livestock and to abide by grazing restrictions imposed by associated SPAs. An annual cash bonus is paid to individuals if the entire community refrains from poaching leopards or large wild ungulate prey. Funded initially by a consortium of national and international conservation organizations, the program expects to be self sufficient in a short time. Economically the program has been successful in its first year. It is too early to determine what conservation benefits will accrue, but interest in participation is spreading among herders in snow leopard range, and awareness of snow leopard conservation issues is growing within a herder community that has already shown respect for the animal.

Despite these advances, economic disincentives to conservation also exist. With the loss of the Soviet Union as the primary trading partner, more trade is now conducted with China. The number of border trading stations has increased in recent years and the level of law enforcement on the frontier is questionable. The value of snow leopard bones on the Chinese medicinal market is not known, but hides are rumored to be worth $300-$400 each, which is similar to black market prices in Ulaanbaatar, and up from the $30 street price of 1993. In Bayan Olgi herders reported that a single hide could be traded for a used jeep in Russia. That a single leopard could bring the equivalent of a park ranger's annual salary, or be traded for a vehicle, could soon make poaching a far greater issue. Mongolian customs agents have been provided training in enforcement of CITES by international experts, but the number of border trading stations, and shear length of unprotected border make enforcement difficult. Education of citizens on the cultural, biological and economic value to Mongolia of a healthy snow leopard population has been initiated through multi-media campaigns and conservation education in schools, and may prove to be as strong a force toward conservation as enforcement.

Domestic commerce in snow leopard parts is also an issue of concern. While it is currently illegal to hunt, trap, or sell the hide, fur or any other part of a snow leopard, there is no legal restriction on purchasing, owning or possessing the same. A new general wildlife law is being considered by the Mongolian parliament and will hopefully correct these omissions. However, to address the issue of widespread ownership of leopard products, a registration system for legally owned hides and other parts should be considered. Such a system would make it more difficult for individuals to own parts from cats killed after leopard hunting was made illegal. A pilot registration program in western Mongolia is scheduled to be initiated in early 2000.

Mongolia's progress in passing environmental laws, augmenting its protected area system, and joining international conservation treaties and conventions is admirable, well intentioned and improves the prognosis for snow leopards and other wildlife. However, adherence to fundamental tenets of these actions is not yet widespread even at the government level. In 1999, products made of snow leopard fur were still for sale in the State Department store in Ulaanbaatar.

Table 1-1. Habitat feature marked by snow leopards on sign transects in Mongolia, 1993-1998.

	Sign Type		
Feature	% of Scrapes (n = 354)	% of Feces (n = 256)	% of Scent Sprays (n = 62)
Saddle[a]	60.2	51.6	3.2
Pass	7.3	5.9	0.0
Boulder	11.0	13.7	45.2
Cliffbase	3.7	4.3	45.2
Vegetation	6.5	3.9	0.0
Cave	0.8	2.3	6.5
Ridgeline	3.1	6.3	0.0
Kill	0.0	0.4	0.0
Other	0.6	1.6	0.0
None	6.8	10.2	0.0

[a] A saddle was defined as a break in a ridgeline that was smaller than a true pass.

Table 1-2. Habitat characteristics and selectivity values for snow leopard as determined by comparing sign sites and random sites from transects in Mongolia, 1993-1998.

Characteristic	Sign Sites	Random Sites	Selectivity
Elevation	$Chi^2 = 25.48$, df = 4, $p < 0.0001$		
< 1500 m	0	0	
1501 - 2000 m	81	108	0 p = 0.148
2001 - 2500 m	188	302	- p < 0.0001
2501 – 3000 m	174	248	+ p < 0.0001
3001 – 3500 m	112	102	+ p = 0.0011
3501 – 4000 m	9	18	0 p = 0.0641
> 4000 m	0	0	
Slope	$Chi^2 = 24.03$, df = 3, $p < 0.0001$		
0 – 20 °	10	14	0 p = 0.4457
20 – 40 °	17	48	- p < 0.0001
40 – 60 °	21	23	0 p = 0.8081
60 ° +	50	39	+ p < 0.0001
Ruggedness	$Chi^2 = 61.80$, df = 4, $p < 0.0001$		
Rolling	7	64	- p < 0.0001
Slightly broken	90	109	0 p = 0.4701
Moder. Broken	295	355	0 p = 0.4410
Very Broken	156	132	+ p < 0.0001
Cliff	13	10	+ p = 0.0452
Distance to cliff	$Chi^2 = 73.5$, df = 8, $p < 0.0001$		
< 5 m	133	98	+ p < 0.0001
5-10 m	44	38	+ p = 0.0085
11-20 m	35	54	0 p = 0.0689
21-30 m	33	41	0 p = 0.4897
31-50 m	20	38	- p = 0.0163
51-100 m	26	51	- p = 0.0033
101-150 m	6	20	- p = 0.0024
151-200 m	2	7	0 p = 0.0714
>200 m	0	16	- p = 0.0001
Topography	$Chi^2 = 109.48$, df = 6, $p < 0.000$		
Valley bottom	112	177	- p < 0.0001
Stream bed	21	63	- p = 0.0002
Hillside	17	57	- p < 0.0001
Ridgeline	407	346	+ p < 0.0001
Cliff	0	5	- p = 0.0148
Other	5	22	- p = 0.0465
Habitat Type	$Chi^2 = 14.9$, df = 2, $p = 0.0061$		
Barren	88	128	- p = 0.0182
Grass	141	203	- p = 0.0032
Shrub	323	335	+ p = 0.0002
Grazing Use	$Chi^2 = 1.31$, df = 2, $p > 0.4$		
None	223	250	0 p = 0.1178
Seasonal	317	392	0 p = 0.1593
Year-round	20	25	0 p = 0.4702

Table 1-3. Results of interviews with semi-nomadic herders regarding livestock, predators, and wild ungulates in 4 aimags of Mongolia, 1997-98.

	Gobi-Altai	Khovd/Uvs	Bayan Olgi	Total
Households interviewed	29	37	39	105
Total livestock	8,273	14,583	10,687	33,543
Average holding	285	394	274	319
Small stock	91 %	80 %	81 %	83 %
Large stock	9 %	20 %	18 %	17 %
Losses to Predators				
Snow leopards[a]	11.6	27.3	18.0	56.9
Average herd loss[b]				
Small stock	0.1 %	0.1 %	0.05 %	0.1 %
Large stock	0.7 %	0.7 %	0.9%	0.8 %
Wolves[a]	46.0	62.3	60.0	168.3
Average herd loss[b]				
Small stock	0.4 %	0.3 %	0.5 %	0.4 %
Large stock	2.5 %	1.4 %	1.3 %	1.6 %
Have Hunted for:				
Snow Leopards	10 %	3 %	15 %	10 %
Wolves	28 %	35 %	46 %	37 %

	Gobi-Altai		Khovd/Uvs		Bayan Olgi		Total	
Attitudes to Protection[c]	SL	Wolves	SL	Wolves	SL	Wolves	SL	Wolves
Full Protection	42%	0%	26%	0%	66%	0%	45%	0%
Remove Depredating	21%	0%	42%	0%	16%	3%	26%	1%
Limited Hunting	21%	8%	16%	6%	9%	9%	15%	8%
Open Hunting	17%	92%	16%	94%	9%	88%	14%	91%

	Gobi-Altai			Khovd/Uvs			Bayan Olgi			Total		
Perception of Trends[d]	+	0	-	+	0	-	+	0	-	+	0	-
Snow Leopards	6	4	0	16	6	4	15	9	4	37	19	8
Wolves	18	0	0	31	0	0	35	1	0	84	1	0
Ibex	4	3	10	6	13	8	14	11	7	24	27	25
Argali	1	1	6	5	7	4	15	13	5	21	21	15

[a] Mean total annual losses for all herders over three-year period, 1995-1998.

[b] Mean percentage of herd lost for each individual herder, by stock type.

[c] Percentage of respondents on snow leopards (SL) and wolves that favored complete protection, sanctioned hunts for removal of known depredating animals, a limited hunt, or unlimited open seasons.

[d] Number of respondents who perceived increasing (+), stable (0), or decreasing (-) wildlife populations

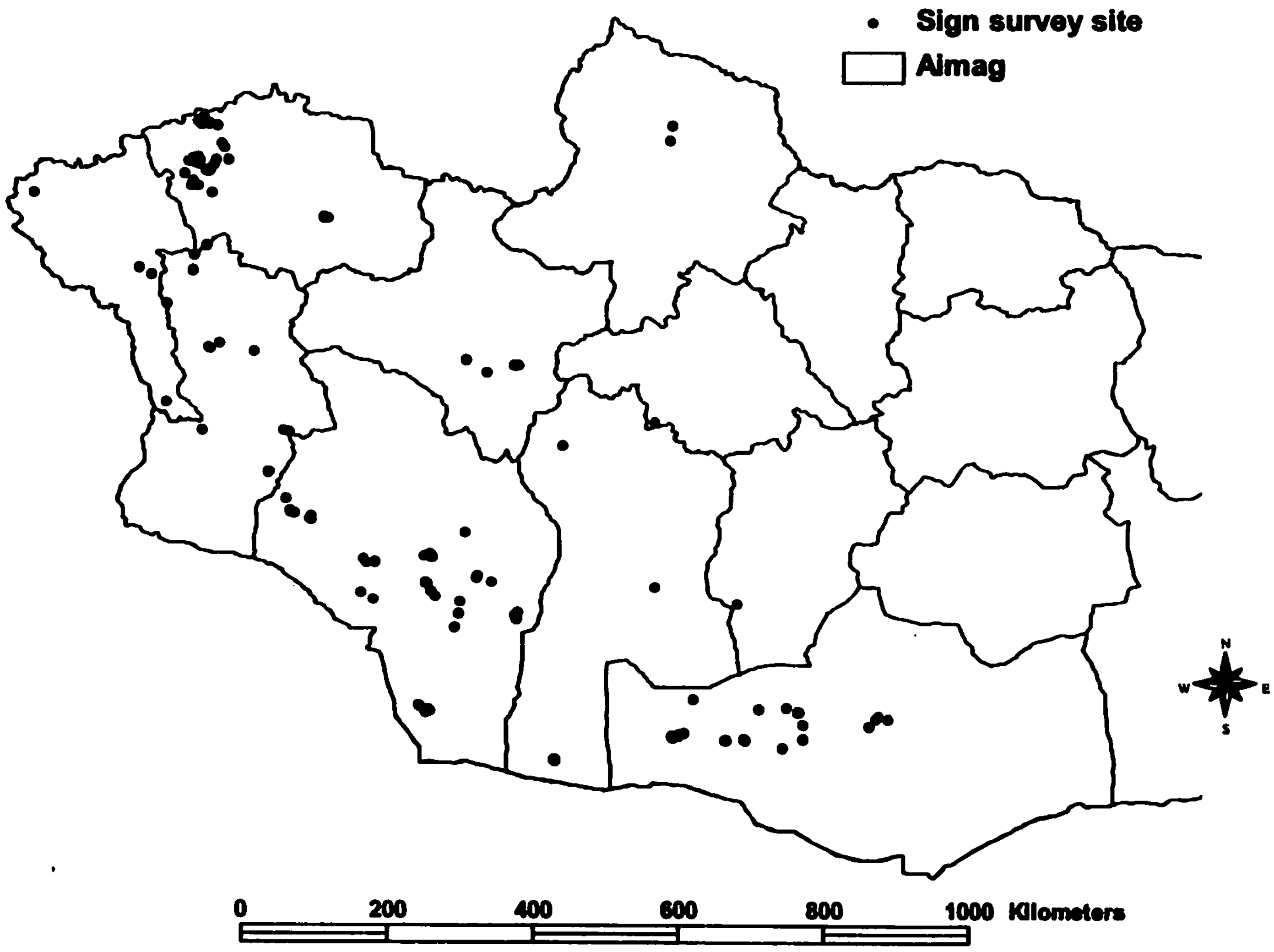


Figure 1-1. Snow leopard sign survey sites in Mongolia, 1993-98.

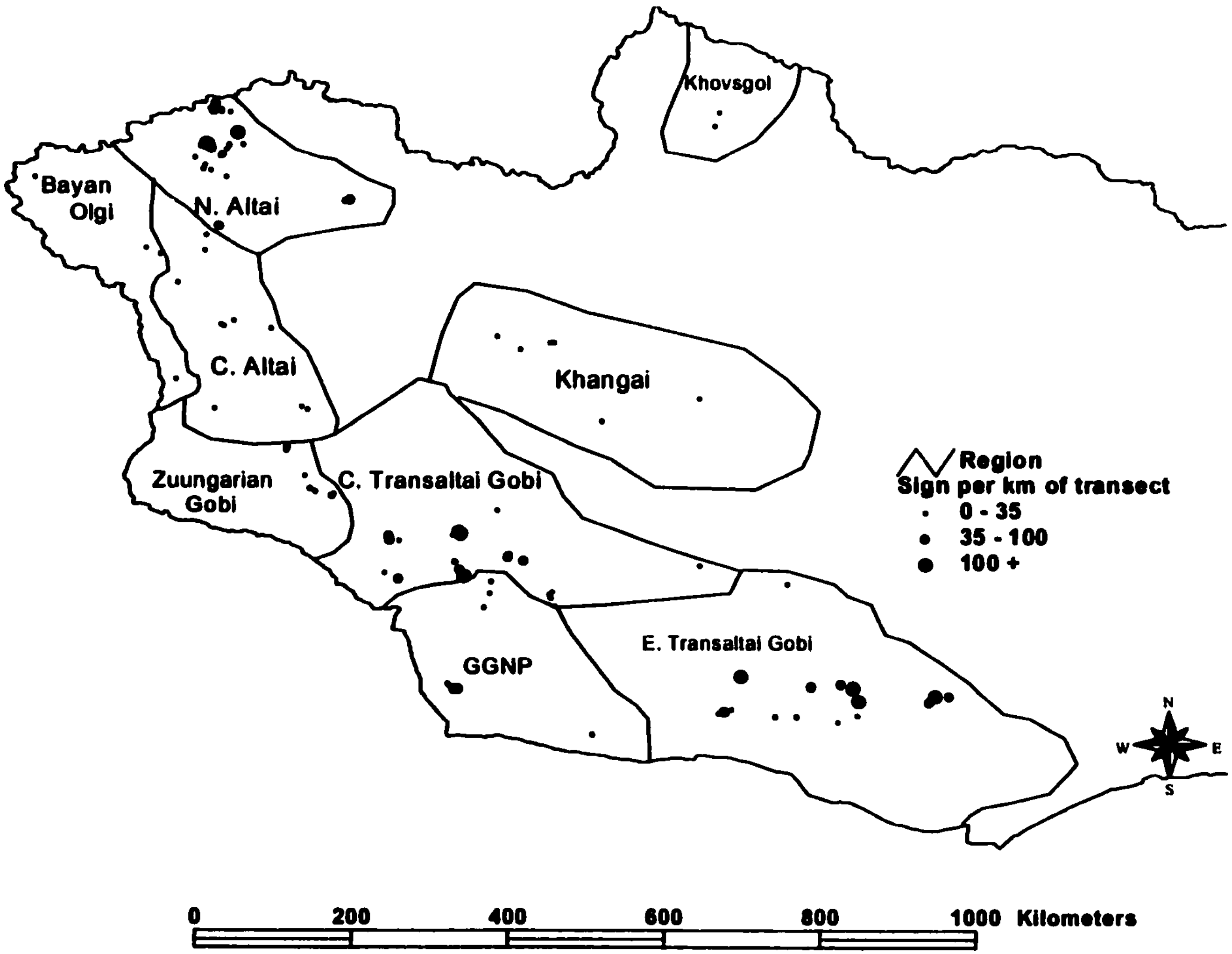


Figure 1-2. Regional variation in snow leopard sign density observed on transects in Mongolia 1993-98.

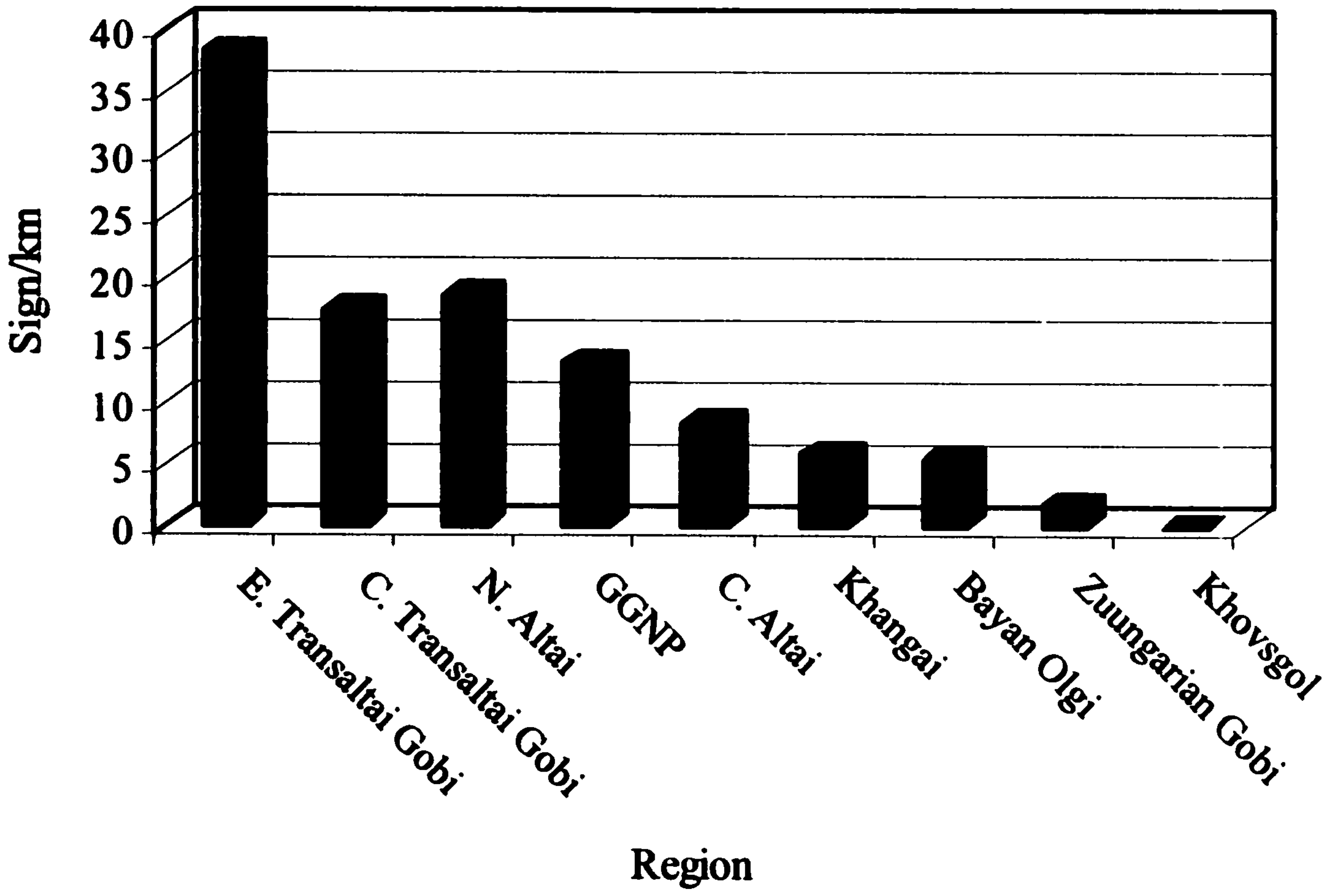


Figure 1-3. Snow leopard sign density per km of transect, by region in Mongolia, 1993-98.

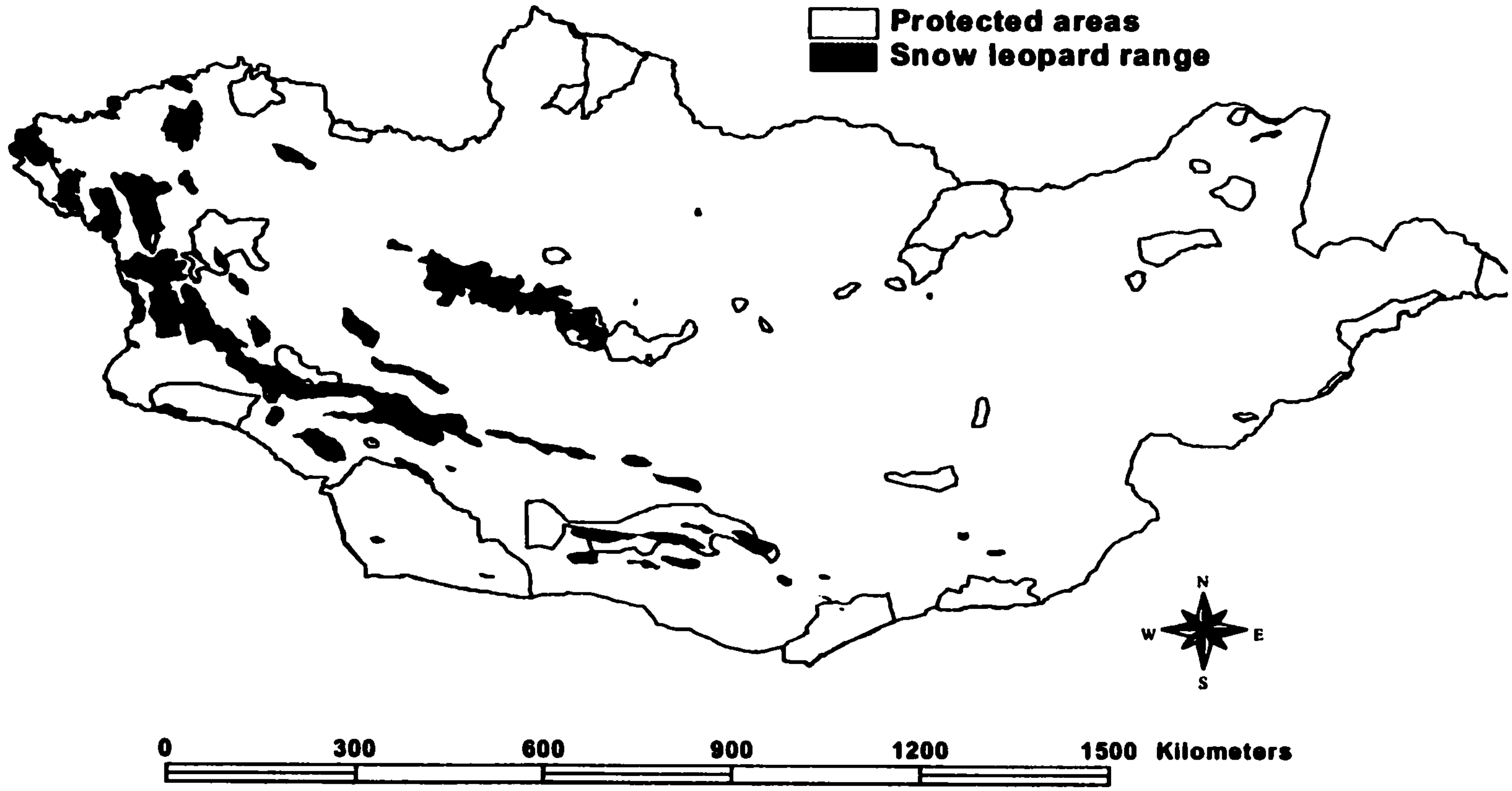


Figure 1-4. Snow leopard range and protected area coverage in Mongolia.

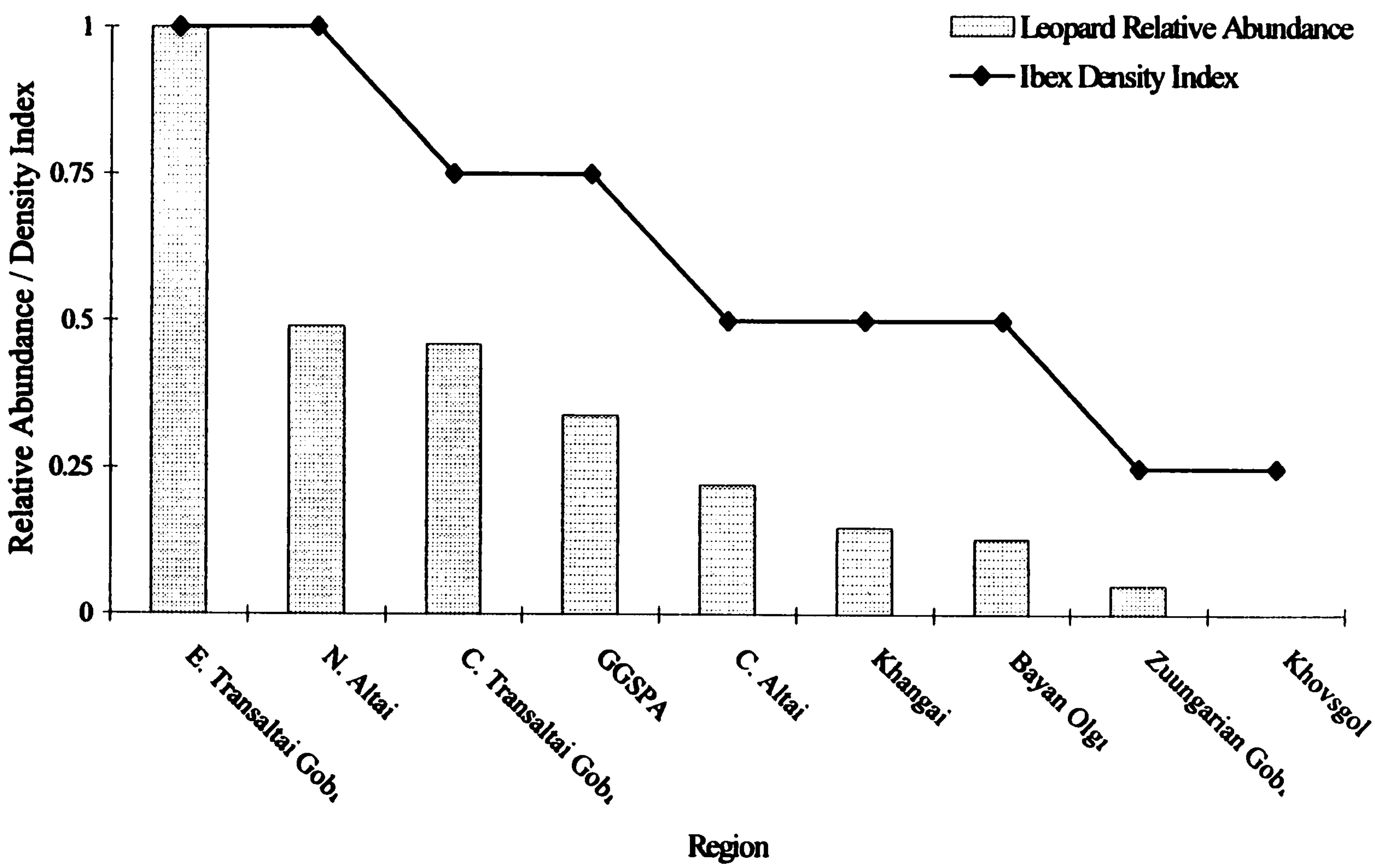


Figure 1-5. Comparison of leopard relative abundance and ibex density index by region, Mongolia, 1993-99.

CHAPTER 2

HOME RANGE, HABITAT USE, AND ACTIVITY PATTERNS OF SNOW LEOPARDS IN MONGOLIA

Snow leopards (*Uncia uncia*) are one of the least studied of the large cats, due in part to the remote and rugged habitat of the central Asian mountains where they occur. Prior to the 1980s most information on snow leopard ecology was anecdotes gleaned from reports by naturalists and hunters visiting the region, but the cat's cryptic nature and low population densities made direct observations extremely rare. Pug marks suggested that snow leopards were normally solitary, but no information was available on intraspecific interactions, range use, or activity patterns. Schaller (1977:155) speculated that snow leopard home ranges must be very large given the time interval between observing fresh pug marks in certain valleys in the Himalayas. Jackson (1989) recognized that the cat's "almost legendary secretiveness and camouflage" meant that radio-telemetry offered the "only realistic option for gathering information on snow leopard movements, home range, patterns of habitat utilization, social organization, and activity". His pioneering work with radio-tagged snow leopards in Nepal in the early 1980s provided much of our current knowledge of the species and has not been repeated. Although radio-collared snow leopards have since been the subject of studies in India (Chundawat 1990), Mongolia (Schaller et al. 1994), and again in Nepal (Oli 1997), these investigations were of short duration (less than 3 months) and had small sample size (1-3 cats). Importantly, by the early 1990s no long-term study of the cat's ecology had been conducted outside of what is considered the prime habitat of the Himalayan region (Fox 1989).

The status of snow leopards in Mongolia had been only superficially dealt with prior to 1989 (Bannikov 1954, Bold and Dorzhzunduy 1976, Mallon 1984, Zhirnov and Ilyinsky 1986, O'Gara 1988) and most information concerned distribution, abundance, and basic food habits. More detailed information on snow leopard ecology in Mongolia was lacking. In 1990, Schaller et al. (1994) initiated an ecological study of snow leopards in the Altai Mountains of southwest Mongolia and monitored a single radio-collared male for just over a month in early winter. The study was suspended during the ensuing years of economic and political uncertainty as Mongolia shifted from communism to a democratic market economy. In 1993, we reinitiated and expanded studies of snow leopards in Mongolia. Specifically, we captured and radio-marked 4 leopards to obtain year-long information on movements and activities in an area where prey densities were relatively low and more representative of much of the range in Central Asia. We suspected that calculated home ranges of such animals would be much larger, and thus densities much lower, than previously reported for the species. The results of these studies, carried out between 1994 and 1997, are reported here. We also initiated a companion project on snow leopard distribution and abundance throughout Mongolia (Chapter 1) in order to be able to better conserve the species on a national scale.

Study Area

The Altai Mountains to the north of the Great Gobi National Park (GGNP) are a stronghold of snow leopards in Mongolia, and we focused research there with the logistical assistance of the Park. Our study site was on the southern flank of the Altai range in Gobi-Altai aimag (province), about 80 km south of where Schaller et al. (1994) followed their radio-marked leopard. Initially the study site was arbitrarily defined as a 400-km^2 rectangle. Later, a more ecologically meaningful boundary along landform edges was identified that contained most of the potential snow leopard habitat and could be reasonably accessed and mapped from the ground. The study area encompassed 277 km^2 and was centered on the Saksai River drainage at about 96° 15' E, 45° 17' N. (Figure 2-1). Elevations range from 1450 to 2600 m. The Saksai and Tugrog Rivers, which bisect the area, are the primary year-round water sources within 50 km. While portions of the area are extremely steep and broken by cliffs, steep-walled valleys and sharp ridgelines, just over 60% is rolling plateau or hills. The southern edge of the study area is bounded by the mountain and desert-steppe interface. Temperatures in the area range from –20° to +25°C with less than 400 mm of precipitation annually. Snow is ephemeral in winter and quickly sublimates or is blown from the slopes and accumulates in shaded valleys. The region is included in the desert-steppe geobotanical region of Mongolia and is characterized by steppe and desert plants (Shiirevdamba 1998:54). About 30 percent of the area is barren, the remainder in grass, or grass-shrub types. Some high-elevation meadows support a grass-sedge complex.

The faunal composition of the study area as determined by direct observation, sign, or local government records, includes several mammal species: snow leopard, wolf (*Canis lupus*), red fox (*Vulpes vulpes*), ibex (*Capra siberica*), stone martin (*Martes foina*), ermine (*Martes erminae*), lynx (*Lynx lynx*), Tolai hare (*Lepus tolai*), marmot (*Marmota bobac*), pika (*Ochotona pallasi*), and numerous small rodents including species of vole (*Clethrionomys* spp., *Microtus* spp., *Alticola* spp.), hamster (*Cricetulus* spp.), gerbil (*Meriones* spp.) and shrew (*Sorex* spp.). Numerous old horns found in the study area indicate that argali sheep (*Ovis ammon*) were previously resident, but they were never observed during this study. Pallas cats (*Felis manul*) are thought to occur in the region in low numbers but none were noted.

There are resident populations of chukar partridge (*Alectoris chukar*) throughout the study area and Altai snowcock (*Tetragallus altaicus*) are relatively common at high elevations. Numerous raptors occur, most notably lammergeyer (*Gypaetus barbatus*), Cinereous vulture (*Aegypius monachus*) and steppe eagles (*Aquila rapax*). Reptiles, though present at low elevations, were rare, the only species identified being the common viper (*Vipera berus*).

The study area is occupied by semi-nomadic herders and their livestock. At least 13 families use the area seasonally and graze upwards of 3,500 head of stock, primarily sheep and goats. Large livestock include horses, camels, yak and cattle. Most local residents travel by camel or horse. Access to the area is possible by motor vehicle on dirt tracks from the south and north, but no through passage is possible. The western edge of the study area is bounded by a field road that leads to the nearest som (local administrative center) 60 km to the northwest.

Methods

Capture

A base camp was established adjacent to the Saksai River in spring 1994 from which all work was conducted. Leopards were live-trapped using Aldrich-type foot snares (Novak 1980) placed in blind sets on trails. Snares were usually placed within a few meters of leopard scrapes or scent sprays which are often found along cliff-base trails and ridgelines (Ahlborn and Jackson 1988). Occasionally, snare sites were baited with live goats or commercial lynx urine (Hawkbaker and Sons, Ft. Loudon, PA). Snare cables were fitted with positive stops at about 15 cm to avoid over-constriction on the limb. Snare cables were attached to heavy scrap-metal drags (60-80 kg) or large boulders. Use of drags reduced risk of leg injury, and when boulders were used we incorporated a heavy spring into the cable, again to reduce injury potential. We normally ran a trap line of 10-18 snares along 8 km of cliff-bottom trails, or ridgelines. Snares were checked each day at dawn or more frequently.

Handling

Snow leopards were immobilized with a mixture of tiletamine HCL and zolazapam HCL (Telazol: Wildlife Pharmaceuticals, Inc., Ft. Collins, CO.) administered at a dose of about 3 mg per kg of estimated body weight, by jab stick. Cats were weighed, measured, eartagged and inspected for parasites, wounds, and signs of current or previous lactation. We estimated age roughly by body size and tooth wear (Jackson 1996). A tooth (I_1) was extracted for cementum aging (Fancy 1980) unless extreme cold prevented working with ungloved hands for extended periods. For ease of identification cats were given identifying "names" that corresponded to sex and ear-tag color (e.g., M-Red).

Each cat was fitted with standard 450-gVHF radio-collar equipped with motion sensor (Telonics, Inc., Mesa, AZ.), except for one cat that received an 800-g ST-10 satellite transmitter (Telonics). The ST-10 collar was pre-programmed to transmit twice a day at times corresponding to overpasses by Argos 12 and 14 satellites. To maximize collar life, it was set to transmit daily for the first 30 days and alternate days after that until battery depletion. The satellite collar also had a VHF transmitter to allow ground telemetry, but was not equipped with a motion sensor.

Telemetry

We tried to locate each cat daily by ground-based telemetry using standard triangulation techniques (Samuel and Fuller 1996). The period during which we conducted telemetry was discontinuous due to demands of country-wide surveys (Chapter 1). The number of days we attempted to locate each cat ranged from 41 to 207, depending on when the cat was first instrumented. We recorded locations to the nearest 100 m on 1:100,000 topographic maps.

During the first 2 years of study we were only able to deploy VHF collars on two male cats. It rapidly became clear that monitoring snow leopards by ground telemetry in the rugged terrain of the Altai was exceedingly difficult and the success rate for daily locations was low. Cats went unlocated for weeks at a time because no more than 50% of the study area could be searched in a single day, and cat movements and home range sizes were clearly greater than what had been reported from previous studies (e.g., 11.7 – 38.9 km^2; Jackson 1989). In 1996 technological advances in radio-collar design made it possible to obtain a satellite platform with a weight and battery life (1 year) suitable for our snow leopard study. Two collars were brought to the field in spring of 1996 in hopes of placing one each on a male and female. Two females were captured; the first received a satellite collar and the second a standard VHF collar. We were unable to capture a male, despite efforts to free-range dart one of the existing VHF-collared males.

The data from the satellite collar were not available until after most ground work in the study area was complete. The initial satellite data set included 107 locations. We defined a maximum acceptable areal extent for locations centered on the study area with an X extent of 1000 km and a Y extent of 700 km assuming no snow leopard would range this far from its capture site and that any such location would represent telemetry error. Five locations that fell outside this range were deleted. We decided whether to include any of the remaining locations by comparing each to its preceding and subsequent locations and making a subjective judgement on whether the snow leopard would likely have moved that much in the interval of time between transmissions. Also, if the preceding and subsequent locations were clustered, but the location itself was substantially removed from that cluster, we assumed that the location was in error. For any location that was questionable, we took into account the Argos supplied data quality fields (LC94, NLOC94, APBEST, DUR, NOPC) for that transmission in making a decision. Eventually, 91 locations were accepted.

The home range identified from satellite telemetry data was unexpectedly large, much of it falling well outside the mapped study area. Analyses of these data were necessarily different than for VHF-collared cats. Three location data sets for the satellite-monitored cat were available: VHF, satellite, and combined. The combined data set was used to estimate home range size, core activity isopleths, movements and intraspecific distances. Only those locations, or portions of home range, that fell within the mapped study area were included in the use-availability and cat-to-habitat attribute distance analyses. We compared same-day locations by VHF and satellite telemetry to access accuracy. We also examined satellite locations for days when a VHF location was attempted but unsuccessful to determine if distance or topography was more likely the limiting factor in those VHF failures.

Habitat Mapping

We mapped biotic and physical habitat attributes of the study area on 1:50,000 topographic charts. Biotic attributes included ibex sightings and seasonal ibex range, marmot range, large and small livestock summer and winter range, and herders' seasonal camps. Physical attributes mapped included roads, rivers, and relative habitat ruggedness (rolling, slightly-, moderately- and very-broken). Ruggedness categories followed the definitions of the Snow Leopard Information Management System field protocols (Jackson and Hunter 1996:53) as modified for our range-wide surveys (Chapter 1). Mapped attributes and all leopard locations were then digitized into a geographic information system (GIS) database.

Home Range Calculations

We considered all cat locations in all area-use calculations, including same-day locations. Autocorrelation is thought to be a concern when using multiple locations from the same day in home range analyses (Litvaitis et al. 1996), particularly core activity centers, and it is suggested that only locations separated by adequate time to allow animal movement across their home range be used. We elected to use all locations in our home range analyses for reasons explained below in the discussion of daily movements. The PC-based program Calhome (U.S. Forest Service) was used to calculate minimum convex polygon (MCP) home ranges (Mohr 1947), and the adaptive kernel (Worton 1989) subroutine to identify core activity centers (30% isopleths) for each cat. The results were output to the GIS database. A combination of PC-based Arcview and workstation Arc-Info (both Environmental Systems Research Institute, Redlands, CA) facilitated habitat and home range analyses.

Analyses of Distribution

We determined snow leopard habitat selection at both the study area and home range level. We compared snow leopard habitat use with availability by comparing the proportion of each cat's radio locations that fell within a specific habitat type to the proportion of that habitat type available in the study area and in the individual's home range (Neu et al. 1974, Marcum and Loftsgaarden 1980). Preference or avoidance was determined at both levels using Bonferroni simultaneous confidence intervals when habitat attributes were mutually exclusive (e.g., slope, ruggedness and aspect). For other attributes we used standard confidence intervals. At the study area level we tested for selection using 95% confidence intervals, and at the home range level using 90% confidence intervals. Selectivity indices of + (selected for), 0 (no selection indicated), and – (selected against) were assigned for each habitat attribute. Affinity for some habitat attributes is better tested by looking at distances between the animal and the attribute. To test the hypothesis that distances from snow leopard locations to habitat edges were random, we generated 200 random points within the study area and compared these to the mean distances of all cat locations pooled using standard paired t-tests at $P<0.05$. We compared cat and random point distances to the edge of the ruggedness polygon they occurred in for each ruggedness category to determine if distance to edge varied by habitat type.

When consecutive-day locations were available we calculated the minimum straight-line distance moved from one day to the next. When multiple locations were available for the same day we calculated daily distance moved. The consecutive-day and daily distances were then contrasted. Intraspecific distances between cats located on the same day were calculated and compared by sex.

Activity Monitoring

Cat activity, either sedentary or active, was recorded at each location. On several occasions we also monitored individuals for 24-hour periods at 15-minute intervals. Activity monitoring was not possible for F-Yellow because her collar did not have a motion sensor. Snow leopards were able to move with enough stealth to not always trigger the motion sensor. In those instances the change in signal strength as the collar moved through signal blocking obstacles indicated the cat was active despite an "inactive" pulse rate. When we were able to observe cats visually for extended periods we recorded activity continuously, noting the time of each activity change. Cat activity patterns were examined for seasonal variation between summer (May-October) and winter (November-April).

Results

Captures and Study Animals

We captured individual snow leopards (2M:2F) 6 times during 1,872 trap-nights (1 capture/312 trap-nights). One male was captured 3 times, the first 2 instances being 5 days apart and in the same snare. He was captured again 8 months later. We knew of only 3 instances when snares were likely sprung by snow leopards but did not result in a capture. No captures were made in sets baited with lynx urine, although we did not keep records of how frequently the lure was refreshed. Snares baited with live domestic sheep or goats comprised less than 8% of our sets, but accounted for 2 of 6 snow leopard captures. Snares set next to ibex that snow leopards had killed (<1%) were never successful, but a snare set at a domestic goat depredation site on a hillside captured a leopard on the first night. Blind trail sets in valley bottoms accounted for 2 captures, and ridgeline sets for 3 captures.

All snow leopards responded well to the immobilizing drug (Telazol) at 3 mg/kg estimated body weight. Onset of anesthesia was rapid (4 to 6 minutes) and lasted for 45-60 minutes. Two trap-related injuries to leopards were noted. The first male we captured (M-Red) had the snare cable close on the lower part of the front paw rather than the leg, and he received deep lacerations on two toes. Topical and injectable antibiotics were administered. Subsequently, we observed this cat walking on two occasions and there were no apparent ill effects of the injury. A female (F-Green) received a superficial split in a toe pad digging at the snare cable. She was also observed to have suffered no ill effects.

We placed snares around two of M-Blue's fresh ibex kills when we were attempting to capture him a fourth time and change his VHF collar for the satellite model. In both cases he immediately left the area and did not return for the ibex despite more than 50% of each carcass remaining. We also noted that he avoided blind-set trail snares at least 3 times late in the study, urinating on one and walking deftly around at least two others. Non-target species captured included two domestic camels, one lynx, two adult female ibex, and one ibex kid. All non-target captures were released without incident with the exception of one adult ibex that was killed and partially eaten by a snow leopard.

Both captured males appeared to be fully grown adults (Table 2-1). From cementum annuli counts M-Blue was 4-5 years old, matching our field estimate of 4-6 years, and based on tooth wear was judged to be younger than M-Red from whom we did not extract a tooth.

The first female we captured (F-Yellow) was of advanced age, estimated at 9 years or older, and subsequently (after her natural death 2.5 years later) confirmed to be 11 years old by tooth cementum annuli. We could not extract a tooth for aging at capture due to extreme wear or previous breakage. She was in poor condition compared to all other captured cats. She had two toes missing from her right front paw, 3 broken canine teeth, nearly half of the right ear was missing, the lower lip had previously been torn to the gum line, and there were several old puncture wounds about the face and head. None of the injuries were fresh and all were long healed. She was the only cat that had any sign of previous injuries. Her fur was also in poor condition and she appeared emaciated, weighing nearly 10 kg less than similar-sized F-Green (Table 2-1). Nipple pigmentation indicated F-Yellow had previously lactated, although she was not lactating at capture. Given her condition, we hesitantly fitted her with a slightly heavier satellite collar. That concern proved unfounded as we tracked her over the ensuing months. On one occasion we watched her for 9 hours at the site where she had killed a large male ibex. She alternately ate and rested, the collar posing no apparent problem, and often serving as a prop for her head as she lay on an outcrop.

F-Green was the youngest animal captured and we estimated her age at 3 years, based in part on the lack of previous lactation and otherwise mature appearance. Her capture was non-standard in that she broke the snare cable when it caught in the cleft of a rock, allowing her to escape before we arrived on the morning of capture. It had snowed the night before and we were able to track her about 2 km to a cave. She was found crouched in the extreme back end of a very narrow 8-meter serpentine tunnel that barely allowed space for a person to crawl to within 1 m of her. Although vocalizing, she made no attempt to attack when the immobilizing drug was administered using a shortened jabstick.

F-Green produced her first offspring, and the only young observed during this study, in spring of 1997. She was first observed with 2 cubs in July 1997, and when she saw us she immediately departed, moving the cubs several kilometers. Despite numerous attempts to make additional direct observations, we were not successful. Her movements during that summer likely were modified by her being with cubs, although we never again saw the cubs or their tracks to confirm their continued existence. She did make further use of caves that summer. On several occasions she was radio-located on a cave-riddled and steep rocky hillside above the Tugrog River where we believe she kept the cubs during the day.

Telemetry Locations

The 4 radio-collared animals were located a total of 248 times which included 157 from ground-based and 91 from satellite based telemetry (Table 2-2). We attempted to locate cats by ground-based telemetry on 207 days, and by satellite on approximately 199 days. Success rate varied by cat from 11% to 42%. The success rate for the satellite collar was 40% after omitting likely outliers. The satellite transmitter battery lasted as expected and provided just over 12 months of alternate-day, twice-daily transmissions. The VHF portion of the unit continued to operate for 30 months. There were no instances of pre-mature collar failure or loss during the study.

The number of consecutive-day locations attained ranged from 9 to 31 per animal. The mean number of days between locations ranged from 2.4 to 9.4. The fact that M-Red had the longest mean interval between locations and lowest location success rate stems from his departure from the human-defined study area and a gap of more than 1-year in collecting telemetry data from him.

Activity Patterns and Observations

We recorded the activity (active/inactive) of radio-collared snow leopards on 1,333 occasions. The majority of the recordings were for the male M-Blue (n = 1,057), and fewer observations for M-Red (n = 86) and F-Green (n = 194). Pooled data from all cats across all seasons (Figure 2-2) indicated snow leopards were active 37.3% of the time. Activity level was lowest between noon and 1800 hours, and only exceeded 50% between 2000 hours in the evening and about 0400 hours. A slightly crepuscular pattern was apparent. Activity increased earlier in the evening and later in the morning during winter, as would be expected with changes in sunrise and sunset.

Only M-Blue provided enough data to allow us to look at an individual cat's activity pattern, and for seasonal variations (Figure 2-3). He was active 32.1% of the time in summer and 37.3% of the time in winter. The bi-modal or crepuscular pattern is slightly more obvious in both M-Blue's winter and summer activity pattern, than in the pooled data for all cats.

We only observed snow leopards directly 8 times, all during the day. Visual observations were rare, even when radio-collared animals were known to be moving across nearly barren hillsides in close range of researchers. In 6 of 8 instances the leopards were resting when first observed and in 2 cases they were walking. We never observed a leopard hunting. Resting leopards usually appeared to sleep, but were easily roused, even by seemingly ambient sounds such as birds calls. In two cases leopards were disturbed by our presence and left the area. One leopard, F-Yellow, was observed for 9 hours between 0900 and 1800 hours during which she alternately ate and rested, moving at most 50 m from the ibex kill she was on. We recorded her activity continuously by noting the time of each change. She rested 63% of the time and moved or ate for 37%. When we departed, one observer purposely passed below F-Yellow's position on the rocky outcrop she was in. The second observer watched from a hidden vantage point to monitor her response. F-Yellow quickly took notice of the human but remained motionless until he had passed by about 60 m below. She then moved 20 m into some brush and remained hidden for at least 30 minutes at which time both observers departed.

Daily Movements

The mean minimum straight-line distance between consecutive-day locations for individual cats averaged 5.1 km (range = 0.54-10.77 km; Figure 2-4). Cats moved 1 km or less between consecutive-day locations 41% of the time, and less than 2 km 59% of the time. Satellite telemetry helped us determine that movements of >12 km were not uncommon (14%). The greatest distance traveled between consecutive-day locations was 27.9 km by F-Yellow (satellite-detected); M-Blue exhibited the greatest ground-telemetry detected move of 11.8 km. M-Red was known to move from the Saksai study area to Mother Mountain, a large isolated massif to the south. This move would have required traversing 30-40 km of open steppe and was quite probably made in a single day, although we can not confirm how long the crossing actually took. Seasonal variations in distances moved were noted. On average, leopards moved farther between consecutive-day locations in the summer (x = 6.8 km, SE = 9.1), than in winter (x = 3.9 km, SE = 6.3).

F-Green was monitored during a 24-hour period in July 1997 when she was with cubs. During this period she spent most of the day and night on the cave-riddled hillside and avoided observation. At 0400 she departed the caves, made a 3.9-km circuit to the next valley, and returned to the caves 6 hours later. We could not determine if she took the cubs with her. F-Green made several moves of between 1 and 2 km that summer when we assumed she still had cubs.

In addition to consecutive-day distances, we also calculated distances moved on the same calendar day when more than one location was made. For each cat, and for all cats combined, the mean same-day distances were greater than the mean consecutive-day distances (Figure 2-4). Although the differences were not significant (P>0.05) the consistency of the direction of difference suggests that consecutive-day measurements might underestimate 24-hour travel averages. It also suggests that cats travel some distance during activity periods, but return to the same rest site, resulting in underestimation of distances moved day to day.

Home Range Size

Home ranges of snow leopards, as calculated using minimum convex polygons for ground-based telemetry locations, ranged from 14 km^2 to 142 km^2 (Table 2-3, and Figures 2-5, 2-6, 2-7, 2-8). When F-Yellow's satellite locations were included, her home range increased in size from 58 to 4,530 km^2. This calculation included 91 satellite locations which we considered plausible. When we took an even more conservative view of her satellite data and removed additional locations that represented single visits to sites well outside her core activity area, her home range was about 1,590 km^2, more than an order of magnitude greater than the largest home range we determined for any leopard using ground-based telemetry.

There were only three same-day locations for satellite and VHF telemetry of this cat and these were taken several hours apart. The mean distance between VHF and satellite locations on the same day was 6.3 km (range = 1–11.5 km) which was less than her mean daily movement distances. There were 10 days on which VHF telemetry for F-Yellow failed but a satellite location was acquired. The mean minimum distance between F-Yellow's location and the unsuccessful ground-telemetry observer was 20.5 km (range 3.3 – 53.0 km). There were only 2 instances where ground telemetry observers were less than 12 km from the satellite location and failed to gain a signal and in both cases the cat and the observer were separated by a high ridgeline. Most importantly, all but 2 of the satellite locations for days when VHF monitoring attempts failed were outside of her VHF-generated MCP home range. This supports our contention that VHF locations provide only a minimum estimate of snow leopard home range sizes.

The calculation of M-Red's home range was also not straight forward. Because he dispersed out of the study area and out of the mountain range the study area was in, and did not return, we elected not to include the new Mother Mountain locations (45-65 km distant) in the MCP. Had we done so, large expanses of steppe-desert that spanned the area between his old and new ranges would have been included. We used only the locations with the Saksai study area in his range calculations.

Sociality

Snow leopards exhibited substantial home range overlap at the MCP level (Figure 2-9). The 30% isopleth core areas also overlapped for 3 of the 4 cats. F-Green, who was with cubs during much of the period we tracked her, had a core area that did not intersect either male's and was on the periphery of the other female's. The core areas of all cats were contained within a relatively small portion (~10%) of the study area.

Information on same-day distances between snow leopards is limited (Table 2-4). We would always attempt to locate every cat when conducting telemetry by scanning all frequencies often, particularly from ridgeline vantage points. Still, we located both males M-Blue and M-Red in the study area on the same day only 3 times and the mean separation distance was 1.3 km (SE=0.5). Male:female distances were the most frequent cat to cat distances we attained and were larger than male:male distances (4.8 km, SE=5.4). The greatest mean distances were between females (7.8 km, SE=6.6).

We did not observe two cats together during the study. In late February 1996 M-Blue and F-Green were within 0.5 km of each other, and within 0.8 km of our camp, for 2 days when the female may have been in estrus. M-Blue yowled frequently each evening between the hours of 1900 and 2200 for 3 days, but we heard no reply from F-Green. We did not detect them closer than 0.5 km by telemetry during that period. We knew of no other male in the study area that winter and F-Green did give birth the following spring. The only other instance where we thought an interaction between cats may have taken place occurred during F-Green's cub rearing period, when she abruptly left her cave rest area upon F-Yellow's arrival. The severe injuries that F-Yellow had sustained in the past may well have been from intraspecific aggression or an attack by wolves. The injuries were not consistent with a human encounter.

Habitat Use

Snow leopard home ranges and cores areas did not contain habitats of various physical or biotic attributes in proportion to their occurrence in the study area although small sample sizes (less than 6 animals) precluded statistical testing of compositional analyses as described by Aebischer et al. (1993). Though untested, rolling and slightly broken habitats appear to be under-represented in home ranges and markedly so in leopard core areas (Figure 2-10), while very broken terrain appear over-represented. Habitat with slope less than 20° composed a large portion of the study area, but much lower percentages of home ranges, and relatively little of leopard core areas. All slope categories above 20° were included at proportions greater than occurrence. Of seven biotic habitat attributes we measured, only two appeared to influence snow leopard range use (Figure 2-11). Ibex range, both summer and winter, was included in snow leopard home range and core areas in proportions substantially exceeding occurrence. There was no clear trend for marmot range, or seasonal ranges of small and large livestock.

Use, as measured by snow leopard locations, differed significantly from availability of several habitat parameters at both the study area and home range level (Table 2-5). The selectivity indices for pooled locations of all cats statistically supports the preferential use of habitat inferred in compositional analyses. Snow leopards used steep and rugged terrain much more than expected, while biotic factors were less likely to influence use, with the exception of ibex presence. Most of these preferences held up when we tested for selection of individual cats at the study area level, although the margin between observed and expected use were often reduced. Selection was less often apparent when locations were compared to availability within home ranges (Table 2-5).

Snow leopard locations were not randomly distributed ($P<0.001$) in relation to habitat edges (Table 2-6). This was most apparent when cats were in rolling habitat when they were substantially closer to edge than random points were. Within very broken habitat, cat distances to edge were not different from random points ($P=0.67$).

Discussion

We found that snow leopards in the Saksai River study area of Mongolia exhibited activity, movement, and home range patterns unlike those previously documented for the species. We observed less activity during the daytime hours of 0800-1600 (34.8%) than Jackson did in Nepal (43.8%), but cats in our study were more active (51.4%) between 2000 and 0400 than in his (44.1%). In both Nepal and elsewhere in Mongolia (Schaller et al. 1994) a strong crepuscular pattern was observed, with peaks at both dawn and dusk. Our data indicate slight peaks in activity at those times, but a fairly consistent level of activity was maintained throughout the night, similar to increased nocturnal activity reported for other large felids including puma (*Felis concolor*; Seidensticker et al. 1973), tigers (*Felis tigris*; Sunquist 1981), and common leopards (*Panthera pardus*; Bailey 1993:126).

Snow leopards may be less active during the day, but our telemetry data indicate that substantial movements during that time are common. Notably, we found that the minimum straight-line distance traveled between locations on the same day (6.7 km) was greater than that for consecutive day locations (5.1 km). The sample size was small, but the pattern was consistent in all 4 collared leopards. This may indicate that snow leopards move about during both the day and night, but frequently return to the same daytime rest site. Schaller et al. (1994) observed a male snow leopard in Mongolia using the same rest site on several consecutive days. This argues against using only consecutive-day locations to determine travel distances and also has implications for home range and core activity area calculations. It is common to omit same-day locations from telemetry data sets when home range use is analyzed (Swihart and Slade 1985, Litvaitis et al. 1996), particularly core activity centers. Given that same-day movements can exceed those between consecutive days, at least for snow leopards in our study, we contend that they should not be the analyses. Clearly, auto-correlation does become an issue when locations are taken at insufficient intervals, but this has to be balanced against loss of habitat use information and carefully considered when designing further studies.

Mean distances traveled by snow leopards in a 24-hour period substantially exceeded those reported elsewhere for the species (Jackson and Ahlborn 1989, Chundawat 1990), as well as for other similarly sized felids such as puma and common leopard (Seidensticker et al. 1973:26, Bailey 1993:145). Satellite telemetry allowed us to detect some large movements we otherwise would have missed, but even our ground-based telemetry data include daily movements of more than 12 km, which is nearly double that previously reported for snow leopards. Common leopards in Africa (Bailey 1993:145) moved as much as 13 km in a day, but less than 0.2% of their daily movements exceeded 10 km. Snow leopards in this study moved more than 10 km on 18% of consecutive days monitored. We suspected that snow leopards in Mongolia were capable of long-distance moves in short periods after we documented their use of isolated massifs as potential way points when crossing large expanses of open steppe and desert between mountain ranges (Chapter 1). M-Red's departure from the study area for Mother Mountain some 45-65 km distant confirmed this.

We gained insufficient data to do more than comment on activity and movement patterns of female leopards when accompanied by cubs. F-Green was monitored on 196 occasions during the summer after her cubs were born and was active 43% of the time. She was more active during mid-day and exceeded 60% activity between noon and 1300 hours. She made at least one movement of nearly 4 km in less than 6 hours, but we could not confirm that the cubs joined her, or if she had left them in the cave she departed and returned to on that trip. The fact that F-Yellow arrived in the cave area when F-Green departed and stayed until about the time she returned, leaves us to speculate as to whether it was a factor in the abrupt move.

Snow leopards are primarily solitary and avoid conspecific contact, a social system likely facilitated through a mixture of visual and olfactory queues such as scrapes, claw rakes, feces, and scent sprays (Ahlborn and Jackson 1988, Fox 1989:16). In the Saksai study area snow leopards conformed to this pattern and when located on the same day were separated by an average of 1.6 to 7.8 km, despite having nearly complete overlap in home ranges. The greatest separation was between females, and least between males. Jackson (1996) reported similar separation on the same day between males, but much lower values than we saw for females. The mean distances between F-Yellow and any other cat would likely have been greater if ground telemetry had continued on other cats during the period she was tracked by satellite. For example, distances of more than 40 km between F-Yellow's locations and M-Blue's core area were recorded, so the values we report here are likely a substantial underestimation of true mean intraspecific distances. Although we never saw two cats together in the Saksai other than F-Green and her cubs, we have observed sub-adults together and tracks of a family group including an adult and two cubs elsewhere in the Altai Mountains. Local herders and some biologists in Mongolia have reportedly seen up to 7 snow leopards together on a kill, but these are unsubstantiated. F-Yellow's wounds indicate that intraspecific contact might well lead to aggression rather than benign sharing of resources, although her injuries could not be definitively attributed to another leopard.

Snow leopard home ranges in the Saksai were on average much larger than the 10.7 km^2 to 36.2 km^2 (x = 18.6 km2) previously reported for the species (Jackson and Ahlborn1989, Chundawat 1990, Schaller et al. 1994, Oli 1997). Home ranges in our study were larger, despite being based on relatively few locations. The male for which we had the fewest locations (M-Red with 24) had a minimum home range of 61 km^2 without considering his move out of the study area. M-Blue, with the most VHF locations, had a minimum home range (141 km^2) that was 7 times the largest ever reported for a snow leopard. Given our inability to locate him on 68% of attempts, his range was certainly underestimated. Only F-Green, the female who was with cubs for most of the time we tracked her, had a home range size comparable to that reported for snow leopards elsewhere (13.5 km^2). We suspect her range was normally larger when she was solitary, as cub rearing has been shown to reduce range size and movements in puma and common leopards (Bailey 1993:168, Seidensticker et al. 1973:24). Jackson and Ahlborn (1989) also noted increases in home range size for a snow leopard with cubs as the young became more mobile.

Both Jackson (1996) and Oli (1997) believed that movements and home ranges of snow leopards have probably been underestimated due to the difficulty of ground-based radio-tracking in the type of terrain they occupy. The extent to which that has been confirmed by our use of satellite telemetry was unexpected. The 4,530-km^2 home range calculated using the minimum convex polygon method may well overestimate F-Yellow's area of use, although neither the movements required or the habitat of the locations could be used to negate the estimate. When we take an extremely conservative approach and remove all potential error points from the satellite data, her range estimate still approached 1,600 km^2 and even the 75% isopleth encompasses some 585 km^2, which is 16 times larger than any female snow leopard in the literature.

F-Yellow was a very old animal and not one we would expect to make large exploratory movements outside her normal home range, such as those seen by sub-adult common leopards in Africa (Bailey 1993:156). Bailey also noted that leopards in good physical condition tended to move further than less healthy animals, yet F-Yellow was in the poorest condition of all our cats at capture. Older animals, especially those in poor condition might be more easily displaced from their range and forced to explore alternate sites. F-Yellow, however, was not displaced and continued to use the core area she shared with 3 other collared leopards throughout the study, and she died in her core area. F-Yellow may not represent the "normal" snow leopard in our study area and her calculated range size could be real, but an aberration. One puma in California had a home range 5 times the mean for the other 7 study animals (Hopkins et al. 1986). Substantial annual fluctuations in home range size for individuals have also been documented in bobcats (*Lynx rufus*) where a female varied range size by a factor of 10 between years (Knick 1990). With a single year of data for F-Yellow, we cannot determine if movements and range size were representative of her long-term habits. These findings make our failed attempts to place a satellite collar on a second snow leopard even more unfortunate in terms of validation, and we are left with an unclear picture of range extent and use. Despite uncertainties about our satellite telemetry results, and the movement of one male out of the study area, it is clear that snow leopards in the Saksai use larger ranges to meet their needs than snow leopards in previous studies in Nepal, India, and elsewhere in Mongolia.

Habitat use determined in this study was consistent with that for snow leopards elsewhere in terms of showing a strong affinity for steep and rugged terrain, high use of areas rich in ungulate prey, and affinity for habitat edges (Jackson and Hunter 1996, Fox 1989).

Ibex comprise the majority (60-70%) of snow leopard diets in Mongolia (McCarthy unpublished data, Schaller et al. 1994, Amarbat 1998) and their distribution within the country is closely linked (Chapter 1). Marmots make up between 15-20% of the diet, domestic livestock less than 5%, and other small mammals, birds, or vegetation the remainder. Snow leopards will opportunistically take other large wild ungulates, such as argali, red deer (*Cervus elaphus*), musk deer (*Moschus* spp.), khulan (*Equus hemionus*), and gazelle (*Procapra* spp.), but none of these were present in our study area. Hence, the strong selection for ibex range exhibited by leopards in the Saksai was not unexpected. The distribution of ibex within the study area may explain much variation in snow leopard habitat use, and the density of ibex may provide a clue to the home range sizes that we estimated. The required large ungulate prey to snow leopard ratio has been variously reported to be within range of 114-230:1 (Jackson and Ahlborn 1984, Fox 1989, Oli 1994) and varies with proportion of the diet comprised of alternate prey such as small mammals and livestock. Snow leopards in the Saksai had limited access to marmots, and livestock depredation amounted to only a few animals a year (Allen and McCarthy, in press).

From our experience in observing and noting the numbers of ibex in the study area while locating snow leopards, we mapped their distribution and estimated that about 250 lived in the 277 km^2 that we regularly surveyed (i.e., 0.9/km^2). At this prey density, a single leopard would need a range of 126-256 km^2 (114-230/0.9) to incorporate enough prey to live on. If 3 leopards lived in identically sized, overlapping home ranges, then 3 times the number of ibex would have to be present/shared and this would require 378-768 km^2. Thus the large ranges we observed in Saksai are in line with relative prey abundance. Home range size has been shown to increase for other felids when prey densities are low including bobcat (Litvaitis et al. 1986) and lynx (Ward and Krebs 1985). Predator range size may also increase when prey are clumped or occur in high-density patches separated by large space, as seen in cheetahs (*Acinonyx jubatus*; Caro 1994). This may result in predators "trap-lining", or exploiting these high-density pockets by moving from one site to the next (Bradbury 1981). Snow leopards in this study appear to be ranging far greater distances to secure required prey than is necessitated in prime habitat, such as Nepal and India where other studies have taken place. However, the data do not reveal several core activity sites we would expect if leopards were using multiple small patches of high-density ibex range, in contrast, all of our leopards focused their activity on a single core area. We believe snow leopards in the Saksai feed primarily on ibex that are most abundant in the core area, but take the occasional one from among those that occur sparsely throughout most of the study area. Peripheral sites may be less densely populated, but ibex there may be less wary due to infrequent hunting pressure by leopards.

Management Implications

If range use as depicted in this study is representative of snow leopards across occupied habitat in Mongolia, density and total population may be less than previously thought. Large-scale movements and exceptionally large home range sizes may be an adaptation to low prey densities that occur in many parts of the country. Lower population density and movements that take cats across habitats that offer little escape cover serve to make leopards more vulnerable. This, coupled with dependence on an ungulate population that is coming under increasing pressure from domestic stock grazing, argues strongly for greater protective measures. Conservation measures based on research conducted in prime habitat in the Himalayas may not meet the needs of snow leopards in Mongolia. Mongolia has expanded its protected area system dramatically in recent years, but much of snow leopard range remains unprotected. Further, many reserves are of inadequate size to afford protection to snow leopards whose ranges exceed the size of the reserve.

This study only began to examine snow leopard ecology and habitat requirements in Mongolia. Additional studies should be undertaken to gain clearer picture of snow leopard range size, long-distance movement patterns, and dispersal. Recent technological advances in GPS satellite collars (Arthur and Schwartz 2000) could take much of the ambiguity out of telemetry studies for this species. Noninvasive genetic techniques (Chapter 5) may also provide an alternative to capture and handling of leopards. Feces and hair from rub sites may allow individual identification, as well as census, pedigree, and home range assessment using DNA microsatellite analyses.

Table 2-1. Weight, measurements, estimated age, and reproductive history of snow leopards captured and radio-collared in Gobi-Altai, Mongolia, 1994-96.

	Snow leopard			
	M-Red	M-Blue	F-Yellow	F-Green
Capture Date	3/15/1994	10/9/1994	2/16/1996	3/28/96
Sex	M	M	F	F
Weight (kg)	41.3	40.0	30.0	38.6
Estimated age (years)	7-10	4-6	9+	3
Body length[a, b]	120	122	117.5	117
Tail length	92	99	89	92
Total length	212	221	206.5	209
Chest girth	71	82	66	65.2
Zygomatic width	14.5	14.9	13.7	13.5
Skull length	20.5	20.8	19.0	21.4
Fore paw (l x w)		9.8 x 10.2	9.5 x 10.2	9.0 x 11.0
External parasites		2 ticks on neck		
Reproductive history			Previous lactation, not current	No previous lactation

[a] Measured from tip of nose to base of tail.

[b] All measurements in cm.

Table 2-2. Radio-telemetry history of 4 snow leopards in the Saksai River study area, Gobi-Altai, Mongolia, 1994-97.

	Snow Leopards					
	M-Red	M-Blue	F-Green		F-Yellow	
Capture date	3/15/94	9/10/94[a]	3/28/96		2/16/96	
				Ground	Satellite	Total
Total locations	24	84	26	23	91	114
Days located	22	61	17	22	79	94
Days attempted location	207	191	41	85	~199	300
Success Rate (%)	10.6	31.9	41.5	25.9	39.7	31.3
Mean interval (days)	9.4	3.1	2.4	3.9	2.5	3.2
Consecutive days located	9	28	10			31
Last location	11/24/96	11/22/96	9/9/97	8/7/97	2/18/97	8/7/97

[a] Subsequent captures on 9/15/94 and 5/10/95

Table 2-3. Home range size (convex polygon and harmonic mean isopleths, km^2) of radio-collared snow leopards in the Saksai River study area, Gobi-Altai, Mongolia, 1994-97.

			Core activity isopleths		
Snow leopard	Locations	MCP[a]	30%	75%	90%
M-Red	24	61.1	9.8	120.3	
M-Blue	84	141.5	1.8	24.6	294.2
F-Yellow (ground telemetry)	23	57.6	1.2	43.3	181.4
F-Yellow (all locations)[b]	113	4,530.1	27.5	584.6	11,830.3
F-Green	26	13.5	1.5	11.4	24.9

[a] Minimum convex polygon.

[b] Includes both ground and satellite telemetered locations.

Table 2-4. Distances (km) between radio-collared snow leopards when located on the same day in the Saksai River study area, Gobi-Altai, Mongolia, 1994-97.

Sex	n	Mean	SE	Minimum	Maximum
Male:Male	3	1.6	0.5	1.3	2.2
Male:Female	16	4.8	5.4	0.3	21.4
Female:Female	7	7.8	6.6	1.0	18.5

Table 2-5. Snow leopard selection of habitats of various attributes determined using Bonferroni simultaneous and standard confidence intervals to compare radio-locations and habitat availability at the study area and home range levels, in the Saksai river drainage, Gobi-Altai, Mongolia, 1994-96.

	Selectivity[a]								
	Locations vs. study area[b]					Locations vs. home range[c]			
	All cats	M-Red	M-Blue	F-Yellow	F-Green	M-Red	M-Blue	F-Yellow	F-Green
Ruggedness									
Rolling	-	-	-	-	-	-	-	0	0
Slightly broken	0	0	0	0	0	+	0	0	0
Moderately broken	+	0	0	0	0	0	0	0	0
Very broken	+	+	+	+	+	+	+	0	0
Slope									
<20°	-	0	-	-	-	0	-	-	-
20-29°	+	nr	+	+	0	nr	+	0	-
30-39°	+	0	+	0	+	+	+	0	+
40-49°	+	nr	+	0	0	nr	+	0	0
>50°	+	nr	nr	0	nr	nr	nr	0	nr
Aspect[d]									
N (316°-045°)	-	nr	-	0	0				
E (46° – 135°)	+	0	+	0	0				
S (136° – 225°)	0	0	0	0	0				
W (226°- 315°)	0	0	0	0	0				
Range									
Marmot	0	0	0	0	0	-	0	0	0
Small stock winter	0	0	-	+	0	-	-	+	0
Small stock summer	-	-	-	-	-	0	-	-	0
Large stock winter	0	0	0	0	0	0	-	0	0
Large stock summer	0	0	0	0	0	0	0	0	-
Ibex winter	+	+	+	0	+	0	+	+	0
Ibex summer	+	+	+	+	+	0	+	+	0

[a] + = selected for, 0 = no selection shown, - = selected against, nr = insufficient locations in this habitat type to assess selection.

[b] Tested at 95% confidence interval.

[c] Tested at 90% confidence interval.

[b] Availability of aspect categories at the individual home range level was not calculated.

Table 2-6. Comparison of distances (m) of snow leopard radio-locations and random points to habitat edge in the Saksai River study area, Gobi Altai, Mongolia, 1994-97.

	Locations (n=196)		Random points (n=200)			
Habitat attribute	$\bar{x}$	SE	$\bar{x}$	SE	Z	P
Ruggedness Edge[a]	198.0	227.0	500.0	467.0	8.21	<0.001
Edge of type if in[b]						
Rolling	316.4	520.1	629.4	330.8	4.48	<0.001
Slightly broken	238.1	267.2	450.1	367.8	3.29	<0.001
Moderately broken	135.0	113.6	176.7	135.6	1.36	0.91
Very broken	132.9	104.8	116.6	65.4	0.45	0.67

[a] Distance to the edge of the ruggedness polygon the point or location is in regardless of ruggedness type.

[b] Distance to the edge of the ruggedness polygon the point or relocation is in by type.

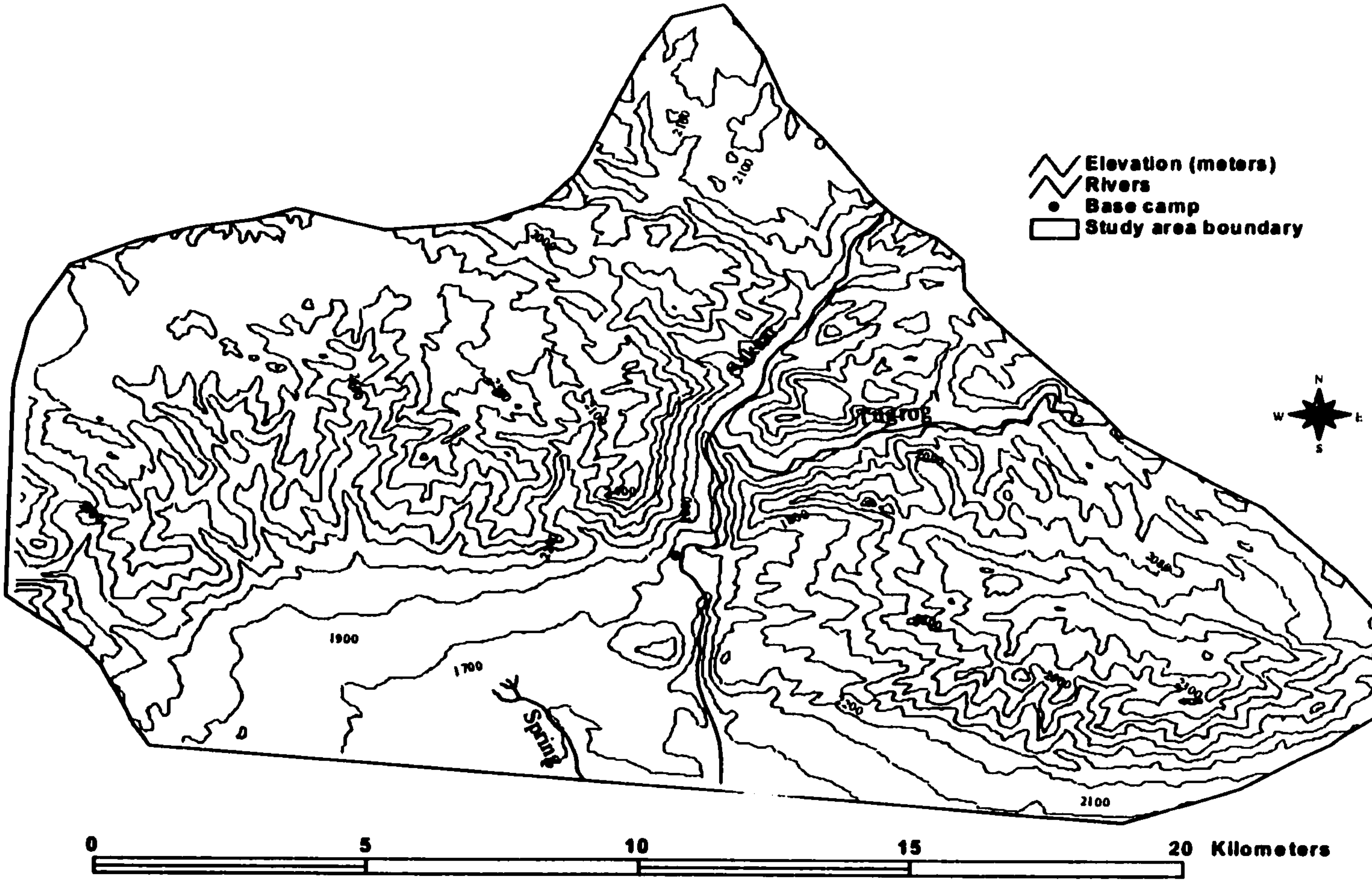


Figure 2-1. Saksai River study area, Gobi-Altai Aimag, Mongolia.

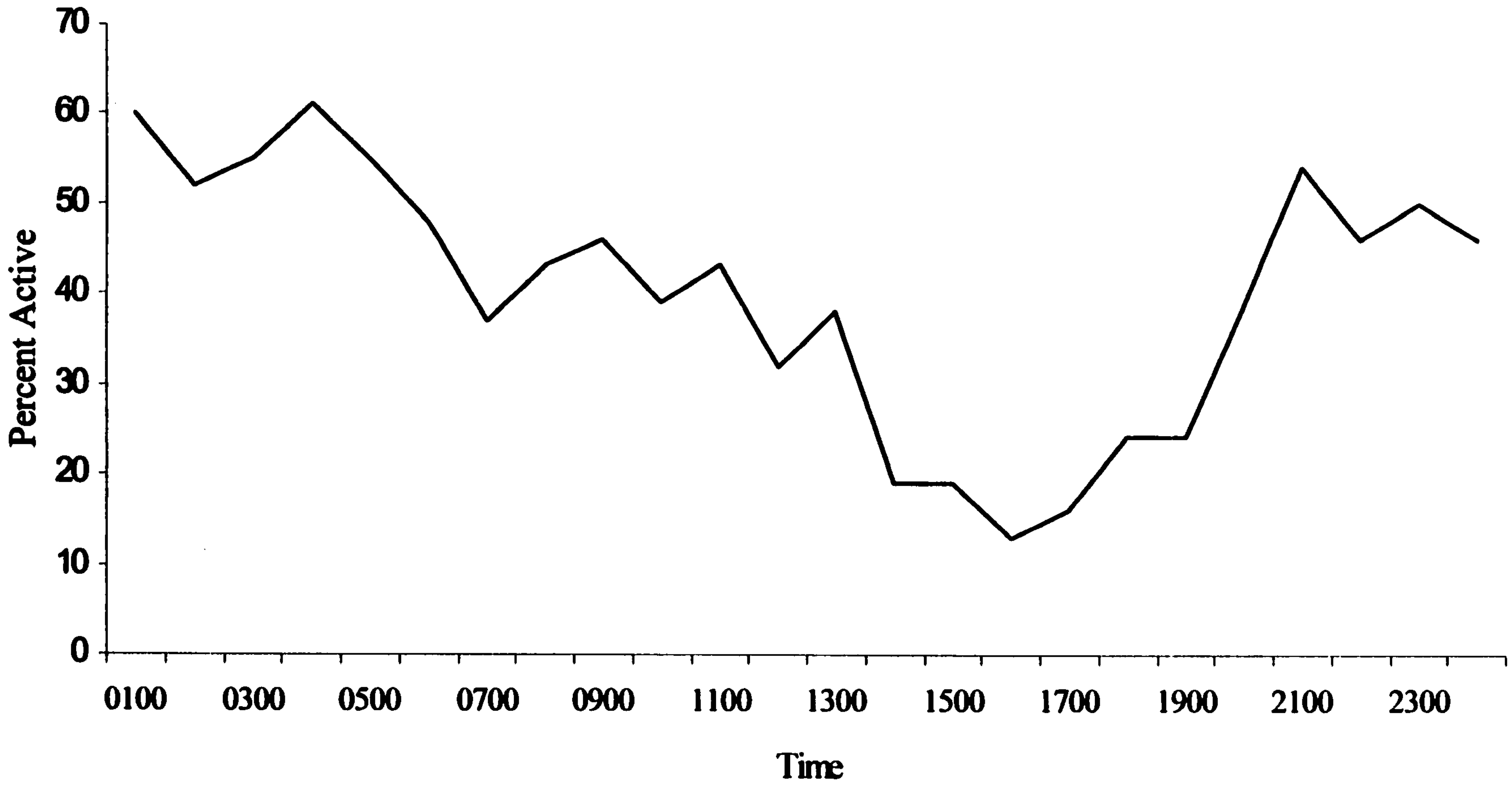


Figure 2-2. Activity patterns of radio-collared snow leopards based on pooled data (n = 1,333) for 3 cats over all seasons in the Saksai River study area, Gobi-Altai, Mongolia, 1994-97.

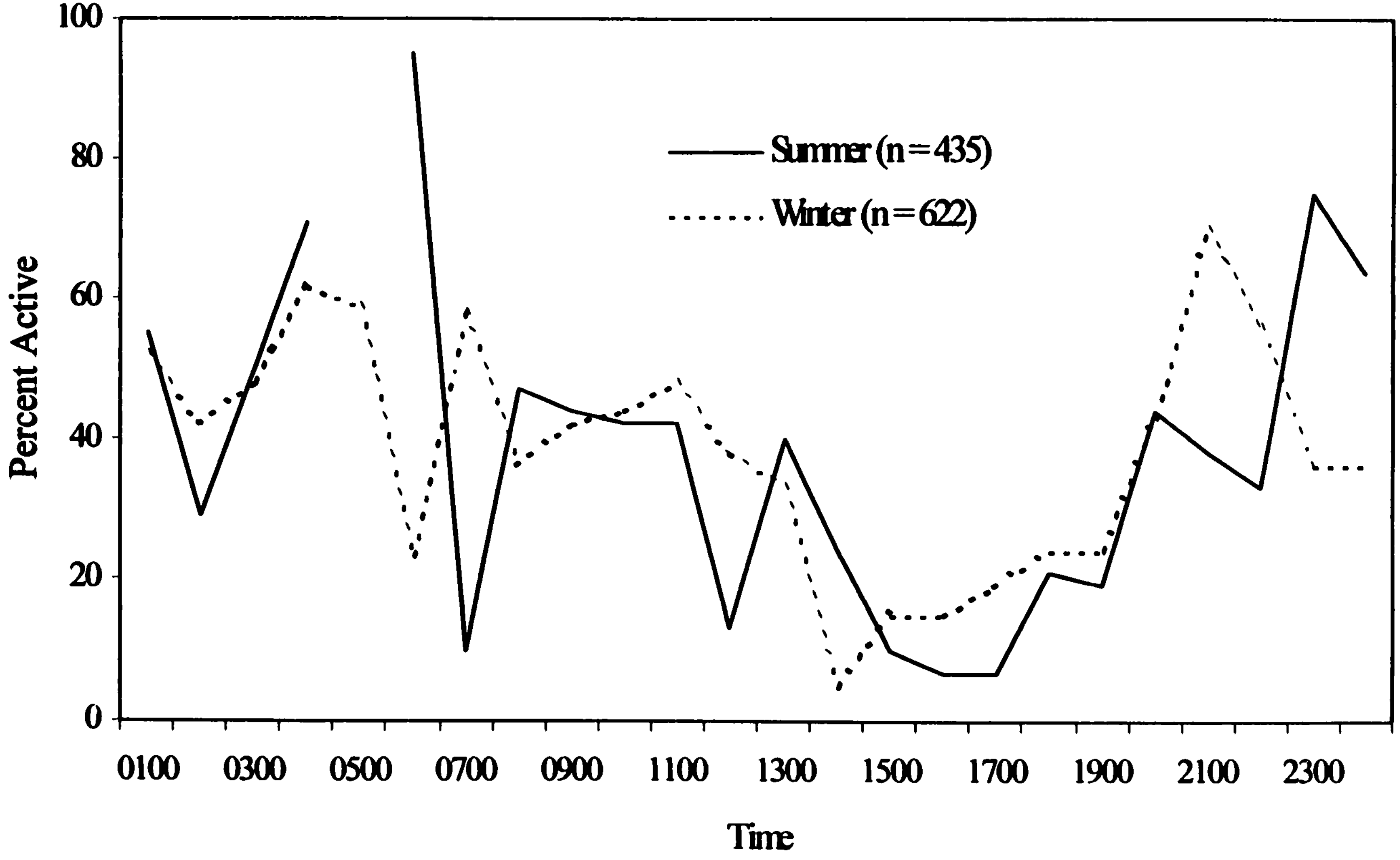


Figure 2-3. Seasonal activity patterns of a radio-collared male snow leopard (M-Blue) in the Saksai River study area, Gobi-Altai, Mongolia, 1994-97.

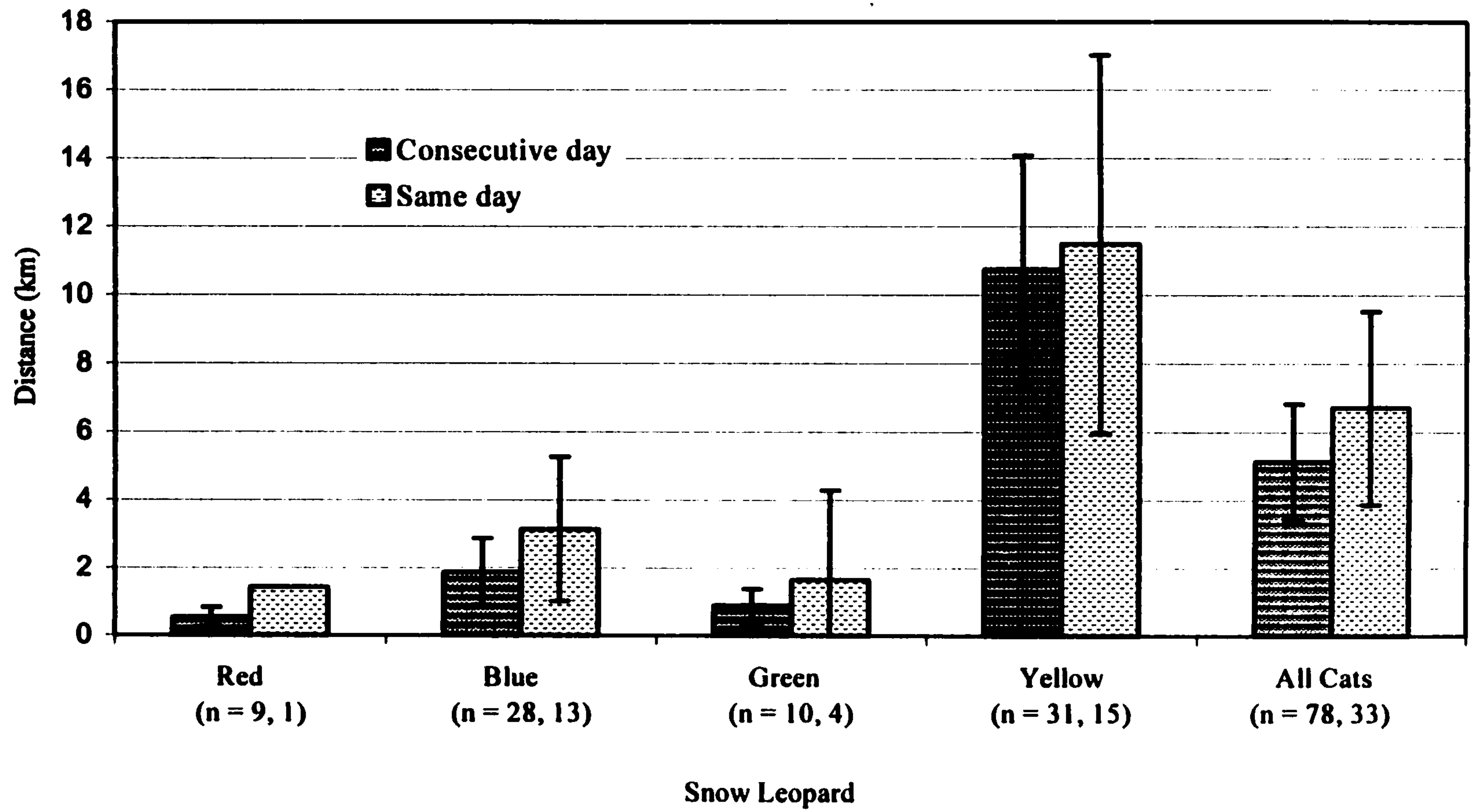


Figure 2-4. Mean and SE of minimum straight-line distances moved between consecutive and same-day locations of radio-collared snow leopards in the Saksai River drainage, Gobi-Altai, Mongolia, 1994-97.

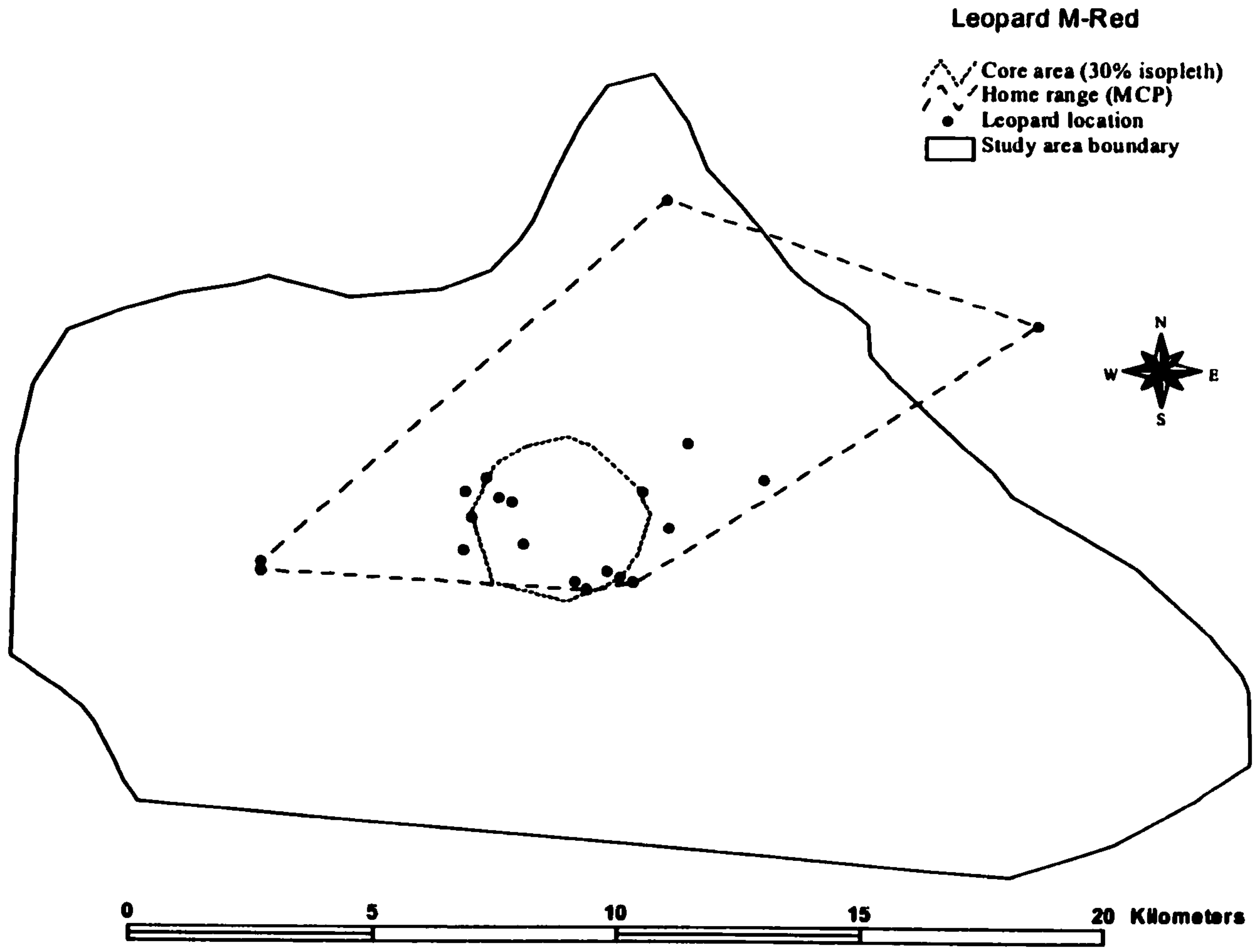


Figure 2-5. Home range (MCP) and core activity are (30% isopleth) for leopard M-Red.

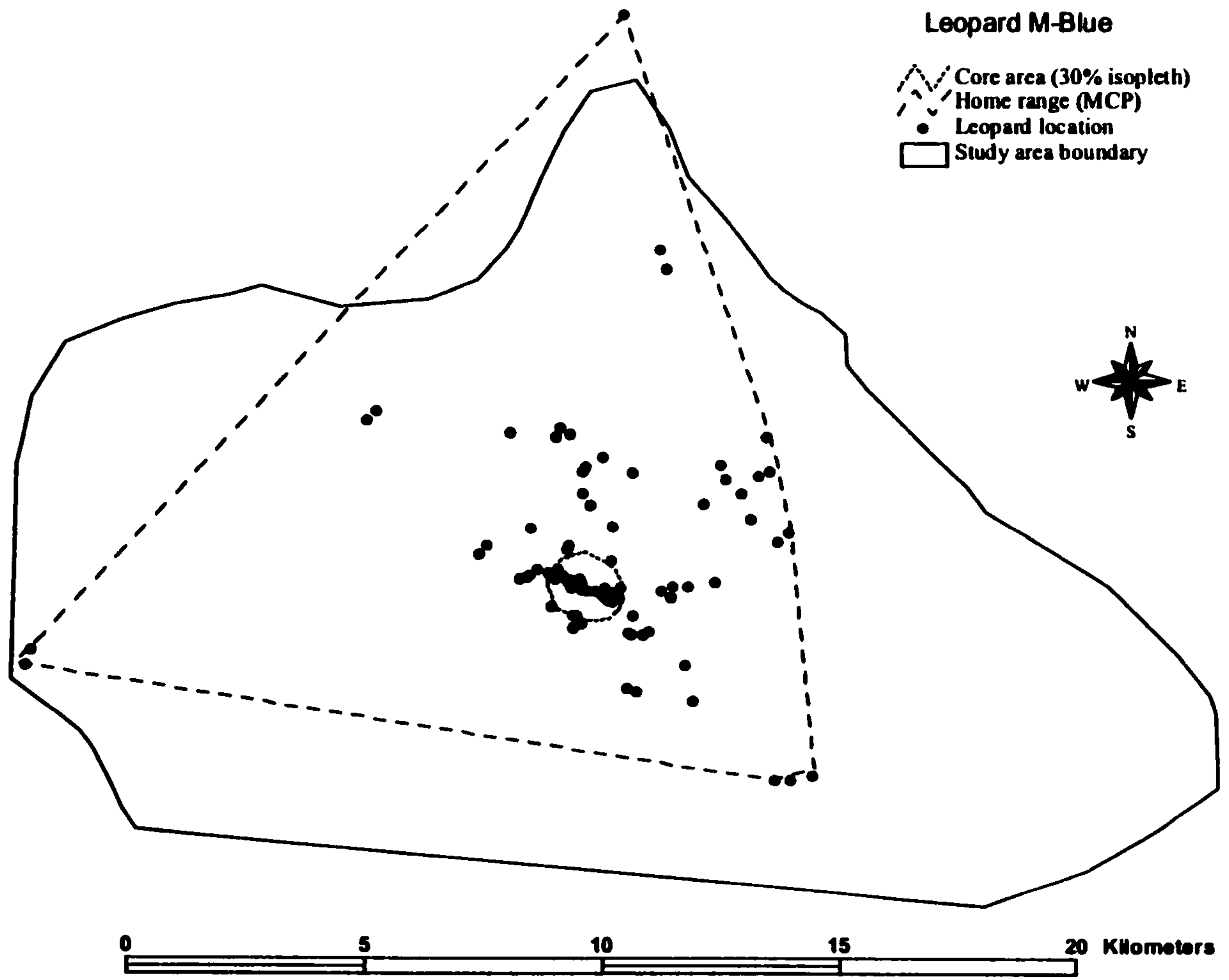


Figure 2-6. Home range (MCP) and core activity are (30% isopleth) for leopard M-Blue.

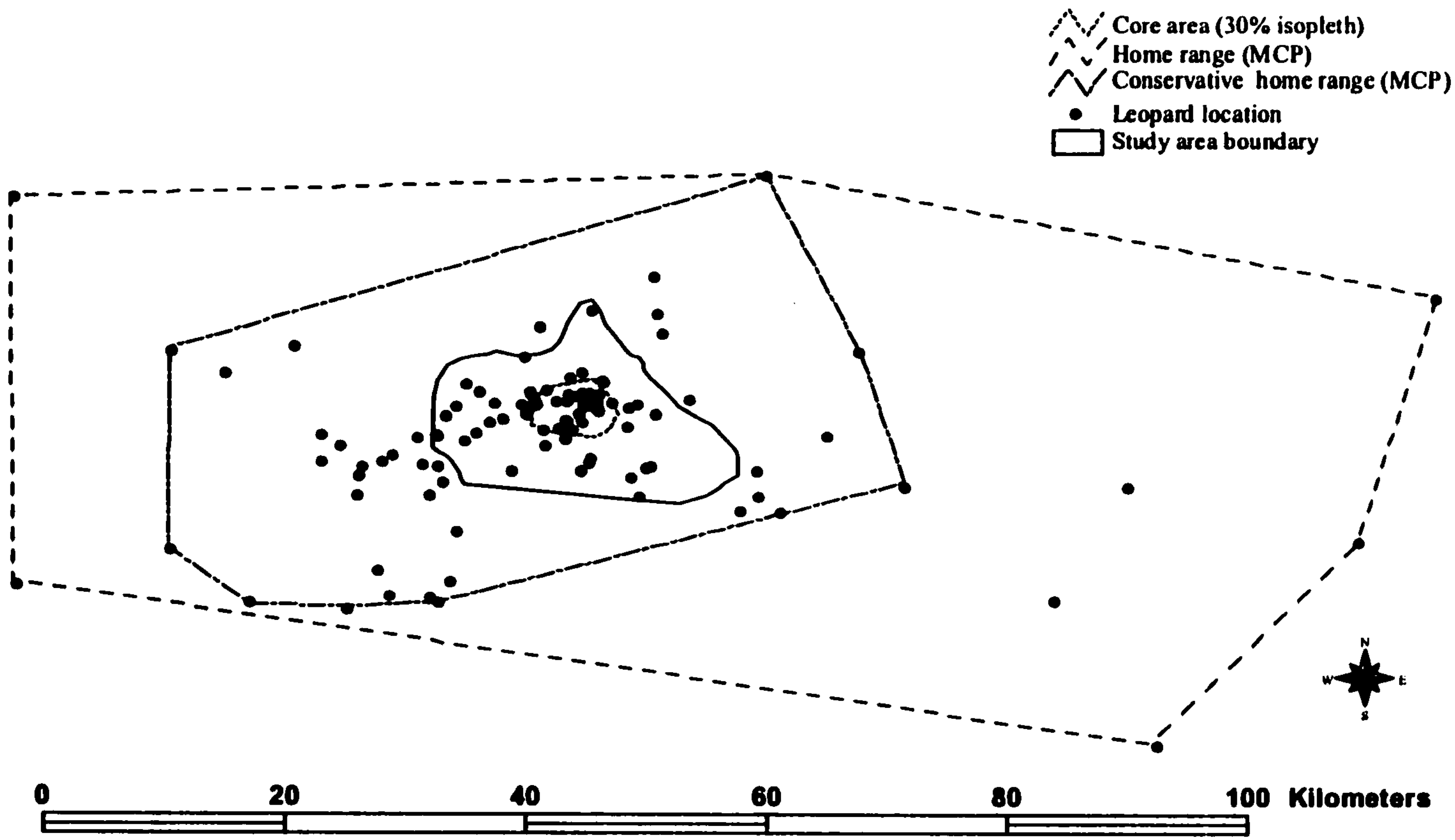


Figure 2-7. Home range (MCP) and core activity are (30% isopleth) for leopard F-Yellow.

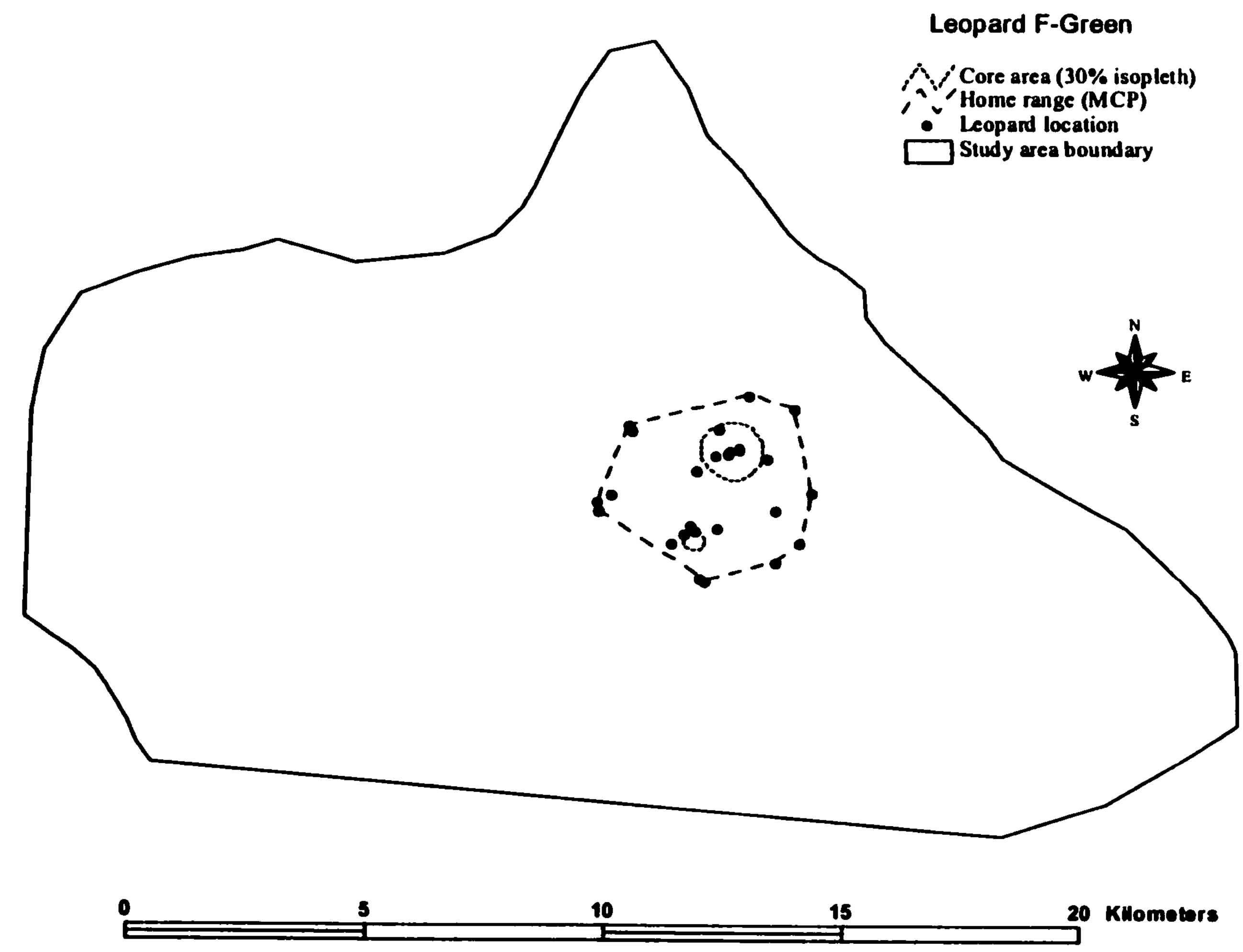


Figure 2-8. Home range (MCP) and core activity are (30% isopleth) for leopard F-Green.

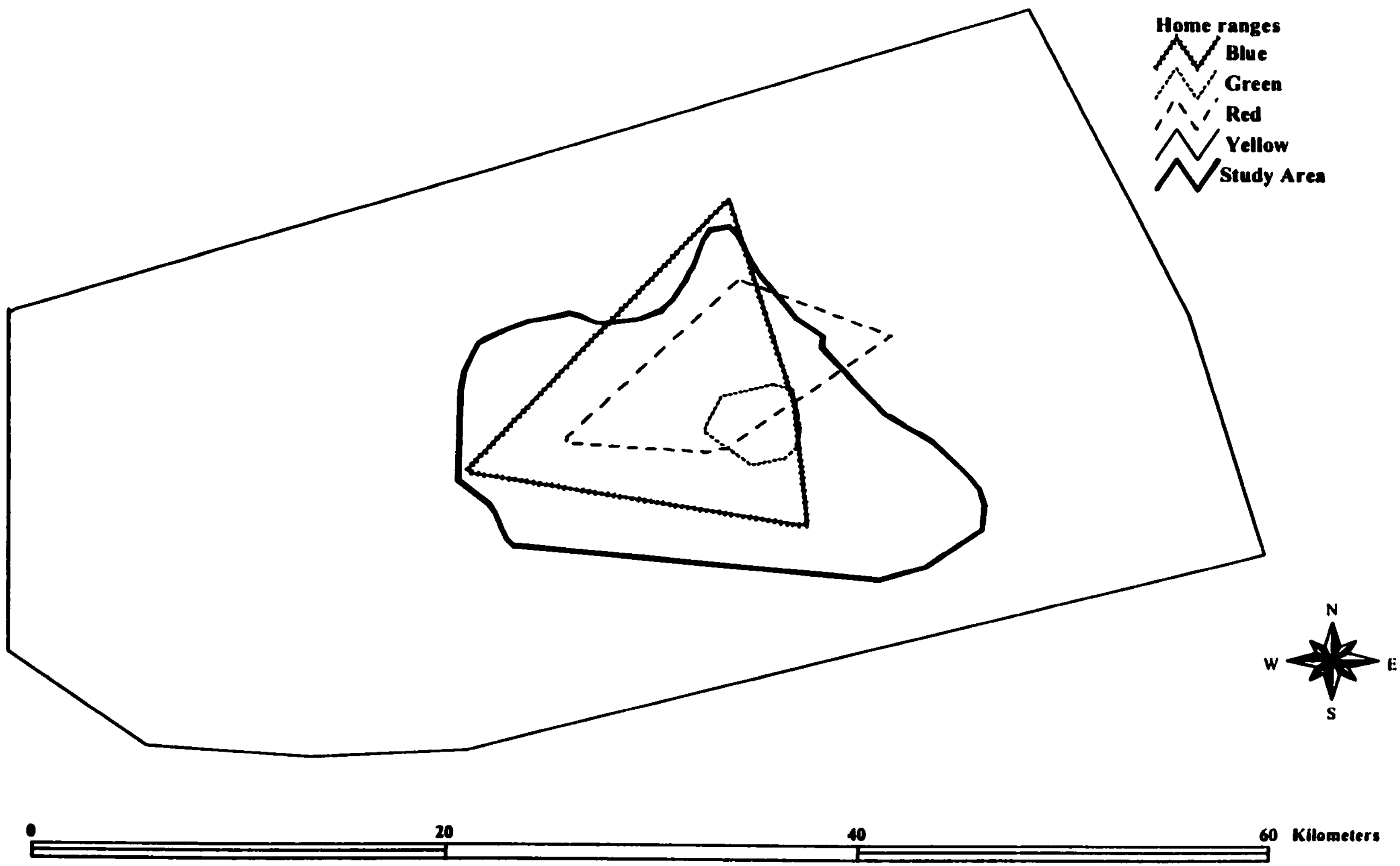


Figure 2-9. Home ranges of radio-collared snow leopards and study area boundary, Saksai River drainage, Gobi-Altai, Mongolia, 1994-97.

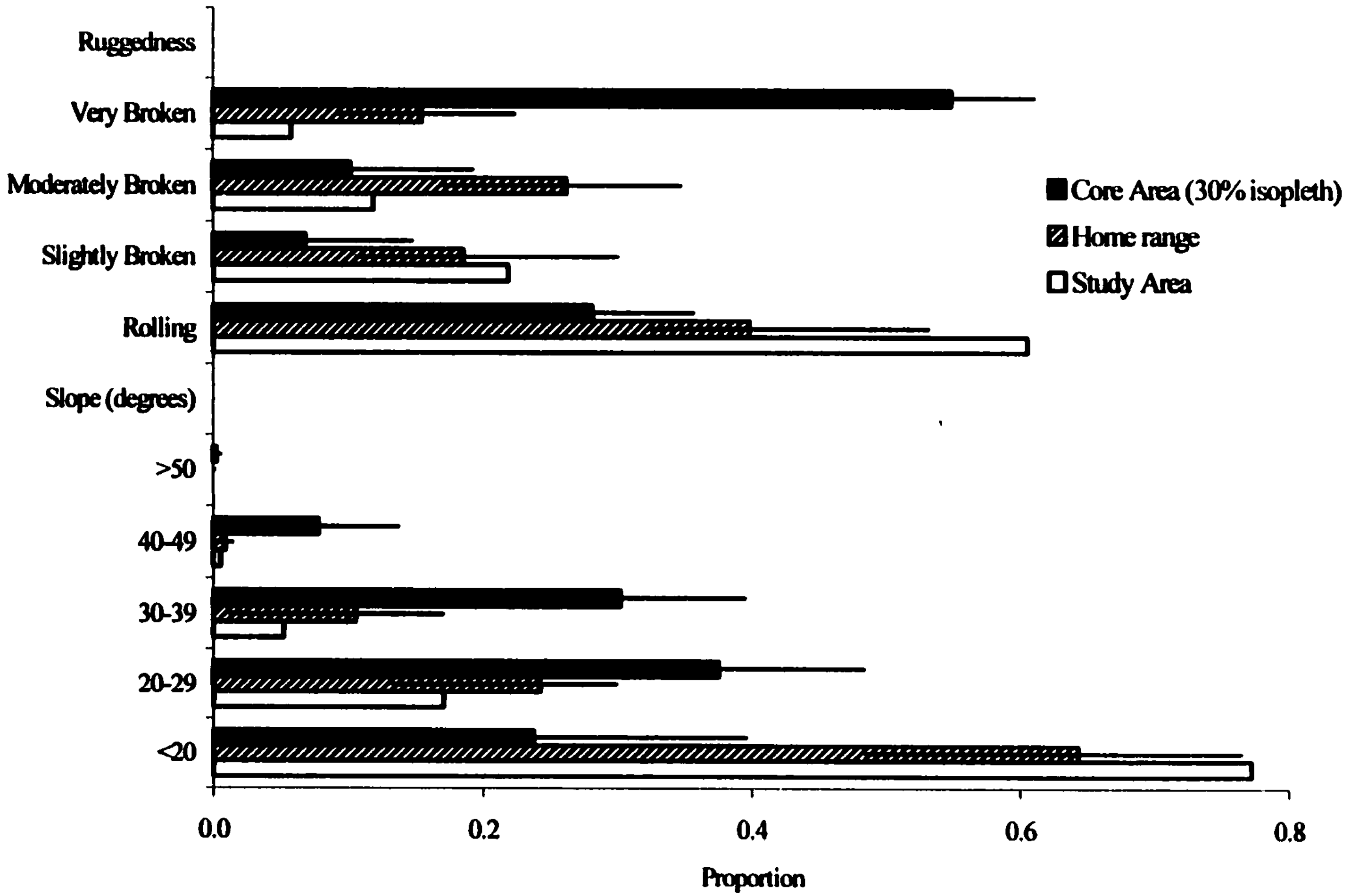


Figure 2-10. Proportional composition of the Saksai River study area, snow leopard home ranges, and core activity areas (30% isopleth) in terms of habitat ruggedness and slope.

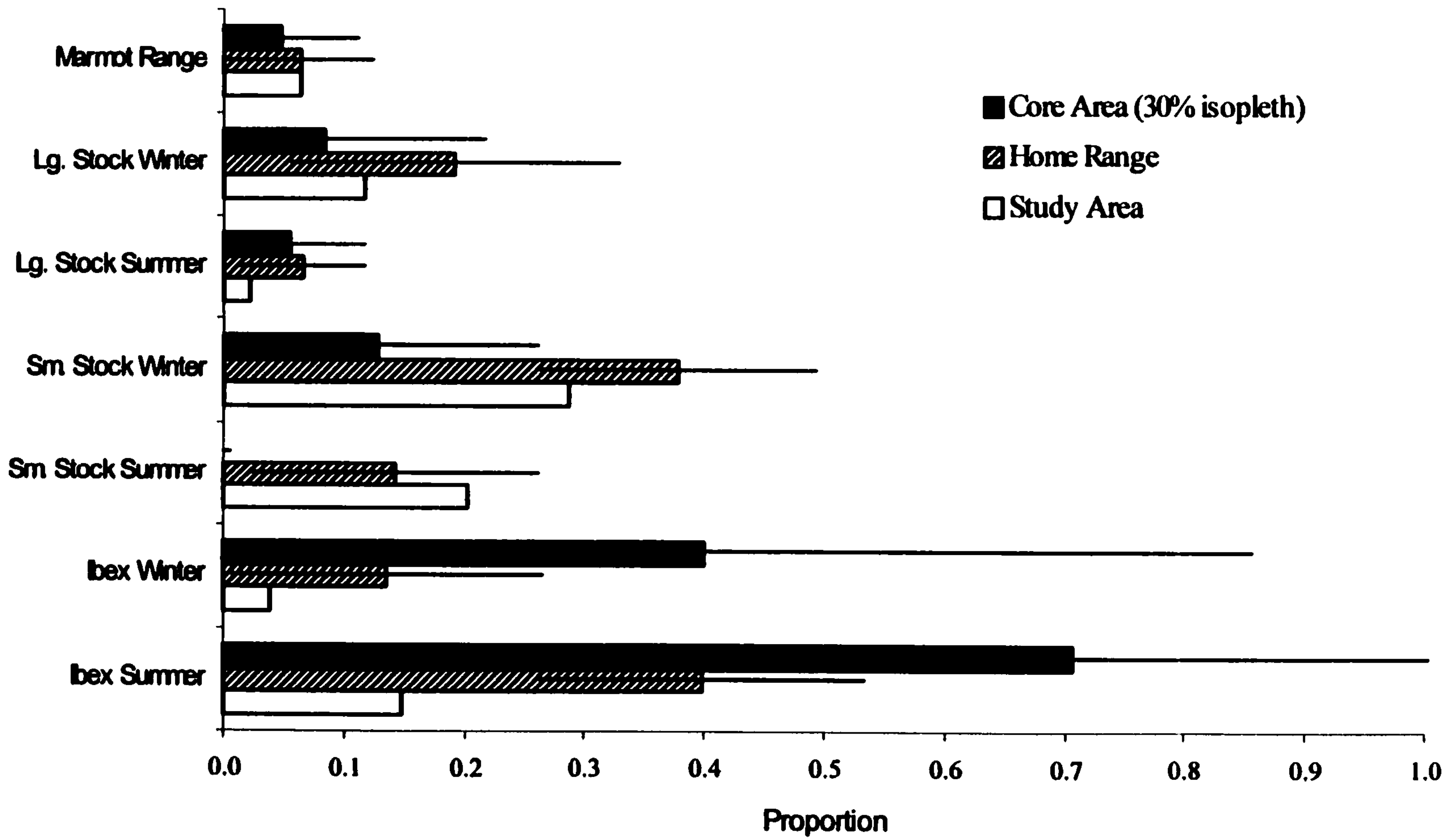


Figure 2-11. Proportional composition of the Saksai River study area, snow leopard home ranges, and core activity areas (30% isopleth) in terms of marmot range, and seasonal livestock and ibex range.

CHAPTER 3

A SNOW LEOPARD CONSERVATION PLAN FOR MONGOLIA

Species

Irbis, Snow leopard, *Uncia uncia.*

Legal Status in Mongolia

Listed in the Mongolian Red Book as Very Rare (corresponds to the *Endangered* category in the IUCN Red Data Book). No personal or commercial taking is allowed.

Legal Status Worldwide

Listed in the IUCN Red Data Book as Endangered, and on Appendix I of the Convention on International Trade in Endangered Species of Fauna and Flora (CITES) which include species considered threatened with extinction. The IUCN Species Survival Commission Cat Specialist Group assign the snow leopard a Global Vulnerability Ranking of Category 2 (highly vulnerable) and actively threatened due to hunting.

Distribution

The range of the snow leopard is restricted to the mountainous regions of Central Asia including the Altai, Tien Shan, Kun Lun, Pamir, Hindu Kush, Karakoram, and Himalaya ranges. It is known to occur in twelve countries, namely Afghanistan, Pakistan, India, Nepal, China, Bhutan, Mongolia, Russia, Tajikistan, Uzbekistan, Kazakhstan, and Kyrgyzstan, with occupied habitat of about 1.6 million km^2. Snow leopards most frequently occur at elevations between 2,000 and 5,500 m, in areas of steep and broken rocky slopes that support shrub, grass, or steppe vegetation. On the northern limits of their range in Mongolia and Russia they may use elevations as low as 600 m in hilly, and occasionally occur in forested habitat. Rangewide, population estimates vary from 4,500 to 7,500.

Snow leopards are widely distributed in the mountains of western Mongolia and occur in the Altai Mountains, the Khangai Mountains, the Hanhoohy Uul and Harkhyra ranges, and in isolated mountainous sections of the Trans-Altai Gobi. They are thought to occur in up to 10 aimags and 107 soms with a total range of about 100,000 km^2. Population estimates vary from about 800 to 1700 animals. Highest densities are thought to be in the South Gobi, Central Transaltai Gobi, and Northern Altai. Remnant populations occur in the Khangai and possibly Khovsgol, although no leopards have been sighted in the latter since the 1960s.

Principal Threats

Poaching

Despite being afforded complete protection in Mongolia, illegal hunting is a problem of unknown magnitude. Although the illegal kill has been estimated at more than 100 animals per year, there is no clear method for calculating more than a minimum estimate. There are two primary incentives for poaching: 1) for trade, and 2) retribution for livestock depredation.

Poaching for commercial reasons may well be on the rise as trade with China increases, particularly at border stations where law enforcement is more difficult. The value of snow leopard bones on the Asian medicinal market will likely continue to make this an attractive activity for poachers and traders. An increasing demand for pelts in Eastern Europe may also be driving up prices up for snow leopard hides in Russia.

Killing of snow leopards by herders who have experienced livestock losses is difficult to quantify and it is likely that only a small fraction of kills are made known to authorities. Snow leopards are more likely to kill horses, yaks, and camels than small livestock because large stock is often allowed to roam freely in areas where leopards occur. The economic impact of snow leopard depredation can thus be substantial to an individual herder, despite the fact that overall, herders lose a very small percentage of their herds to the cat. Snow leopards are not easily hunted in the wild, but can be relatively easy to shoot or trap when they are on livestock kills. Because most herding in snow leopard range is conducted far from towns, kills of the cat are rarely reported to or discovered by authorities.

Habitat Fragmentation

Snow leopards exhibit an extremely patchy and fragmented distribution which may reduce genetic interchange and thus diminish long-term population viability. Within Mongolia this is particularly true with isolated populations in the Khangai, Great Gobi, South Gobi, and other sites. The potential to further fragment snow leopard habitat exists as herding in remote areas increases.

Wild Prey Loss

Competition with domestic stock and poaching are causes for declines in ibex (*Capra ibex*) and argali (*Ovis ammon*), the two primary wild prey species for snow leopards. Marmots are also an important prey item that are also known to be decreasing in several areas due to excessive hunting. Cat numbers will likely fall as wild prey declines and the ability of the area to support snow leopards is reduced. Loss of wild prey can also lead to increased depredation on domestic livestock and more human- snow leopard conflicts.

Disease

Reports of a mange-like skin disease come from the western aimags where some snow leopards have apparently died from the affliction.

<u>Conservation Goals</u>

Snow leopards are a symbol of wilderness and much that is great about Mongolia. They are worthy of conserving for this and future generations. To maintain healthy and sustainable populations of snow leopards in Mongolia it is necessary to:

- Ensure that adequate and representative areas are placed into protected status across the range of snow leopards in Mongolia.
- Enact and enforce national laws, statutes and regulations to protect snow leopards and their prey, and their habitat from degradation.
- Abide by and enforce pertinent international conservation laws and conventions to which Mongolia is a signatory.
- Establish and maintain a snow leopard population monitoring program and database.
- Educate citizens and visitors about conservation issues, and when appropriate, emphasize concerns regarding snow leopards and other endangered species.
- Educate the public and government on the cultural, ecological, and financial values to the country of a healthy snow leopard population.
- Strive to reduce snow leopard-human conflicts, particularly in protected areas and other areas where snow leopards are abundant.

Management Authority

The Mongolian Law on Environmental Protection delegates authority for management of wildlife to the State Administrative Central Organization in charge of nature and environment, which is the Ministry for Nature and Environment (MNE). Pursuant to the Constitution of Mongolia all wildlife is the property of the State.

Relevant Mongolian Laws

The Law on Special Protected Areas, 15 November 1994

The Law on Environmental Protection, 30 March 1995

The Hunting Law, 10 April 1995

Proposed Law on Fauna, 1999

Proposed Revised Hunting Law, 1999

Stakeholders

National

Ministry for Nature and Environment (MNE)

The Nature Conservation Agency (NCA)

The Endangered Species Commission (ESC)

Mongolian Association for Nature and Environment (MACNE)

The Biological Institute of the Mongolian Academy of Science

The Biological Faculty of the Mongolian State University

World Wide Fund for Nature – Mongolia (WWF)

Mongol-An Hunting Organization

International

David Shepherd Conservation Foundation, UK (DSCF)

International Snow Leopard Trust, USA (ISLT)

Wildlife Conservation Society, USA (WCS)

German Technical Cooperation (GTZ) - Mongolia

Peace Corps – Mongolia (PC)

Current Status and Actions to be Taken

Legal Issues

Situation - It is currently illegal to hunt, trap, or sell the hide, fur or any other part of a snow leopard (Law on Hunting, Article 4). However, there is no legal restriction on purchasing, owning or possessing snow leopard parts.

Action (1) – MNE, with input from interested Mongolian and international agencies and NGOs, will seek to amend existing law, or enact laws or statutes that make purchase of snow leopard parts illegal, and ownership of snow leopard parts from animals killed after the enactment of the current hunting law (1994) illegal. The law should require that all legally owned snow leopard hides and skulls be registered with the State.

Situation – There is no method to monitor or register existing legally owned snow leopard parts.

Action (2) – MNE, or an entity designated by MNE, will undertake to register all hides and skulls currently owned by government, economic entities, or individuals. MNE will advertise the pending criminalization of owning unregistered snow leopard parts and offer an amnesty period (6 months) for all existing parts to be registered with the government. Each hide or skull will be presented by the owner to the registration authority who will record information on source, method of procurement, size and description of the hide or skull, and will attach a permanent locking numbered tag to the specimen. A small sample of skin or hair may be collected at the time of registration for future genetic studies. Individual owners will be informed in writing at the time of registration that it is illegal to sell or trade the registered part.

Any unregistered hides or skulls encountered by law enforcement agents after the end of the amnesty period will be confiscated and the possessors prosecuted.

Situation – The current penalties are inadequate to deter violations of the hunting law. The Animal Fund values a snow leopard at 80,000 Tugrogs (about $ 75 USD) and the fine for illegal kill would be double that, or about $150 USD. Hides can easily bring $300 in Mongolia and perhaps 10 times that outside. Hence, there is very little deterrent in this fee structure.

Action (3) – The basic fine schedule is included in the Hunting Law itself and cannot be amended. However, the penalty for illegal take of an animal includes both the basic fine and compensation to the

Animal Fund. Compensation to the Fund is based on the current value of the animal to the State. The value will be reviewed annually and is sufficiently higher than the market value of the animal parts to deter poaching. Market value can be determined through consultation with international entities who monitor trade in wildlife, such as TRAFFIC.

Situation – Detection of snow leopard poaching and violations of other environmental laws is difficult in remote areas, particularly outside of Protected Areas. Augmentation and training of rangers and nature wardens is a focus of other programs and beyond the scope of this plan.

Action (4) – The existence of the Whistle-blower provision of the Hunting Law will be well advertised. Article 28 of the Hunting Law allows for citizens who report violations to be rewarded with 15% of the imposed fines. There is not now a provision for anonymity of informants. The legal assurance of granting anonymity must be explored.

Situation – Snow leopard hides and bones are valuable on Asian and European black markets. Although Mongolia acceded to CITES in 1994, and customs agents and border guards have received training on enforcement, illegal trade in snow leopard parts occurs and can be expected to increase. Information on the numbers of confiscated hides is not easily obtained and makes monitoring of the problem difficult.

Action (5) – Border trade will be monitored by sporadic and unannounced visits from MNE nature guards. The practicality of using undercover MNE agents should be considered. An agreement will be reached with Customs officials to supply MNE with information on all wildlife trade interceptions promptly (quarterly?). Snow leopard trade data should be provided to MACNE for inclusion in the database (see SLIMS database below). TRAFFIC should be invited to make a survey to determine the level and methods of illegal trade.

Situation – Many Mongolians and visitors remain unaware of national and international laws regulating the sale and export of snow leopard parts. Hides are routinely offered for sale to tourists in Ulaanbaatar as well as in the countryside and an unknown number of hides illegally leave the country each year. An informational multi-media campaign aimed at tourists and Mongolian citizens and focusing on illegal wildlife trade and featuring the snow leopard was initiated in 1998 by WWF, WCS, and DSCF.

Action (6) - Continue and expand on the informational campaign for both visitors and nationals. Establish and publicize through the media campaign a "Hotline" telephone number in Ulaanbaatar for reporting illegal wildlife trade activity.

Monitoring of Snow Leopard Distribution and Abundance

Situation – The status of snow leopard population levels in Mongolia must be monitored over time and between areas to detect changes in numbers and to determine the effectiveness of conservation efforts. The Law on Environmental Protection established the Environmental Information Databank which requires annual input on observations, measurements and research on wildlife. Meeting scientific needs and monitoring requirements for snow leopards is difficult due to their secretive habits and remote habitat. Monitoring snow leopards numbers requires training and use of standardized techniques. The International Snow Leopard Trust (ISLT) has developed the Snow Leopard Information Management System (SLIMS) which includes field techniques and data storage procedures for snow leopard surveys. Many Mongolian biologists have been trained in the SLIMS techniques during two seminars and field training sessions in 1994 and 1998. SLIMS is now being used in most protected areas where snow leopards occur to monitor population trends of leopards and large prey (ibex and argali). SLIMS training in Mongolia has been facilitated by MNE, UNDP, MACNE, WWF, ISLT and WCS. At the International Snow Leopard Symposium in Xining, China in 1992 MACNE, with the endorsement of MNE, agreed to be Mongolia's cooperating entity and to host the SLIMS database in Mongolia. ISLT currently funds the upkeep of the database, and the salary and field costs of a Mongolian Snow Leopard Conservationist who works directly for MACNE.

Action (6) – Establish a Snow Leopard Expert Working Group made up of knowledgeable individuals from various agencies and academies to advise MNE and others on conservation issues.

Action (7) – To avoid expensive and unnecessary replication, and to ensure comparable results, the MACNE/ISLT database should be recognized as the primary snow leopard data repository for Mongolia by concerned parties. Wherever possible, snow leopard surveys should follow the SLIMS techniques and copies of the results provided to MACNE and their Snow Leopard Conservationist. MACNE should provide consultation in SLIMS techniques and provide standardized dataforms for use. This process should be facilitated by MACNE's Snow Leopard Conservationist with technical input from ISLT (which also agrees to fund this position for an initial period when it will be assumed by MACNE or another appropriate Mongolian NGO). MACNE must also provide to all participating agencies, organizations, and individuals an annual report of survey accomplishments and findings. The SLIMS results should also be entered into the Mongolian Environmental Information Databank at the national, aimag, and som levels.

Situation – The distribution of snow leopards has been described by various researchers in recent years. An accurate map of current range and a schedule of surveys to monitor changes in presence/absence and relative density is needed.

Action (8) – A range map will be produced after consultation of snow leopard experts. MACNE, MNE, and Academy of Science biologists will develop a cooperative monitoring program and schedule of snow leopard surveys.

Situation - Many areas of high density snow leopard populations and important dispersal and travel corridors occur outside of the existing Protected Area System. Degradation of range, particularly important dispersal and travel corridors, may result in further fragmentation of Mongolia's snow leopard population leading to small isolated populations and reduced viability.

Action (9) - Results of snow leopard and prey surveys should be used to identify important habitats that are worthy of consideration for reserve status. MNE should be made aware of these sites for consideration as protected areas. For various reasons, not all such areas will warrant reserve designation, but should be designated by MNE as Important Snow Leopard Range and managed accordingly (see Tiered Management System below).

Situation – Large prey species, including ibex and argali, are the subject of surveys conducted by various agencies. As with snow leopard surveys, an effort should be made to avoid duplication of effort yet meet the needs of each agency's conservation programs.

Action (10) – A agreement will be sought between agencies and organizations active in wildlife monitoring on standard methods for ungulate surveys, and a schedule for conducting them. The agreement will stipulate prompt exchange and sharing of new and existing data. Managers responsible for ungulate conservation or hunting must be involved and appraised of findings, and encouraged to take remedial actions when indicated.

Situation – Population monitoring for both snow leopards and their prey are designed to provide area-specific population trend data. Prompt reporting of downward trends to the management authority (MNE) is required of the monitoring entities.

Action (11) - A standardized reporting format will be established and distributed to all relevant agencies. A centralized repository will be designated within the Ministry of Environment.

Situation – Mongolia is bordered by two other states containing snow leopards, Russia and China. The NW corner of Mongolia is situated in what may be an important travel corridor providing linkages to Chinese, Russian, and Kazakh snow leopard populations. Several areas of important snow leopard habitat in Mongolia are near international borders and the potential for trans-boundary protected areas exists.

Action (12) – Establish formal links with Chinese and Russian agencies, land managers and snow leopard biologists in border areas to facilitate information exchanges and cooperative management ideas.

Situation – The potential exists for disease related reductions in snow leopard numbers and some cats are known to have died from a skin disease in recent years.

Action (13) – An effort will be made to secure tissue samples from any snow leopard thought to have died from, or be infected by disease. Methodology for collection, storage, transport and analyses will be established and made known to rangers and nature protection officers country-wide. Veterinary staff will be consulted once disease has been confirmed and identified to determine what if any measures should be taken to reduce spread of the disease. Sub-samples of all tissues collected should be archived with an appropriate international repository, such as the U.S. National Cancer Institute's Laboratory of Genomic Diversity.

People and Snow Leopards

Situation – Currently 20-25% of snow leopard range in Mongolia is under some form of protected status. However, in several protected areas the various restricted use zones (Pristine, Conservation, Limited Use, Travel and Tourism Zones) have yet to be fully defined and regulations on use enforced. Hence, people and livestock remain a component of even Strict Protected Areas and conflicts with predators, including snow leopards, occur. Herders face economic hardship due to depredation.

Action (14) – Establish a Tiered Management System within snow leopard range that encourages people to voluntarily limit their use of certain areas. Such a system could have three Levels:

Level 1 - Provides complete protection to snow leopards. No leopards would be removed, including cats known to depredate on livestock. No economic compensation or incentives would be provided to herders who lose livestock to predators within these areas. This Level would include the Pristine and Conservation Zones of all Strict Protected Areas and the Special Zone of National Conservation Parks (Table 3-2).

Level 2 – Provides complete protection to snow leopards. No leopards would be removed, including cats known to depredate on livestock. Herders who legally use this area must agree to certain grazing conditions and tolerate losses to snow leopards in exchange for establishment of Irbis Enterprises, an economic incentive program (see page 81,) or compensation for losses. This Level would include the Limited Use and Buffer Zones of Strict Protected Areas (when permits have been granted), all National Conservation Park lands except for their Special Zone, and Nature Reserves classified as Ecological or Biological Reserves. It would also include lands that fall outside of protected areas but have been designated by MNE as Important Snow Leopard Habitat or snow leopard travel corridors. Identification of such habitat would come from SLIMS survey results and other research. (Note – although livestock husbandry is allowed by law in all areas listed in Level 2 lands, it would be undertaken at the herder's own risk).

Level 3 – Provides for the removal of depredating snow leopards by government agents after confirmation of a problem. This Level would include all lands that have not been identified as Important Snow Leopard Habitat or travel corridors by MNE and that fall outside of reserves, or within Paleontological or Geological Reserves, and Natural Monuments.

Situation – Snow leopards take more horse, yak, and camels than other domestic stock because large stock tends to be grazed in mountainous areas without protection by herders. Small stock is taken less often but occasionally losses can be substantial when leopards enter corrals at night.

Action (15) – Research will be conducted on alternative livestock protection methods and information disseminated to herders through a snow leopard conservation education program (see next item). Information exchange will be sought with other Central Asian states where depredation is also a problem to determine best practices.

Situation – Various entities have produced environmental education materials that pertain directly to snow leopard conservation and initiated their use in Mongolia including ISLT, the WCS, WWF, UNDP, GTZ and others.

Action (16) – A review of available materials and programs will be undertaken by a single agency and a comprehensive snow leopard conservation education program developed and made available, along with training in its use, to educators in snow leopard range soms and aimags. Educational materials should be focused on everyone from school children to adults. Informational seminars on improved herding practices that reduce likelihood of depredation by snow leopards and wolves should be included.

Assessment of Progress

Progress toward goals of this Plan will be monitored one year after implementation by a team representing MNE, MACNE, and WWF. A report on accomplishments and shortcomings will be provided to all stakeholders. The team will evaluate the need to reconvene a stakeholders meeting to revise and update the plan, and will decide on a timeframe for further progress monitoring and reports.

Irbis Enterprises Herder Incentive Program

IRBIS ENTERPRISES is a coalition of Mongolian and international nature conservation organizations and Protected Areas. The aim of IRBIS ENTERPRISES is to provide alternative income sources to herders who live in snow leopard habitat. The income source is hand-crafted items produced by the herders and made primarily from livestock products such as sheep, camel and cashmere wool, leather, sheepskin and felt. The finished goods are marketed to tourists in the capital, Ulaanbaatar and abroad through fair trade outlets. The majority of the sales price is returned to the producers and a percentage is placed into a Conservation Fund. The proceeds from the fund can be used for such needs as improving water sources in the buffer zone, an effort that can benefit both herders and wildlife.

Summary of benefits:

- Links income generation to wildlife friendly herding practices.
- Increased income for herders.
- Increased awareness among herders of the value of the protected area.

- Potential for generating a fund for conservation projects.
- Spreads information about Mongolian wildlife issues to an international tourist public.

To protect snow leopards and their mountain ecosystem grazing limitations must be imposed, predation by leopards on livestock must be reduced or tolerated, and poaching of leopards and their prey must stop. For herders who have used those areas for generations, such limitations cause resentment and a lack of cooperation. "IRBIS ENTERPRISES" aims to overcome this by offering herders an incentive to play a positive role in the conservation of snow leopards.

The project was initiated in response to herder concerns about prices for their raw livestock products (sheep, cashmere, camel wool and hides). Distance from markets make herders dependent on passing traders. This project offers the opportunity for herders to make finished products which adds enormously to the value of the raw materials. Herders work under contracts that specify no poaching of snow leopards, or their main prey species, tolerance of stock losses to predation by snow leopards, avoidance of critical lamming and kidding sites of wild ungulates, and reduction or stabilization of herd sizes.

An annual bonus of 20% is payable if all contract conditions have been met, and forms the most immediate link between income generation and wildlife conservation. The entire community will lose the bonus if one herder illegally kills a snow leopard, ibex or argali, thus individual incentive is enhanced by peer pressure. Individual producers will lose bonuses for other violations of wildlife laws or grazing regulations in the Protected Area Buffer Zones. The project also offers less tangible but important conservation linkages such as fostering a positive perception of the Protected Area, greater appreciation of the international interest in local wildlife, and increased awareness of wildlife issues in general.

More than 100 households in Gobi-Altai and Uvs participated in the first year of the project and nearly 2,500,000 Tugrogs ($2,500 USD) was distributed. Expansion to several new areas in the south Gobi and around the Great Gobi Strictly Protected Area are planned for 2000.

The project has received interest and praise within Mongolia and internationally. It has been the subject of newspaper and radio reports within Mongolia. An aspect of the program that separates Irbis Enterprises from other programs that deal with impacts of predators on livestock is the lack of direct compensation for losses. Frequently, herders have been compensated when they experience losses to predators. This tends to reward poor stewardship of stock. Irbis Enterprises offers economic incentives to tolerate such losses, but offers no compensation that may lead to relaxed herding practices and ultimately more livestock losses.

Table 3-1. Time schedule and assignment of responsibilities.

Action	To be implemented by:	In cooperation with	Complete by:
1a. Review laws on sale and possession of snow leopard parts	MNE	WWF, MACNE	March 2000
b. Propose revisions or new laws/statutes	MNE	WWF, MACNE	June 2000
2a. Advertise pending required registration of hides and skulls	MNE	WWF, MACNE	June 2000
b. Conduct pilot registration program of snow leopards in Uvs	WWF		June 2000
c. Conduct countrywide registration of hides and skulls	MNE	WWF, MACNE	6 mo. after law enacted
3a. Review Animal Fund valuation schedule	MACNE, MNE	DSCF, WWF	March 2000
b. Propose update of Animal Fund valuation schedule	MNE		June 2000
4a. Review Whistle-blower provision of hunting law for anonymity.	MNE		February 2000
b. Advertise Whistle-blower provision.	WWF, MACNE	DSCF	Ongoing
5a. Reach agreement with Customs agency on reporting trade data.	MNE		February 2000
b. Initiate border trade monitoring spot checks	MNE	MACNE, ISLT, DSCF	March 2000 onward
c. Provide trade data to SLIMS database manager	MNE	MACNE	February 2000 onward
6a. Establish a snow leopard expert working group.	Acad. Sciences		March 2000
7a. Expand and continue wildlife trade informational campaign.	WWF	DSCF, MACNE	Ongoing
b. Establish informant "hotline" for reporting illegal trade activity	WWF	TRAFFIC	April 2000
8a. Recognition of the SLIMS database	All Stakeholders		November 1999
b. Input to the database	All Stakeholders		January 2000 onward
c. Provide data-forms and consultation on use	MACNE	ISLT	January 2000 onward
d. Report to all stakeholders and national database managers	MACNE	ISLT	June 2000 and annually
9a. Produce updated snow leopard range map	WWF	MACNE, Acad. Science	December 1999
b. Develop Cooperative monitoring program and survey schedule	MACNE	Acad. Sc., WWF, ISLT	April 2000

Table 3-1. Time Schedule and Assignment of Responsibilities (continued):

Action	To be implemented by:	In cooperation with	Complete by:
10a. Identify areas to be added to protected area system	MNE	All Stakeholders	Ongoing
b. Establish Important Snow Leopard Habitat Statute/Regulation	MNE		July 2000
c. Identify and designate Import. Snow Leopard Habitat/Corridors	MNE	All Stakeholders	Sept. 2000 onward
11a. Establish standard method and schedule for ungulate surveys	Acad. Science, MACNE	Interested Stakeholders	April 2000
b. Establish a centralized report repository or entity within MNE	MNE		April 2000
12a. Establish formal links with Chinese and Russian counterparts	MNE	ISLT	June 2000
13a. Determine methods for collection of tissues for disease study	Acad. of Science		April 2000
b. Inform field staff (biologists, rangers, etc) of methods	Acad. of Science	MACNE	May 2000
c. Follow up with veterinary consultation when samples gathered	Acad. of Science		When available
14a. Elaborate a Tiered management system for snow leopards	MNE, ISLT, MACNE	WWF, MACNE, DSCF	September 2000
b. Propose enabling legislation/statute to implement System	MNE	DSCF, WWF	October 2000
c. Implement Tiered Management System	MNE		November 2000
d. Initiate economic incentive programs in Level 2 areas	WWF, DSCF, ISLT	MACNE	Phased from April 2000
15a. Research alternate livestock protection methods	MACNE	WWF, ISLT, DSCF	July 2000
b. Initiate information exchange with Asian grazing communities	ISLT	MACNE, WWF	June 2000 onward
16a. Review snow leopard and conservation education materials	Peace Corp, DSCF	Interested Stakeholders	April 2000
Draft of education program to stakeholders for review	MACNE	"	May 2000
Make education program and training available to schools	PC, DSCF, WWF	"	July 2000
Progress Review	MNE, MACNE, WWF	DSCF, ISLT, WCS	December 2000

Table 3-2. Tiered Snow Leopard Management System for various Mongolia land categories within snow leopard range.

Land Category	Management Status		
	Level 1	Level 2	Level 3
Strict Protected Area			
Pristine Zone	X		
Conservation Zone	X		
Limited Use Zone[a]		X	
Buffer Zone		X	
National Conservation Park			
Special Zone	X		
Travel and Tourism Zone		X	
Limited Use Zone		X	
Buffer Zone		X	
Nature Reserves			
Ecological or Biological Reserves		X	
Paleontological or Geological Reserves[b]			X
Monuments			
Natural Monuments[b]			X
Historic or Cultural Monument[b]			X
Important Snow Leopard Habitat and Corridors[c]		X	
All Other Snow Leopard Range			X

[a] When livestock grazing is legally allowed by permit.

[b] Unless identified as Important Snow Leopard Habitat or Corridors

[c] As designated by MNE after identification by research and surveys.

CHAPTER 4

STATUS AND CONSERVATION OF THE WILD BACTRIAN CAMEL IN MONGOLIA

Despite the occurrence of domestic bactrian camels (*Camelus bactrianus*) across much of central Asia, the continued existence of their likely wild progenitor (*C. b. ferus*) was not revealed to science until the late 1870s when Prejevalski (1879:88-97) visited the Lop Nur region of China. By the end of the 1800s several expeditions (Groum-Grzymailo 1886, Littledale 1894:446-448, Hedin 1898:192-197, Koslov 1899) had confirmed the finding and added knowledge of the camel's biology, habits, and range. The ensuing decades saw little study of the camel except for the first brief descriptions of its occurrence and range in Mongolia (Ladygin 1900, Symukov 1937). More detailed studies came in the 1940s when early Joint Russian-Mongolian expeditions traveled to the Gobi (Bannikov 1945). Hunted for its meat and exceedingly shy of human contact, their range has been dramatically reduced since their discovery (Bannikov 1976, Tolgat and Schaller 1992, Hare 1997). Today the world's remaining wild bactrian camels persist as a fragmented remnant population in the Taklamakan Deserts of China and the western Gobi desert of Mongolia .

The plight of the camel is well recognized and they are protected in both countries, and afforded Endangered status by the IUCN. Half or more of the modern day population occurs in the Transaltai-Gobi region of southwestern Mongolia (Hare 1997) where camel range falls completely within sector "A" of Great Gobi Strictly Protected Area (GGSPA). Established in 1976 to reflect then known range of the camel, the reserve encompasses 44,190 km^2 and is the largest protected area in Mongolia (Anon. 1988). By Mongolian law, all human activity except research is precluded in the core areas, and only limited uses such as national border patrol are allowed elsewhere in the reserve. There are no human residents except the limited military staff at two stations near the Chinese border. The Great Gobi was included in the UNESCO Biosphere Reserve system in 1991. In addition to camels, GGSPA provides protection to several other species of large mammals listed in the Mongolian Red Book (Shiirevdamba et al., 1997) including snow leopard (*Uncia uncia*), argali (*Ovis ammon*), and the endemic Gobi brown bear (*Ursus arctos)*.

The environment of the Gobi is extremely harsh with temperatures ranging from –42° to 40° C and annual precipitation normally below 100 mm, most of which falls in July and August and can be torrential (Dash et al. 1977, Zhirnov and Ilyinsky 1986:16). Snow is infrequent and quickly sublimated. Not a sand desert, the Gobi is characterized by a stone rubble, or "hammada" surface, glazed by frequent winds and baking sun (Bannikov 1976). Much of the Gobi is sloping plains and hillocks, broken by several massifs, notably the Edringen Nuruu along the northern border, and the Atas-Ingis and Tsagaan Bogd ranges in the south portion of the reserve. The mountains, foothills and plains are interwoven by a network of dry water courses or "sairs" which can be scoured by flash floods during the late summer rains. Surface water is scarce with perhaps as few as 35 permanent oases across the reserve (Bannikov 1976), many associated with the aforementioned massifs.

Vegetation is sparse across much of the reserve with stunted stands of xerophytic and hyperxerophitic shrubs and grasses dominating (Zhirnov and Ilyinsky 1986:24-33) The primary desert associations are composed of saxaul (*Haloxylon ammondendron*), anabasis (*Anabasis brevifolia*) ephedra (*Ephedra przewalskii*), salsola (*Salsola arbuscula*) and reaumaria (*Reaumuria songarica*). In areas of permanent water, plant communities include riparian scrub forest and mesophytic grass meadows of tamarisk (*Tamarix ramosissima*), poplar (*Populus diversifolia*), reed grass (*Phragmites communis*) and sedges (*Carex* spp). Associations of winter fat (*Eurotia ceratoides*), bean caper (*Zygophyllum xanthoxylon*) and nitria (*Nitraria sphaerocarpa*) are also seen. Large areas support no plant cover at all.

Since the 1940s the status of the wild camel in Mongolia has been the object of a number of studies and resulted in as many estimates of population size: 300 in1943 (Bannikov 1976), 400-600 in1960 (Tsevegmid 1970), 900 in 1974 (Bannikov 1976), 400-700 in the 1970s (Dash et al. 1977), 500-800 in 1980-81 (Zhirnov and Ilyinsky 1986:55), and 500-600 in the late 1980s (Tolgat and Schaller 1992). Prior to 1980 all surveys were accomplished by ground vehicle or camel-back. From 1981 through 1989 annual aerial counts augmented ground transects. Surveys were extensive, often exceeding 5.000 km per year by ground vehicle, and 1,500 km by air (Tolgat and Schaller 1992). No aerial counts were made again until 1997 when Reading et al. (1999) surveyed the entirety of the GGSPA and estimated a population of 1985 +/- 802 camels. The magnitude of difference in population estimates between that survey and those of the 1980s is of particular interest, given similar sampling intensity and raw counts. Reading et al. attribute this to their use of a statistical model that considers sightability at various distances. However, they urge caution, in that basic model assumptions may have been violated. A critical comparison of the two survey's differences is hampered by lack of detail regarding statistical techniques employed by Zhirnov and Ilyinsky.

Population estimates have varied, but there is general agreement that long-term trends since the early 1980s are downward and recruitment does not appear adequate to sustain camels in Mongolia (Tolgat and Schaller 1992). Camels have a low reproductive potential, with females reaching sexual maturity at 3-5 years old. Breeding takes place from late January through early March and is followed by a gestation period of 390-406 days with birth of a single calf in March and April (Novoa 1970). Thus, camels produce young at best only every second year. Late autumn counts conducted between 1982 and 1989 in the Gobi, when calves would be about 6 months old, yielded an average of only 4.6% calves. Surveys in 1992 and again in 1995 found only 1.8% calves (Schaller 1993, Atkins 1996). In China, calves reportedly composed 13.8% of 80 animals in 13 groups in the Lop Nur region, although no season was specified (Gu and Gao, 1985). Hare (1997) observed 53 camels of which 13 were young (24.5%) during late spring surveys in the southern Taklamakan Desert in 1996. Schaller (1993) suggests that a calf percentage in winter of 10-15% is required to sustain the Mongolian Gobi population given the low reproductive potential, and natural and human induced mortality of adults.

Camel conservation efforts in Mongolia during the 1980s included wolf removals, occasional supplemental feeding, and the initiation of a captive camel breeding program. GGSPA staff killed nearly 40 wolves a year between 1987-1989 (GGSPA records). The harvest was random and opportunistic and efficacy in regard to survival of camel young in removal areas was not monitored. Overall, however, survival rates apparently remained low, as the autumn calf component of the herd averaged 4.8% over the same period.

Between 1987 and 1991 twenty-two wild camel calves were captured at less than one month old and transported to reserve headquarters at Bayantooroi 50 km north of the SPA boundary (Figure 4-1). Of these, 13 survived and were raised with domestic camels to create a propagation and transplant program to augment wild stocks.

Research and conservation progress in Mongolia faltered in the late 1980s and early 90s with the collapse of the communist system, loss of technical and financial support from the Eastern Block, and a painful shift to a market economy . Efforts to address camel conservation issues in Mongolia were renewed when the United Nations Development Program (UNDP), with funding from the Global Environmental Facility (GEF), initiated the Mongolian Biodiversity Project in 1993. The program included surveys of Gobi wildlife with emphasis on wild camels, assistance in furthering the captive camel breeding program, and capacity building for the GGSPA. Upon completion of the 3 year program the GGSPA was again left with limited external support and economic conditions in Mongolia prevented other than limited research and conservation activities.

In 1996 the GGSPA staff consisted of the reserve manager, one biologist, one botanist, 4-5 support staff, and 6 rangers for the 44,190 km^2 sector "A" of the reserve. With vehicular support usually limited to a single working jeep, one truck, one tractor and 4-5 motorcycles, work within the reserve was often limited to annual placement of supplement food pellets for Gobi bears in the spring during which time surveys of wildlife were opportunistically conducted. Fuel availability also limited field work. Maintenance level continuation of the camel breeding program, and propagation of rare plants around the reserve headquarters were the only other long-term conservation actions. Management functions included monitoring semi-nomadic herders who graze under contract with SPA in the buffer zone, and recording of wildlife sightings by rangers stationed around the reserve borders. Even by Mongolian standards the GGSPA is extremely isolated with the nearest regional center some 180 km north and across the Altai mountains. Communications between the SPA and their parent Ministry of Nature and Environment in Ulaanbaatar is sporadic via poor quality groundline telephone. Overall, management of the reserve is rudimentary at best.

Recognizing the need to re-establish basic monitoring programs for key Gobi species, especially the wild camel, we collaborated to initiate a project that would; 1) install basic long-term systematic monitoring protocols for species of concern, 2) answer the most pressing research and management questions as identified by SPA staff, 3) be useful as a training exercise for SPA staff, and visiting Mongolian students and scholars, 4) lead to immediately applicable conservation measures, and 5) be maintainable at projected internal funding levels, or through development of innovative long-term funding sources. The latter is an important consideration. While aerial surveys and other technologically advanced activities can add substantially to the immediate body of knowledge for the Gobi, they are not internally maintainable under current financial constraints. A program of reliable and systematic data collection and analyses, that would lead to realistic and attainable management recommendations was the goal of this project.

Methods

Camel Studies

Camel population status and trends were deemed a high priority by staff. We reviewed and revised camel range maps with current knowledge of seasonally important concentration areas, such as winter and calving habitat. Survey routes comparable to previous studies were desirable, but no maps or raw data have been left with the SPA managers from any surveys conducted prior to 1995. This included all of the Joint Russian-Mongolian Expeditions of the 1980s, during which time the Mongolian counterparts were primarily scientists from agencies and academies in Ulaanbaatar. Our attempts to locate the Russian survey maps and data were unsuccessful, but their reports indicated general locations visited. We planned standardized transect routes that included those sites and that covered as much camel core range as possible within the constraints of fuel carrying capability of 2 jeeps. Past expeditions had included large trucks for fuel and supplies. To be financially sustainable by the SPA, we limited each survey circuit to 1000 km or less and used only jeeps. Each transect was to be visited annually in late summer to be comparable with past surveys. After new baseline data were established, SPA staff would maintain a monitoring program and revisit the same transects at one or two year intervals as funding allowed.

In 1997 and 1998 we carried out 2 surveys per year between August 15 and September 15. One transect was not visited in 1998 until November due to a national fuel shortage in late summer. Transects totaled 962 km in 1997, and 1345 km in 1998. Two jeeps with 2 to 4 observers per jeep traveled together. Weather conditions were recorded daily. All mammals of hare size and larger were recorded. Animals at distance were observed with binoculars or 15-45x spotting scopes. For each observation we noted the time, odometer reading, species, number of individuals, sex and age-class when known, distance to the animal, and angle from the transect line. To provide baseline values for trend monitoring we calculated animals per hour and per km of transect, area surveyed and animals per km^2.

Sighting distance is a function of terrain type and is a critical parameter in calculating area surveyed and animal density. Viewable or effective strip width for jeep-based camel surveys in the Gobi have variously been reported in the range of 3-4 km (Zhirnov and Ilyinsky 1986:56, Atkins 1996). Use of a sighting distance frequency histogram to determine where detection probability falls off (Rabinowitz 1993, Lancia et al. 1996) is a simple method to calculate effective width on line transects, but requires a larger sample size than we obtained. To aid in our sightability estimates we recorded maximum viewing distance and terrain type off each side of the transect at 10 km intervals during the 1998 surveys. Viewing distance was an ocular estimate and was frequently checked by odometer reading. Terrain types distinguished included steppe/desert, hillocks, and canyon. Mean viewable distance was determined for each terrain type and effective strip width calculated using percentage of terrain type over the survey routes

Surveys were also conducted at oases. Each jeep transect segment began and ended at an oasis allowing for evening and morning surveys to be conducted daily. Seven oases were surveyed in 1997 and six in 1998. Observers were placed at outcrop viewpoints above the oases. All mammals hare size and larger were recorded as to time of observation, species, sex and age when known, distance and azimuth to animal.

Standardization of methods is benefited by consistent data collection and analyses protocols. We designed data forms for each survey type and produced them in both English and Mongolian. Computerized data storage and analyses methods were taught and standardized report formats provided to SPA staff.

Our sample size of direct camel observations was small for both jeep and oases surveys, but camel tracks were frequently encountered during both types of surveys. To augment our estimates of herd age-class ratios we developed criteria for aging camels by tracks. Known age wild camel tracks at the captive breeding center in Bayantooroi were used to develop the model. All camel tracks encountered during summer jeep surveys in 1998 were measured. At oases we walked transects perpendicular to paths of ingress/egress. Each track encountered was measured and direction of travel noted. To reduce likelihood of duplication, only tracks in-bound to the oasis were used in age ratio calculations. Ratios of calves, yearlings, subadults, and adult age classes were determined.

Population demographic data were of interest for modeling. We collected all skulls encountered on surveys and added them to an existing collection at Bayantooroi. We measured skull length, zygomatic width, and mandible length and height of each skull. Sex was determined by the size of canine teeth. The first lower incisor was collected and submitted to a laboratory in the USA for cementum annuli aging using both longitudinal and transverse sectioning. We attempted to build a sex-specific model of skull size and age to allow aging of skulls by cranial measurements when teeth are not available. This would also provide SPA staff a skull aging method not reliant on expensive laboratory analyses.

To predict population trajectory under various recruitment rates, we used data generated by this study and from the literature to produce a simple deterministic model of the Gobi camel population. The model we developed was spreadsheet based and female driven. We used age specific survival rates for year classes 1 through 20, at which age all remaining animals died. We used a conservative 0.9 survival rate for yearlings, 0.98 for all ages up to 16 years (Atkins 1996), and then incrementally reduced it to 0.8 by 19 years. The basic model did not consider fecundity rates. Instead, to mimic recruitment rates seen in the wild we set the number of calves in autumn as a percentage of herd size the previous spring. To predict population trajectory under various recruitment levels we used autumn calf percentages of 4, 5, 8 and 10 %, similar to what surveys have revealed. Survival of autumn calves to yearlings was set at 0.95, the majority of the mortality for this group assuming to have occurred between birth and autumn. The sex ratio surviving to yearlings was constant at 50:50. We ran the model using recent population estimates of both 750 and 900 animals at year zero, and a constant overall sex ratio of 1:1.6 males to females (Tolgat and Schaller 1992).

Our tooth age data suggested the possibility of increased mortality for females during the years of first reproduction and we re-ran the model accordingly using 0.95 survivorship for 4 and 5 year old females. We also re-ran the model with a maximum age of 15 to coincide with our maximum camel lifespan as indicated by tooth age.

To examine the potential for herd growth in the absence whatever factors now limit recruitment, we removed the forced percentage constraints on autumn calf numbers. Estimates of age specific fecundity were then required. Domestic bactrian camels have a high incidence of infertility (Novoa 1970), and Atkins (1996) used a 10% rate when predicting growth of the captive wild herd at Bayantooroi. She also assumed first breeding would occur with equal frequency (33%) at ages 3, 4 and 5, and a breeding interval of 2 years in 80% of the females and 3 years in 20%. We used those values and then further reduced fecundity by 10% per year for ages 16 through 18. Fecundity was set to zero at 19 because death was forced at 20 and calves born to 20 year olds were assumed not to survive. Using these values we ran the model under calf survival rates of 40, 50, and 60%.

Wolf Studies

While there is no legal use of the reserve by nomadic herders, they do graze adjacent to the border and incursions by their livestock occur. As part of a larger study of human-livestock-wildlife interactions in western Mongolia, we interviewed households who use the GGSPA buffer zone. Livestock number and depredation rates by wolves and snow leopards for the Edringen mountains along the reserves northern border were summarized.

Results

Camel Range Estimates

Using estimates from SPA staff and other knowledgeable persons we produced a map of current camel range use in the GGSPA (Figure 4-1). We identified about 21,100 km^2 of primary range and an additional 12,200 km^2 that receives only occasional or sparse use, for a total potential range of 33,300 km^2.

Recent changes to use patterns include the abandonment of former calving habitat near Khar Kharain in the north central portion of the reserve. This occurred within the past 4 years and may not be permanent. It is thought to be a result of reduced water availability in the area. We identified 3 distinct areas of currently used winter range and a similar number of unique calving ranges (Figure 4-1). Total winter range was calculated at 2,220 km^2 and calving habitat at 3,260 km^2. We did not include in those calculations the recently abandoned winter ranger (350 km^2) or calving habitat (1,220 km^2).

Camel Surveys

Eighty camels were counted during the 2 jeep surveys in 1997 (Table 4-1). The first survey of 293 km took place from 14-19 August and traveled to oases in the northwest portion of the reserve (Figure 4-2) including Takhilaga Bulag, Maikhan Bulag, On Uul, Otgon Bulag and Togoony Us. No camels were observed on this route. The second survey was driven between 30 August and 5 September, totaled 669 km and visited the oases in the south-central portion of camel range including Shar Khulst, Bogd Tsagaan Ders, Baruun Sharga, and returned via Togoony Us. Of the 80 camels observed on this transect, most occurred between Bogd Tsagaan Ders and Zamiin Bilgeh in the south and included a group of 76 camels observed at a distance of 4.5 km. A smaller group at that distance may have easily been missed, but dust from the running herd was readily detected. Whether or not they were running in response to us could not be ascertained, but we surmise that if we could see their dust, they could see ours and would respond accordingly. Camels at lesser distances always ran on our approach.

Three surveys were accomplished in 1998 and while total numbers were higher than in 1997, camels were sighted at a similar rate per kilometer of transect. The first survey was conducted from 24 - 29 August, totaled 485 km and ran from Hyreen Guun to the oases of Shar Khulst, Baruun Sharga and Togoony Us (Figure 4-2). No camels were observed. The second survey from 7 to 12 September followed the same northwest oasis route as in 1997. Eighteen camels were seen on this transect in 1998 compared to none the previous year.

The southerly transect route was not visited until 26 - 30 November in 1998 due to fuel scarcity in summer. The data must then be compared to 1997 with some caution because the route is within the winter concentration area. As in 1997 most camels were observed in the area between Bogd Tsagaan Ders and Zamiin Bilgeh. A total of 118 were counted along 594 km of transect. Many were at distances exceeding 4 km and could not be accurately placed in age classes. Of 27 camels for which age was estimated, 4 (14.8 %) were calves. For all jeep surveys in 1998 the calf percentage of the herd was 11.1%.

Our mean sighting distances of 1.1 km and 4.5 km in the two survey years would produce quite different estimates of survey strip width if taken alone. To correct for this we estimated maximum distance viewable and terrain category off both sides of the transect at 59 points during surveys in 1998 (Table 4-2). Multiplying the mean viewable distance in each terrain type by the proportion of that terrain type encountered yielded a weighted mean viewable distance of 2.25 km on each side of the road, or an effective strip width of 4.5 km. Given that we routinely observe camels at far greater distances, this is not likely an over estimate, and makes terrain the deciding variable.

Transect length multiplied by a 4.5 km strip width yields survey areas in 1997 and 1998 of 4329 km^2 and 6053 km^2 respectively. Camel density within the surveyed areas was 1.8/100 km^2 in 1997 and

$2.2/100km^2$ in 1998. We do not believe these data can be extrapolated to a population estimate until total current camel range is more accurately defined and stratified by intensity of use.

Oases surveys are summarized for 1997 and 1998 in Table 4-3, and were similar with 2.2 and 2.7 camels per hour and low calf percentages in both years. However, while only 5 animals were seen at northwest oases in 1997, 47 animals were found there in 1998 - 43 at Takhilaga Bulag and 4 at Maikhan Bulag. Of particular interest was the presence of 23 domestic camels intermixed with the wild ones at Takhilaga Bulag. The presence of large numbers of both wild and domestic camels at that oasis lends support to GGSPA ranger's contentions that dry conditions forced use of northwest oases earlier than normal that year. The southern oasis of Bogd Tsagaan Ders, where 50 camels were seen in 1997, was not surveyed in 1998.

Camel Demographics

We measured hind-foot track lengths and widths of known age wild camels at the captive breeding center in Bayantooroi over a two year period. A total of 26 animals of various sex and age classes were included. The results (Table 4-4) indicate a clear separation of camels track sizes for age classes of calf and yearling when measured in autumn. We grouped males and females in the calf and yearling age class for the analysis because of low sample sizes and the lack of significant difference between track sizes by sex at these ages ($p < 0.05$). However, because no wild camels between 3.5 and 7.5 were available to measure, the distinction between sub-adults (age 2.5 to 3.5) and adults is not clear. Domestic camel tracks could not be substituted due to the difference in shape and size (Bannikov 1976, Gu and Gao 1985). For the model we looked at length alone, and a length + width value. When only track length was considered, the 95% confidence intervals overlapped for yearlings and 2-year olds, and also for 2-year olds and 3-year olds. There were no overlaps for the combined length + width values and we believe this is the better model to use for field aging.

Using the combined length + width model as our criteria, we aged 165 sets of wild camel tracks found on surveys in 1998. There were no calf tracks and only a single yearling's. Nine sets of tracks were assigned to age category 3.5 - 7.5 years, and the remaining 155 tracks likely came from animals over 7.5 years old.

Attempting to gain herd demographic data, we measured the skulls of 36 male and 20 female wild camels (Table 4-5). Skulls were sexed based on presence of notably large canine teeth in males. Sexual dimorphism was otherwise not apparent. Age was determined by counts of cementum annuli of 13 females and 10 males (Table 4-6). Transverse sectioning of the tooth at approximately 1 cm above the root tip was preferred to longitudinal sectioning of the root tip. Longitudinal sections yielded indistinct and complex annuli, while in the transverse section annuli condensed more frequently into an identifiable single annulus (G. Matson, Matson's Laboratory, pers. commun.). Because first incisors in camels erupt at age 5 (Ishnyam and Maidar 1988:108), and none of the jaws from which teeth were aged contained deciduous incisors, our reported ages are equal to the annuli count plus 5 years. Maximum age seen in males was 13, and females 15.

Correlation between tooth age and jaw measurement was weak in both females (R=0.18) and males (R=0.38), hence field estimating age from skull size is not yet possible. Jaws are not as commonly found as skulls, but tooth eruption and wear (Ishnyam and Maidar 1988:102-111) may be the best field age indicator available. Jaws whose ages were established by cementum annuli count, and jaws from known age domestic camels, are available to SPA biologists for that purpose.

Population Modeling

When autumn calf percentages similar to those observed in the wild are input, the basic population model predicts extinction in a short time. With a 20 year maximum lifespan, 4% calves, and a population of 900 at year zero, the model predicts extinction in 21 years (Figure 4-3a). With 5% calves, the same population is extinct in 24 years, and with 8% calves at 50 years. A calf crop of 10% was enough to allow population growth, exceeding 2,000 individuals at 47 years, absent environmental limitations. A starting population of 750 and the same calf percentages saw extinction at 21, 22, and 40 years (Figure 4-3b) Again, a 10% calf crop resulted in herd growth, reaching 1630 animals in 50 years.

Altering the model and using the most optimistic population estimate, that of 1,985 animals (Reading et al. 1999) and a calf percentage of 5%, which is well above the 3.3% average observed since 1989, the population still fell to zero in just 38 years.

The model was moderately sensitive to an additional 3% mortality at age 4 and 5 when we attempted to mimic the loss of some first time breeders as might be suggested by our tooth age data. A population of

900 fell to zero two years sooner (25 years) than without the added mortality. When we reduced maximum lifespan to 15 years, as is suggested by tooth ages, extinction was reached at 19, 22, and 33 years under calf percentages of 4, 5, and 8% respectively.

When we removed the autumn calf constraints and applied instead age-specific fecundity and a 40% survival of calves to yearlings, the model predicted camel extinction at 52 years. With 50% calf survival the population was nearly stable, with a modest 1.0065 growth rate. When recruitment was set at 60%, the population grew at an annual rate of about 1.025.

Wolf Investigations

Scientific estimates of wolf numbers in the reserve have not been made. Rangers believed that about 6 to 7 wolf packs, each with 5 to 8 animals occur within camel range. In the vicinity of Atas and Ingis Uul, where camel density is highest, there may be 2 or 3 packs. One pack each are thought to be centered on Shar Khulst, Mazaalain Shand, Ulzi Bilgeh, and Khar Khairhan. If this estimate is accurate, a total of up to 56 wolves may exist in camel range.

Wolf removals by SPA staff fell off dramatically in the 1990s, due primarily to financial constraints on travel. Between 1992 and 1998 a total of only 8 adult and 20 pups were removed from within the reserve, or an average of 4 wolves per year. This is roughly 10% of the level in the late 1980s when up to 40 wolves a year were killed. In the buffer zone kill rates were higher, with 34 adults and 18 pups removed between 1992 and 1998. Many kills occurred near ranger's abodes.

Herders using the GGSPA buffer zone commonly reported an increase in wolf numbers in recent years. We interviewed 25 families who maintained a total of 298 camels among their livestock. Over the time period of 1996 through 1998 they lost an average of 14 (4.8%) of their camels to wolves each year. The majority of the loss was calves (76%). Snow leopards also took both young and adult camels, but the losses amounted to only 0.5% per year.

Discussion

We identified about 21,100 km^2 of primary range and a total potential range of 33,300 km^2. In 1981 the area permanently inhabited by camels was placed at 28,000 km^2 (Zhirnov and Ilyinsky 1986:55). If this value corresponds to what we term primary range, then there may have been up to a 25% reduction since that time, but the relationship in terminology is not clear. Their estimate of total camel range is also somewhat larger than ours.

The observed proportion of young in the Gobi camel herd has remained low since at least 1982 averaging only 4.2% during that time (Table 4-7). Our combined jeep and oasis surveys of 1997 and 1998 show a continuation of that trend with calves accounting for only 4.2% and 5.5% of the herd in those years. The scarcity of young in the population in the late 1980s was attributed more to poor survival than poor reproduction (Tolgat and Schaller 1992), given the steady decrease of young animals during the months after birth. Assuming adequate reproduction, Schaller (1993) strongly suspected wolves were a major source of calf loss and states that of 89 camel kills examined in the GGSPA in the 1980s, 61% were definitely attributable to wolves and that camel calf remains appear regularly in wolf feces. Still, this may not constitute proof as Reading et al. (1999) argue that it is not possible to distinguish between predation and scavenging. In recent years there have been no spring surveys to similarly document current reproductive success, and we gathered no direct data on wolf numbers, leaving the question of cause for low recruitment unanswered.

Wolf censuses have not been conducted in Mongolia, but local herders and SPA staff suggest that wolf numbers have increased in recent years throughout the Trans-Altai Gobi. Government sanctioned and funded hunts during the 1970-80s were common across Mongolia, including in areas near the GGSPA. Economic difficulties in the early 1990s caused wolf eradication programs nationwide to be greatly reduced or eliminated. The potential for wolf population increases may now exist, and could be the cause of escalating livestock losses as documented in our herder interviews. If so, the area outside the reserve may have been wolf "sinks" in the past, but may be "sources" today, or at least not be drawing young dispersing wolves out of the reserve. This, and reduced wolf removals in the reserve, may have led to higher wolf densities within camel range since 1990. Interestingly, we have never seen a wolf on our surveys, and during extensive aerial surveys Reading et al. (1999) saw only 6 animals. We often find tracks of wolves at oases, but in small groups of 1 or 2 individuals.

Even if wolf numbers increased after 1990, low camel recruitment was apparent nearly a decade earlier. Schaller (1993) suggests that drought in the 1980s reduced water and forage availability and concentrated animals around a smaller number of waterholes, making them easier prey for wolves. We examined the weather records for both Bayantooroi and Ekhiin Gol, a community on the eastern border of the reserve at about the same latitude as core camel range (Figure 4-1). Drought years with annual precipitation below 40 mm are apparent between 1982-89, but returned to normal after that for most of the 1990s. However, records only extend back to 1972 for Bayantooroi and 1978 for Ekhiin Gol, and what constitutes 'normal' for the region is unclear. No comprehensive inventory of springs and oases has been conducted in recent times and opinions differ on water availability. We noted standing water of 2 to 8 cm at two oases important to camels in 1997, Baruun Sharga and Maikhan Bulag, both of which were dry in 1998. Similarly, the flow of water at Shar Khulst spring was greatly reduced from 1997 to 1998. The early use of springs further north in 1998 and the apparent abandonment of entire calving areas, may bear out the contention that reduced water availability at core area oases is changing camel range use patterns. Limited water could conceivably concentrate camels at a lesser number of waterholes, particularly in early in spring during calving season, when new vegetation has not yet appeared and camels are obligated to seek water.

If our basic model is correct, about 9.7% calves in autumn is required to hold the population stable. Under the hypothetical fecundity rates we used in the unconstrained model this would require survival of about 50% of calves produced into the yearling age class. The basic model requirements of a 9.7% autumn calf component is probably accurate, while the fecundity driven model's assumptions have not been proven. Clearly more research into the issue of reproductive success, neonate survival, wolf predation, water availability and each factor's influence on camels is urgently needed.

Other conservation concerns exist for the species. During surveys in 1997 it became apparent that violations of grazing regulations along the border were common. Livestock were routinely allowed to enter the reserve, competing with wildlife for forage and for water at natural and man-made water sources. Livestock remain in the buffer zone beyond periods specified by contract. Inter-breeding between domestic and wild camels is possible and poaching is a problem, although the magnitude is not clear.

Wild and domestic bactrian camels are genetically distinct (G. Amato, Wildlife Cons. Society, pers. commun.) and crossbreeding is a concern. The number of wild and domestic camels seen mixing at Takhilaga Bulag during our 1998 surveys bears out this potential. That oasis is near the reserve border and use by domestic camels is a longstanding issue. Several domestic camels have been observed deep in the core areas of camel range in recent years. Each military border station, well inside the reserve, also maintains a herd of domestic camels. Domestic males may find it difficult to breed with wild females (Bannikov 1976, Dash et al. 1977) being much weaker than wild males and easily driven off, whereas domestic females are often taken into harems by wild bulls. Local herders contend that cross bred domestic females return from the reserve to give birth and the offspring are usually killed because they are aggressive and produce inferior wool. However, whether or not crossbreeds become incorporated into wild herds has not been proven and remains a concern.

Poaching for meat is also an issue and we found remains of a recently killed wild camel about 150 km inside the reserve in 1997. The shyness of the animal makes it difficult to approach within a kilometer on foot or motorized vehicle, which may serve to limit poaching. An added concern associated with mixing of domestic and wild camels is the potential to reduce wariness in the wild contingent, making them substantially more vulnerable to poaching. This was evidenced by our being able to walk openly to within 50 meters of a mixed group at Takhilaga Bulag. Losses may also be occurring across the border into China. In March 1998, 23 wild camels were observed to cross the southern border. Poaching of animals straying across the border may be more likely given the higher human density and lack of protected area status on the Chinese side.

Camels are legally protected and the entirety of their range in Mongolia is off-limits to human use, but other direct conservation efforts for camels are not currently in place. The captive breeding program at Bayantooroi was established to provide surplus animals to augment the wild herd. While some success has been achieved and 9 calves produced, the long-term efficacy of the program is questionable. No comprehensive plan exists. Only 2 breeding age males remain, one of which has never successfully bred. This will quickly reduce the genetic variability of the captive herd. Atkins (1996) modeled growth of the captive herd and estimated a population of 50 animals in 10 years with an annual production of about 15 calves. While this would make several animals available each year for augmenting the wild population, the viability of a transplant program for this species is also not proven. For example, 2 captive bulls that had become too aggressive to handle upon reaching maturity were taken 250 km into the reserve and released near Shar Khulst oasis in March 1994. One bull was radio-collared and the other ear-tagged. The collared bull was never relocated despite numerous attempts. The ear-tagged bull traveled back approximately 300 km to a site near where he had been raised and was killed by a local herder. Female camels also exhibit strong range fidelity (Peters 1997) and will travel more than 100 km to give birth in the same site where they first gave birth, possibly necessitating that only sub-adult females be transplanted. Sub-adults with no prior knowledge of food or water sources in the desert may experience high mortality. Before more camels are removed from the wild to provide additional breeding bulls, and prior to investment of added time and funds, a strategic plan must be developed and transplant procedures tested.

Indirect conservation action has been taken. Our project initiated a community-based conservation program administered through the GGSPA in 1998 to improve compliance with grazing regulations and hunting laws, and to foster better relations between the SPA and local herders. The program addresses a frequent complaint of interviewed herders regarding lack of markets for their sheep, camel and cashmere wool. Cooperatives were established in 3 soms (rural administrative units) adjacent to the reserve. Herders were contracted to supply products which are transported by the project to the capital and sold to tourists under a "wildlife friendly" logo. Herders realize substantial profit and receive an annual cash bonus if livestock is kept out of the reserve, and buffer zone grazing regulations and hunting laws are followed. Peer pressure is added in that poaching of large mammals, including camels, results in loss of bonus for the entire community, and permanent expulsion for the individual. Each year 10% of the profits go to a conservation fund administered by a small board of SPA and the herder representatives. The proceeds will be used to fund small projects that benefit wildlife and humans in the buffer zone, such as new wells.

The need for direct and indirect conservation actions is, in part, underpinned by the supposition that camel numbers in the Gobi are declining due to poor recruitment. Yet we must ask, if calf percentages are as low as surveys indicate, why do we not see a marked decline in animal density over the same period? Our density estimate of 1.8 to 2.2 camels/100 km^2 is reasonably close the 2.3/100 km^2 of 1981-82 (Zhirnov and Ilyinsky 1986:57). Further, if we set year-one of our population model to1982, an initial population of 900 animals with 4% in calves in autumn would have declined to only 150-200 animals by 1998. Range-wide density would be about 0.7/100 km^2. We do not see this.

No matter how lenient we are with the parameters of maximum lifespan, age-specific mortality, and starting population, calf percentages like those seen in the wild cause the our model to predict a steep decline in numbers that field surveys do not detect. If recruitment is the most sensitive model value, and real-world and model predictions differ, we must consider the validity of our calf percentage estimates. Researchers using similar survey techniques observed higher calf proportions prior to 1982, so calves are observable by our methods. Importantly, the low numbers are not the product of a few surveys, and have been consistent for 17 years across camel range. Track measurements in 1998 also indicated few young in the herds, and this technique for determining wild camel age ratios has been proven in China (Gu and Gao 1985). The preponderance of evidence indicates recruitment to be low.

We sought to establish a program for the SPA that would allow monitoring of wildlife population trends within the reserve using systematic, repeatable and financially realistic methods. From a fiscal perspective we have may have succeeded, but whether or not the monitoring protocols are adequate to detect anything less than gross changes in animal density is not yet certain. We suspect that camels are declining, but at a rate slower than thought. This may allow time for proactive conservation measures to be taken, including wolf reductions under controlled and monitored conditions, and revitalization of water sources in core areas. However, immediate action is needed..

Table 4-1. Results of jeep-based wild camel surveys conducted in the Great Gobi SPA, Mongolia, 1997 and 1998.

	1997	1998
Km surveyed	962	1345
Hours Surveyed	na	63.9
Camels observed	80	136
Camels/100 km of transect	8.3	10.11
Camels/hour of survey		2.13
Age Class[a]		
Adults (%)	63 (78%)	38 (84%)
Yearlings (%)	12 (15%)	2 (4%)
Calves (%)	5 (6%)	5 (11%)
Number of groups	3	12
Group size $\bar{x}$ (range)	26.6 (1-76)	11.3 (100)
Sighting distance $\bar{x}$ (range)	1050 m (200-4500)	4504.2 (100-7000)

[a] Age class and percentages are calculated using only animals for which age could be estimated. Camels at great distances were counted, but not assigned to an age class.

Table 4-2. Estimated observable strip width of jeep-based large mammal transects in various terrain types, percentages of each terrain type along survey routes, and the weighted average strip widths for surveys conducted in the Great Gobi SPA, Mongolia, 1998.

Terrain Type	n	% of observations	Mean strip width (m)	SE	Weighted width[a] (m)
Canyon	7	11.9	147.1	97.0	17.5
Hillocks	20	33.9	748.5	1007.2	253.7
Steppe/desert	32	54.2	3640.5	2010.8	1,974.6
Weighted mean ½ strip width					2,245.8

[a] Mean strip width x percent of transect in habitat type.

Table 4-3. Results of wild camel surveys conducted at oases[a] in the Great Gobi SPA, Mongolia, 1997 and 1998.

	1997	1998
Hours surveyed	27.8	17.1
Camels observed	62	47
Camels/hour	2.2	2.7
Age Class[b]		
adults (%)	61 (98.4%)	46 (100.0%)
Yearlings (%)	0 (0%)	0 (0.0%)
calves (%)	1 (1.6%)	0 (0.0%)
Number of groups	12	10
Group size $\bar{x}$ (range)	5.1 (3-9)	4.7 (1-20)
Sighting distance $\bar{x}$ (range)	3011 m (200-6000)	2033 m (400-8000)

[a] Oases surveyed: Takhilaga Bulag, Maikhan Bulag, Otgon Bulag, Shar Khulst, Bogd Tsagaan Ders, and Baruun Sharga (all oases were surveyed in both years with the exception of Bogd Tsagaan Ders which was surveyed in 1997 only).

[b] Age class and percentages are calculated using only animals for which age could be estimated. Camels at great distances were counted, but not assigned to an age class.

Table 4-4. Mean track sizes and 95% confidence intervals for known-age wild camels in the captive breeding herd at the Great Gobi SPA Headquarters, Bayantooroi, Gobi-Altai, Mongolia, 1997-98.

		Mean track measurements and 95% confidence interval					
		Track length only (cm)			Total of length plus width(cm)		
Age	n	Mean	Min	Max	Mean	Min	Max
0.5	7[a]	11.7	10.6	12.9	21.8	19.9	23.7
1.5	4[b]	14.3	13.8	14.7	25.8	25.3	26.2
2.5	3[c]	15.5	14.3	16.7	27.8	27.1	28.6
3.5	6[d]	16.0	15.5	16.4	30.3	29.5	31.1
7.5 +	6[d]	18.0	16.6	19.4	33.9	31.4	36.4

[a] Three males and four females.

[b] Two males and two females.

[c] All males.

[d] All females.

Table 4-5. Skull measurements of wild Bactrian camels by sex from skulls of adult animals (age 5+) collected in the Great Gobi SPA, Mongolia, 1998.

	Skull length [a]			Zygomatic width [b]			Jaw length [c]			Jaw height [d]			Skull ln:jaw ln [e]		
Sex	n	$\bar{x}$	SE	n	x	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Males	36	550.5	20.4	36	249.0	6.8	11	423.5	8.7	11	232.0	12.0	1	1.285	--
Females	20	514.8	26.7	18	228.0	12.4	12	386.1	33.0	12	210.0	16.5	4	1.284	0.02

[a] Greatest length (cm) of the skull from the front edge of the premaxilarae to farthest point on the back of the skull.

[b] Greatest width (cm) of the zygomatic arch.

[c] Length (cm)of the mandible from the front point of the mandibulare to the back of the articulated condyle.

[d] Maximum height (cm) of the mandible.

[e] Ratio of the skull length to the mandible length.

Table 4-6. Ages at death of wild bactrian camels as determined by cementum annuli counts of teeth collected from skulls, Great Gobi SPA, Mongolia, 1997-98.

Age	Females	Males
6	1	0
7	2	0
8	3	0
9	1	2
10	0	2
11	0	2
12	3	1
13	0	3
14	1	0
15	2	0
Total	13	10

Table 4-7. Summarized wild camel survey results from the Great Gobi SPA, Mongolia, 1980-98.

Survey Period	Source	Total observed	Percent young
Summer 1980-81	Zhirnov & Ilyinsky	182	13.1
September 1981	Zhirnov & Ilyinsky	151	7.9
December 1981	Zhirnov & Ilyinsky	269	12.2
Oct/Dec 1982	*in* Schaller 1993	189	6.3
Oct/Dec 1983	*in* Schaller 1993	98	4.1
Oct/Dec 1984	*in* Schaller 1993	255	4.7
Oct/Dec 1985	*in* Schaller 1993	157	3.8
Oct/Dec 1985	*in* Schaller 1993	62	3.2
Oct/Dec 1987	*in* Schaller 1993	440	2.5
Oct/Dec 1987	*in* Schaller 1993	322	9.3
Oct/Dec 1989	*in* Schaller 1993	183	3.1
Oct/Dec 1992	Schaller 1993	112	1.8
March 1995	Atkins 1996	55	1.8
Aug/Sep 1997	This study	142	4.2
Aug/Sep 1998	This study	183	5.5

[a] Includes camels observed from both jeep-based transects and oasis surveys.

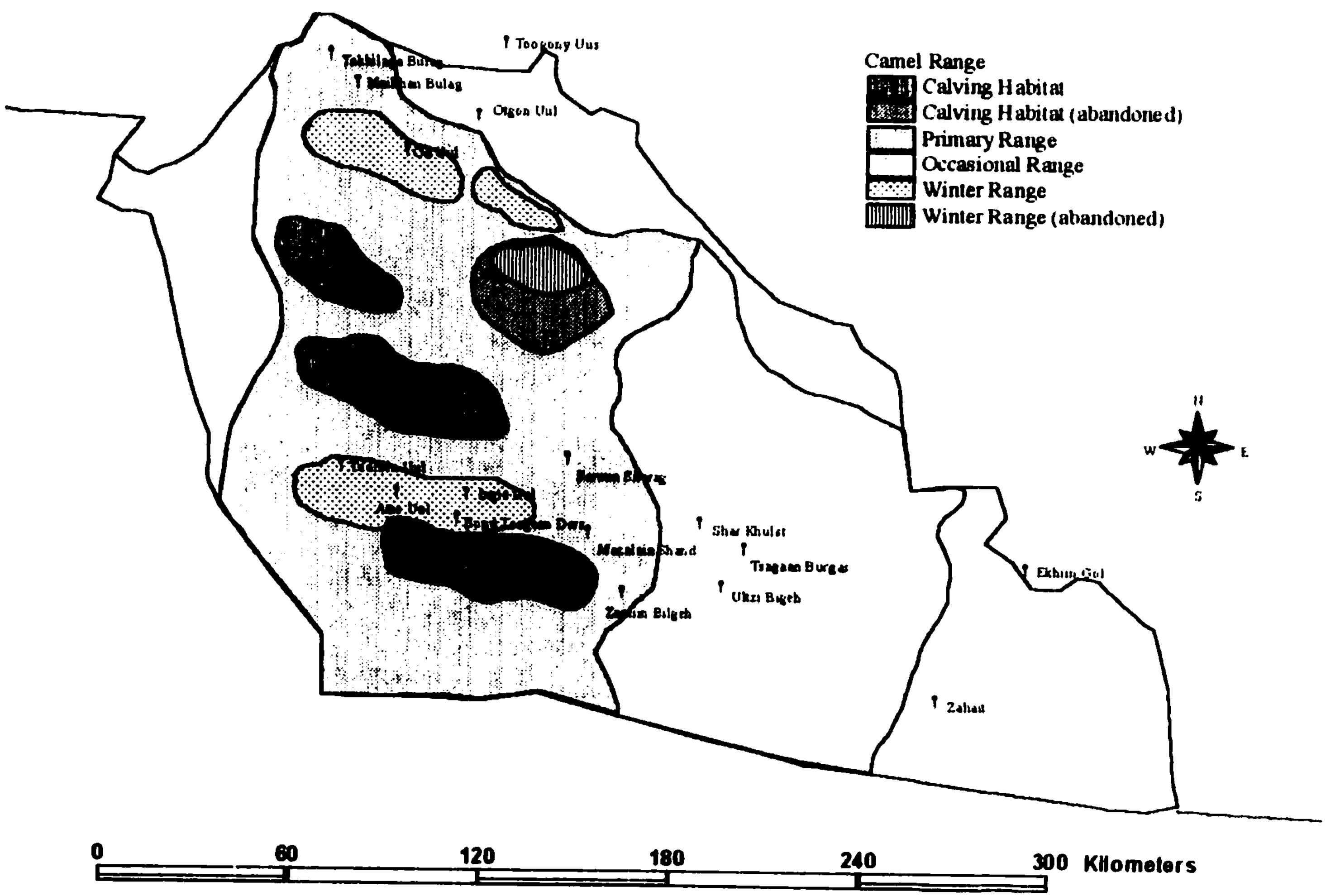


Figure 4-1. Wild camel range in the Great Gobi National Park , Mongolia.

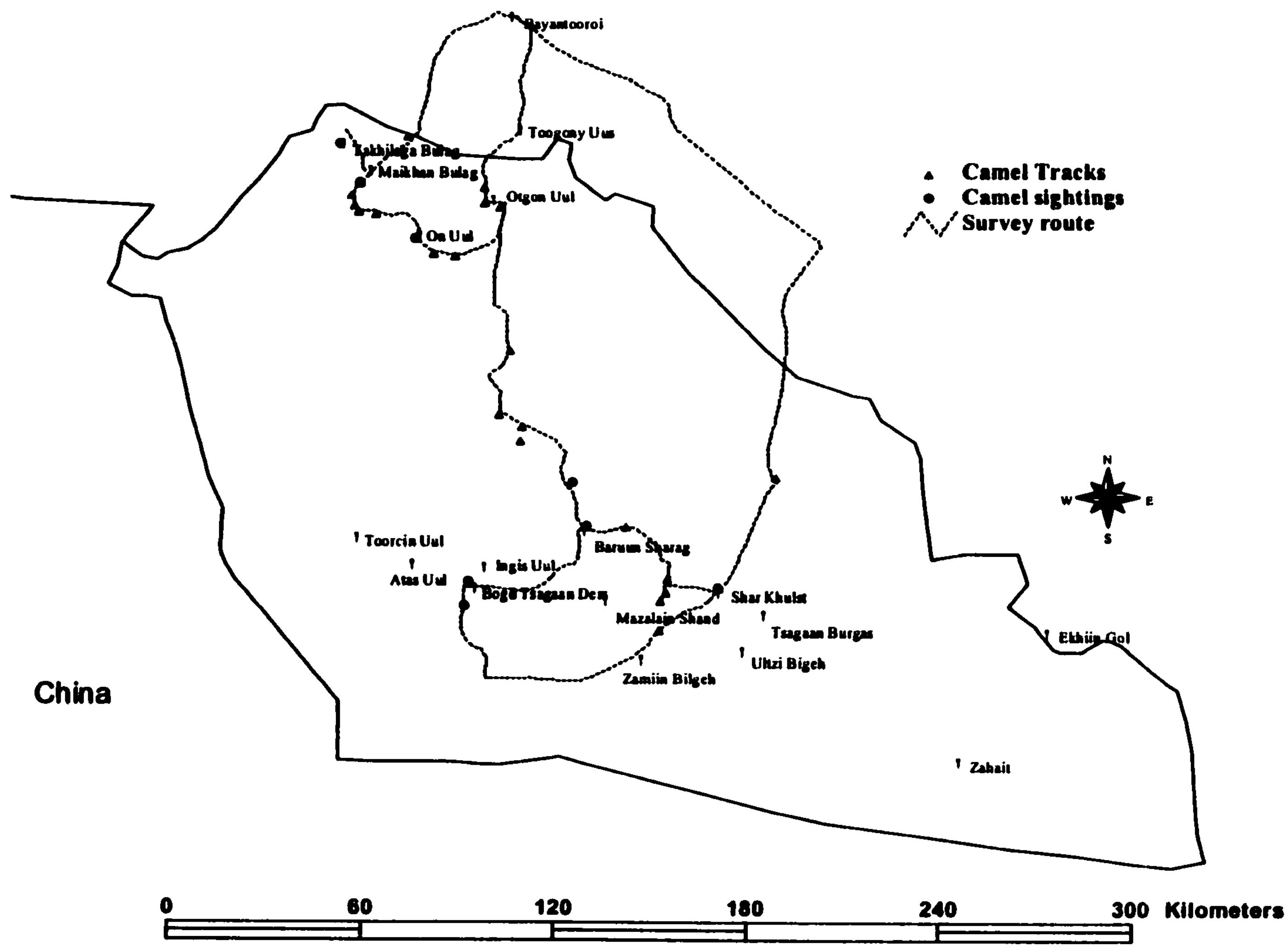
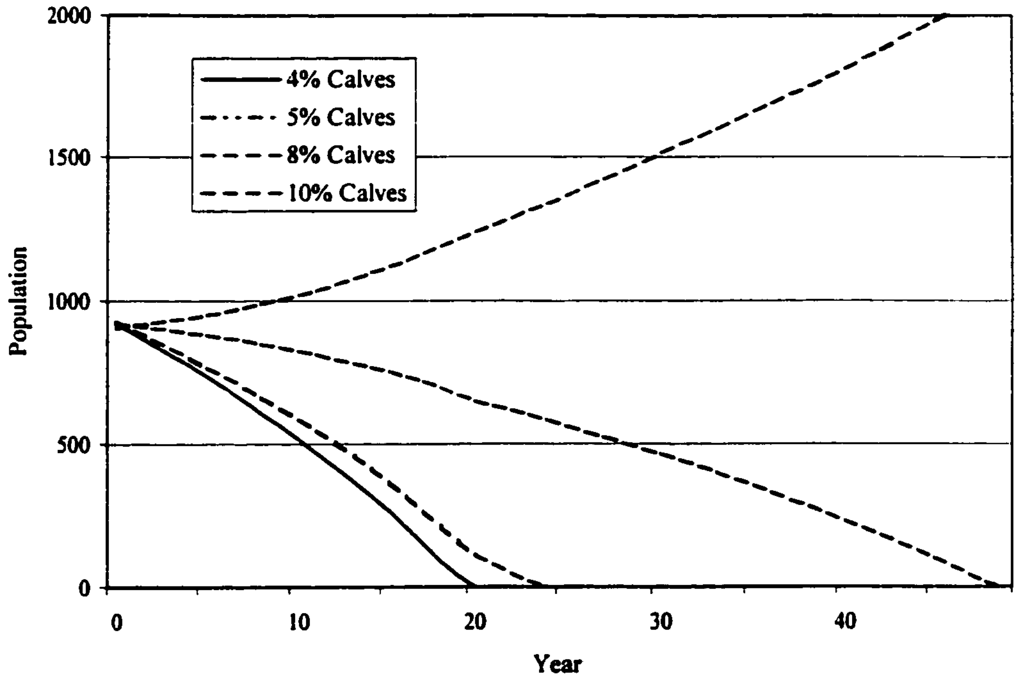


Figure 4-2. Observation of camels and camel tracks on jeep surveys in the Great Gobi National Park, Mongolia, 1997-98.



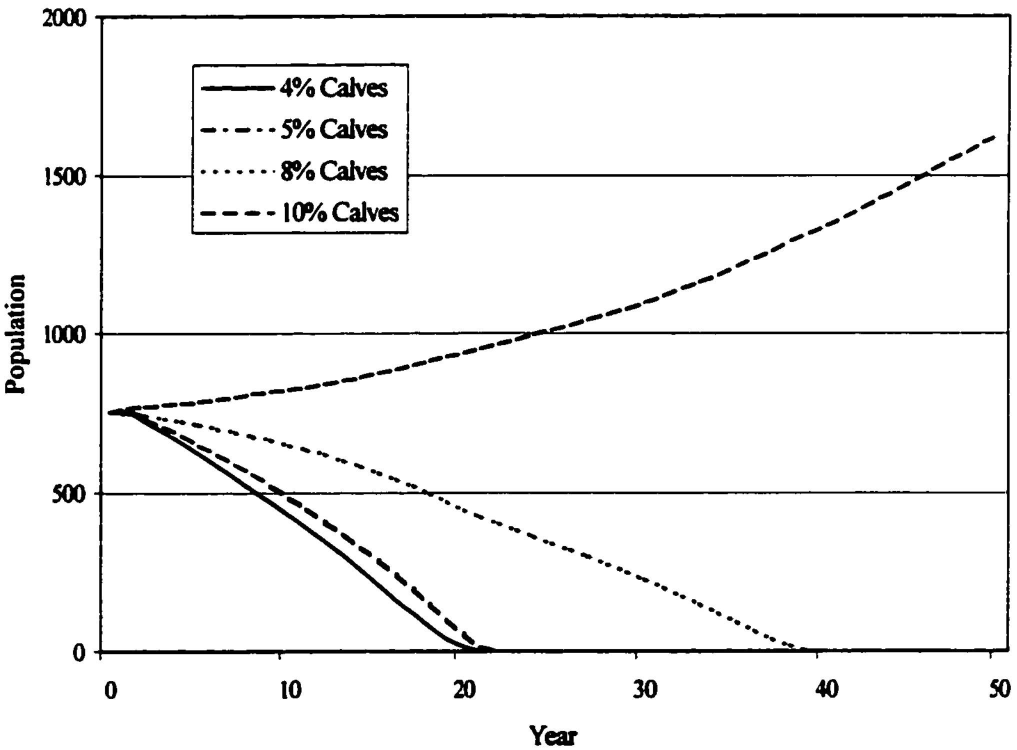


Figure 4-3 a and b. Wild camel population trajectories as predicted under various autumn calf percentages with starting populations of 900 and 750 animals in the Great Gobi SPA, Mongolia.

CHAPTER 5

STATUS OF THE GOBI BEAR IN MONGOLIA AS DETERMINED BY NONINVASIVE GENETIC METHODS

The range of the brown bear (*Ursus arctos*) is holarctic and widespread, but has been substantially reduced over the past two centuries and numerous insular or remnant populations now occur (Servheen 1990). Perhaps one of the least studied and most endangered subpopulations is found in the isolated massifs of Mongolia's Great Gobi. The Gobi bear, or "mazaalai" as it is commonly referred to by local people, is unique among bears in its use of this barren desert niche (Schaller et al. 1993) and its precarious status is evidenced by its occurrence in the IUCN and Mongolian Red Books. Protected in Mongolia, the bear's range lays almost entirely within the core area of the Great Gobi Strict Protected Area (GGSPA) which is closed to all but sanctioned research activities. Human disturbance is minimal and bear management is limited to supplemental feeding each spring. While little investigation of this secretive species has been conducted, information suggests that as few as 25 animals may remain. Living in the harsh desert environment, the bear's continued existence may be precarious. Notably, its range has been reduced by half since 1970 (Schaller et al. 1993) and only three population centers are thought to exist (Figure 5-1); limited genetic interchange between them may be further reducing population viability.

The first recorded reports of an unknown bear dwelling in the Gobi come from the notes of V. Ladygin (In Anon. 1988). In 1900 he found tracks and diggings near Tsagaan Bogd, Tsagaan Burgasny-bulak, and Shar Khulst, all sites that still support small populations of the bears. Joint Soviet and Mongolian scientific expeditions in the mid-1930s were unsuccessful in studying the bear due to its rarity and the first confirmed observations of a Gobi bear did not come until 1943 during an expedition carried out by the Science Committee of the Mongolian Peoples' Republic (Bannikov 1954). With the establishment of the GGSPA in 1975, emphasis was placed on investigating Gobi bear distribution, population size, and ecology.

Bannikov (1954) suggests the range of the Gobi bear previously extended east to the Tost-Ula mountains. As late as 1970, the northern border of their range was reported to be near the Edringen mountains and included the Aj Bogd Range. Currently, the range of the Gobi bear is thought to be restricted entirely to Sector A of the Great Gobi Park and encompasses about 15,500 km^2. Areas of bear activity center around Atas Bogd, Shar Khulst, and Tsagaan Bogd mountains and associated oases. Zhirnov and Ilyinsky (1986) felt that bear home range sizes varied seasonally with food availability, but remained relatively small and individuals rarely ventured far from oases. Despite the use of radio collars, Schaller et al. (1993) were unable to estimate actual home range size, but calculated a minimum home range size of 650 km^2 for one male bear with straight line movements exceeding 48 km, taking him far from the oasis around which his activity centered. There have been no apparent attempts to document movements of bears between activity centers, thus leaving unaddressed the important question of population isolates within the range.

After apparent declines in the 1970s, population estimates for the bear have been relatively constant over the past decade (GGSPA records). Zhirnov and Ilyinsky (1986) estimated that 25-30 bears remained in the early 1980s. Schaller et al. (1993) believed this number was still a reasonable estimate after conducting surveys in 1990, although population parameters remain unknown.

The question of taxonomic status of the Gobi bear has yet to be settled. In contrast to other brown bears, Gobi bears are relatively small with reports of adults weighing between 100 and 120 kg (Anon. 1988, Schaller et al. 1993). The bear is light brown colored, and the head, belly and legs can be noticeably darker than the rest of the body, and light stripes or a collar are often discernible about the neck (Anon 1988). Assuming similarity to the Tibetan brown bear (*Ursus pruinosus*), the Gobi bear is commonly referred to by the former's specific epithet, or as *U. arctos pruinosus* (Mallon 1985, Zhirnov and Ilyinsky 1986). Schaller et al. (1993), having observed both the Gobi bear and the Tibetan brown bear, noted distinct differences in appearance and question the likelihood of them being the same species or subspecies. They suggested the Gobi bear is more likely the same subspecies as brown bears that inhabit either the nearby Tian Shan Mountains, *U. a. isabellinus*, or the Altai Mountains, *U. a. arctos*. Sokolov and Orlov (1992) established the Gobi bear as a distinct species, *U. gobiensis*. However, they base that contention on morphological measurements from a limited number of individuals, thus leaving the new taxonomic distinction questionable. There have been no attempts to deal with the taxonomic question through modern genetic analyses.

The GGSPA and the Mongolian Ministry of Nature and Environment (MNE) recently identified the Gobi bear as "a species of special concern" and in need of immediate protective measures and additional research. In 1995, MNE sought funding to capture and radio-collar several Gobi bears for study, and to move them between oases to facilitate genetic interchange. Given the potential risks associated with capture, the near impossibility of long-term telemetry studies in the Gobi without aid of aircraft, and the fact that breeding isolates had not been shown to exist, the project received no support from donor agencies. Recent advances have led to increased use of molecular genetic techniques to answer such conservation biology questions (Paetkau and Strobeck 1998, Taberlet et al. 1999). Microsatellites, short hypervariable tandem repeats of 1-5 nuclear DNA base pairs, have been used in bear research to identify individuals, access parent-offspring relations, estimate home-range and movements, or to measure genetic variation within and between populations (Paetkau et al. 1995, Taberlet et al. 1997, Paetkau and Strobeck 1998). Microsatellite analyses can be used with shed hair or fecal samples, making handling of animals unnecessary. We were able to convince officials to authorize the use such non-invasive techniques to study the Gobi bear's status as an aid to responsible conservation planning.

In 1996 we initiated a field study to: (1) establish a minimum population size estimate for Gobi bears within the GGNP; (2) determine sex ratio of the sampled population; (3) document either movement of individuals, or genetic material between population centers to determine if population isolates exist within the GGNP; and (4) initiate preliminary investigation of the taxonomic status of the Gobi Bear.

Methods

Field

Three oasis complexes were identified by GGSPA staff as bear activity centers: Baruun Torooi, Shar Khulst, and Tsagaan Bogd (Figure 5-1). Each of the complexes contains several individual water holes and is separated from other complexes by a distance of open desert ranging from roughly 60 km (Baruun Torooi - Shar Khulst) to approximately 100 km (Shar Khulst - Tsagaan Bogd). We set an initial target of 50 hair samples from each of the oases complexes.

To minimize disturbance of bears, we collected hair samples by use of "hair-traps". Three types of traps were used. Barbed wire was strung 30 - 40 cm above the feed troughs of established supplemental feeding stations. Where no feeders existed we hung bait from trees and strung barbed wire around the trunk and out to an adjacent tree or stake. In areas lacking both trees and feeders, we brought in tripods made of 4-m long logs. Barbed-wire was strung between and wrapped around, the legs of log tripods. Bait was hung from the tripod apex. We deployed 17 hair traps.

Collection of hair samples was initiated following den emergence in spring 1996 and continued through late summer 1998. A circuit of more than 600 km by jeep was required to reach all traps; hence, visits were opportunistic and accomplished in conjunction with other Park work. Baits were refreshed on each visit.

For each specimen we recorded type of collection device, date, location, and whether or not all the hairs in the sample were positively from a single animal. For example, multiple hairs pulled from around a rub tree are possibly from more than one individual, while a clump of hairs on a single barb at a wire trap are probably from one animal. Samples were collected using tweezers or sterile rubber gloves and placed in individual sealed paper envelopes.

Laboratory

For 156 samples initially submitted, analyses were restricted to samples with 5 or more hairs with roots. This minimum number of roots was chosen as a conservative method to provide enough DNA to avoid genotyping errors that are known to occur in microsatellite analysis of samples with low quantities of DNA (Taberlet et al. 1997, 1998, 1999; Goossens et al. 1998). Only 33 samples met this criteria and were processed. Because the initial collection was small, a second batch of hairs was collected late in the study with emphasis on gaining multi-hair samples. Forty-two samples were acquired of which 38 had roots and were processed, including 9 that contained less than 5 hairs.

All DNA extraction and polymerase chain reaction (PCR) were performed in a low-quantity DNA rooms dedicated to processing bone, scat, and hair samples to avoid contamination errors. DNA was extracted from all samples with visible roots. DNA was extracted using 200ul of 5% Chelex solution (Walsh et al. 1991) and further purified with a Geneclean II Kit (Bio101). A suite of six microsatellite loci (G1A, G10B, G10C, G10L, G10X, G1D) of 200 base pairs or less was used for individual identification (Paetkau et al. 1995). Brown bears have been previously surveyed across North America using these loci (Paetkau and Strobeck 1998), and a large number of alleles (5-13) have been identified. PCR conditions and ABI gel separation methods are described in Woods (1999). Genotypes for each sample were determined using the Genescan and Genotyper software packages (Perkin Elmer).

Excluding errors in genetic analysis, a difference in genotypes between individuals is proof that they originate from different animals. However, for samples with identical genotypes, it is possible that they match for the surveyed loci, but actually represent two different individuals that will have different genotypes if more loci are examined. Thus, a statistical basis for match declarations must be used. The probability of identification *P*(ID) is generally calculated for each locus using pi^2 for homozygotes and 2 *pi* *pj* for heterozygotes (where *pi* and *pj* are the frequencies of the ith and jth alleles), and these single locus values are multiplied across all analyzed loci to give an overall probability of a match (Woods 1999). This calculation makes the assumption that samples are drawn at random from a population, and this is a potential problem for hair-trapping studies of free-ranging mammals due to population substructure and possible sampling of family groups (Waits et al. 2000, Woods 1999). Therefore, formulae have been developed to determine the match probability for parent-offspring (*P*off) or sibling-pairs (*P*sib) (Waits et al. 2000, Woods 1999). Generally, these conservative estimators and a statistical criterion of $P\text{sib} < 0.05$ are used for declaring a match.

All samples with unique genotypes were analyzed to determine gender. This is accomplished by co-amplification of a ZFX/ZFY fragment (X and Y Chromosomes) and SRY fragment (Y chromosome) using SRY primers described by Taberlet et al. (1996) and ZFX/ZFY primers described by Woods (1999). One primer of each pair is fluorescently labeled for quick resolution of the 130 bp X chromosome fragment and 120 bp Y chromosome fragment on a 5% acrylamide gel using the ABI 377 fluorescent detection system. All individuals with an X and Y fragment are scored as males, and all individuals with an X fragment only are scored as females.

The sampling location of each genotype was plotted on a map and digitized for GIS analyses of bear range extent and movement.

DNA sequencing of a short segment (300 bp) of the mtDNA control region was completed for three individual Gobi bears, and one brown bear from Kamchatka, Russia using the ProC and Tdkd primers described in Waits et al. (1998). Phylogenetic relationship of Gobi bears to other ursids was assessed using these sequences and published control region sequences from North American and European brown bears.

Cladistic analyses of character state matrices were performed using the computer program PAUP (Swofford 1991). Heuristic searches of potential trees were conducted using American black bear (*Ursus americanus*) as outgroups. Strict consensus trees were produced and used to depict phylogenetic relationships.

Results

Hair samples were not collected in equal numbers from all oases due to difficulties reaching Tsagaan Bogd, and of the 196 hair samples collected only 22 came from that oasis (Table 5-1). Both Baruun Tooroi and Shar Khulst were well represented. Of the 196 samples collected 75 were extracted, and of those 30 failed to amplify after repeated attempts and apparently no DNA was recovered. This success rate for obtaining nDNA from hair (60%) was considerably lower than other samples the laboratories had processed (generally 80-85%). A complete 6-locus genotype was obtained for 22 samples, 5-locus genotype for 9 samples, 4-locus genotype for 1 sample, 3-locus genotype for 6 samples, and a 1- or 2-locus genotype for 8 samples (Table 5-1). A minimum of 3 successful loci were required to identify a genotype. We obtained no complete genotypes for the Tsagaan Bogd oases.

We identified 15 unique microsatellite genotypes (Table 5-2) which appeared in samples from 1 to 11 times each. Genetic diversity was very low in the Gobi population and no genotype met the standard criterion for identity of $P(\text{sib}) < 0.05$. Hence, while each genotype represents a minimum of one individual, we can not say with certainty that the appearance of a given genotype more than one time represents the same individual.

Genetic diversity for the population was estimated by 3 methods; number of alleles per locus, expected heterozygosity, and population probability of identity. By all three methods the genetic diversity was determined to be very low in this population (Table 5-3). The number of alleles per locus ranged from 1 (G10X) to 4 (G1D) with an average of 2.3. Expected heterozygosities by locus ranged from 0 to 0.71 with a mean of 0.32. Observed values were below expected. The population $P(\text{ID})$ was 0.0139.

Insufficient DNA was available for gender testing in many samples, the priority being given to determining microsatellite genotypes. Sex was established for only 4 genotypes, 3 male and one female. Additionally, genotype H was typed as a male 5 times and a female 6 times, indicating that both a male (Hm) and a female (Hf) had the same microsatellite genotype. Hence, 16 unique genotypes occur when sex is considered (Table 5-2). Gender tests returned ambiguous results in some instances. We subdivided 2 different field samples and submitted them to the laboratory as multiple unique samples to test genotyping consistency. Although the microsatellite genotyping proved consistent, both split samples were ambiguously identified as both males and females in separate trials. The primers used in the sex test are not species-specific and contamination by human Y chromosomes is possible. That type of error occurs in less than 5% of PCRs (Taberlet et al. 1996, Goossens et al. 1998) but may have been the cause of the equivocal results.

A control region sequence of 358 bases from the 5' end was obtained for 2 Gobi bear samples, and a sequence of 672 bases for a third sample. These sequences were identical in the region of overlap. The Kamchatka sample yielded a 651-base sequence. We compared these to similar sequences for 16 European brown bear lineages and 28 North American brown bear lineages. Using the American black bear as an outgroup, a heuristic search found 450 equally parsimonious trees and a strict consensus tree was developed (Figure 5-2).

Five clades of brown bears have been previously identified in the literature (Taberlet and Bouvet 1994, Waits et al. 1998). Although several unresolved nodes exist near the terminal taxa, all 5 clades are clearly apparent in our analyses. The geographic distribution of the 5 clades is generalized by the labels we applied to the main branches of the tree; Europe, Russia/Alaska, Western Canada, Lower 48, and ABC (for Admiralty, Baranof, and Chichigof Islands in southeast Alaska). While some overlap exists between the clades geographically, for the purposes of comparing the known clades with the Gobi and Kamchatka bears, our broad geographic labels are adequate.

The analyses placed Kamchatka bears into the Russia/Alaska clade. The Gobi bear fell outside of all known clades. The ABC clade was shown to have diverged from other lineages of brown bears earlier than other groups, consistent with previous findings (Talbot and Shields 1996). Based on the rates of molecular substitutions at specific codons of mitochondrial genes, it has been estimated that the ABC lineage diverged from the line leading to the remaining clades between 550,000 and 700,000 years ago (Waits et al. 1998). The Gobi bear lineage is indicated to have diverged prior to this.

Discussion

Our success rate for obtaining DNA from hair was low and we considered potential reasons for this. The study area was extremely remote and difficult to access, which meant that visits to hair traps were infrequent and opportunistic. Hairs may have been exposed to the elements for 3 to 6 months in traps, and for unknown periods on rub trees. We anticipated that the desiccating conditions in the Gobi would work in favor of long-term preservation of the hair roots. But lengthy periods of exposure to extreme heat and cold, and mechanical abrasion by frequent sand storms, may have contributed to the reduced success rate. The low density of bears also led to infrequent hair captures in our traps, which in turn caused us to rely more on rub trees for samples. Hairs left at rub trees were often single, and were more likely to be shed hairs without roots (C. Strobeck, University of Alberta, Edmonton, personal communication). Sample quality might be improved by placing more traps and monitoring them more frequently.

Two primary goals of our research were to determine a minimum population size and sex ratio for Gobi bears in the GGSPA. Prior to this study estimates ranged from 25 to 35 animals (Zhirnov and Ilyinsky1986, Schaller et al. 1993), with bears nearly equally distributed between the 3 activity centers (B. Choygin, GGSPA, personal communication). We identified a minimum of 16 bears that occur the Shar Khulst and Baruun Tooroi oases, or about 70-95% of the number of animals thought to occur at those oases. The sex ratio of the population remains much less clear with at most 6 animals typed, only 2 of which were females. At least one potentially unique allele and genotype were seen in the material from the Tsagaan Bogd oasis, but those samples provided very little DNA which increases the likelihood of genotyping error (Taberlet et al. 1999) and we did not feel confident about their validity. Information from that oases, then, is completely lacking.

Detecting movement of bears between oases was also an important goal of the study. We identified 6 unique bears using Baruun Tooroi and 8 unique bears using Shar Khulst. Two additional genotypes (G and Hm) appeared at both oases. Because no *P*(ID) or *P*(sib) value in this study met minimum confidence levels (<0.05), we can not say with a high degree of certainty that the matching genotypes represent the same individual, or that they indicate movement of bears between oases. However, if interchange was frequent and widespread we should have seen more instances of genotypes being common to both oases.

Genetic diversity in the overall population is low, characteristic of a small inbred population. To what degree this might be influenced by population isolates within the reserve remains unclear. In only two other bear populations has genetic diversity, expressed as alleles/locus and expected hetrozygosity, been reported to be as low as that of Gobi bears: the 5 animals remaining in the Pyrenees, and Kodiak Island (Table 5-4). Genetic drift operates more rapidly in small populations such as that of the Gobi bear, and resultant inbreeding depression could make them less fit to survive in their extremely harsh and demanding habitat.

The non-invasive genetic techniques we used provided little information on sex ratios, or individual identification that could be used in pedigree analyses or mark-recapture studies. It did provided partial answers to basic questions about the Gobi bear in terms of minimum population size, movements, and genetic diversity. We now need to ask how much more the method can add to our understanding. Testing additional loci might have added information, although in many cases inadequate amounts of DNA were available. More frequent field collections and more hair-traps may also have improved sample quality and reduced the chances of genotyping errors. Funding and logistic obstacles precluded any of these measures during this initial study. Taberlet et al. (1999) warn that the application of these techniques may be most difficult for endangered species with low levels of heterozygosity; certainly, this is true in our case. Continued technological advances may overcome many of the technique's limitations, but costs will increase proportionally.

In the case of the Gobi bear, advancement of knowledge through non-invasive techniques will certainly be costly in financial terms. Yet reverting to capturing and radio-collaring bears could be nearly as expensive and definitely more risky, especially if the sex ratio is as skewed toward males. Loss of any reproductive females could be catastrophic. Proactive management, such as capturing and moving bears between oases to facilitate gene flow is expensive, even more risky, and unlikely to provide any benefit with an overall population this small. Use of non-invasive genetic techniques, with some modifications to overcome realized difficulties, affords the best chance of providing information necessary for conservation planning while putting the remaining bears at the least risk.

With perhaps as few as 25 animals remaining, low genetic diversity, and few females, the Gobi bear is quite likely headed for extinction. However, research and management decisions must consider not only the

Gobi bear's precarious situation, but its uniqueness as well. Our preliminary phylogenetic assessment indicates that the Gobi bear is distinct from any previously identified clade of brown bear in Europe, Russia or North America. However, the Gobi bear may be genetically further removed from geographically close brown bears in Tibet (Massuda et al. 1998) than from their European relatives. Sokolov and Orlov's (1992) designation of the Gobi bear as a distinct species (*Ursus gobiensis*) may not be justified, but the bear does represent a genetically divergent population, which are increasingly being recognized as the appropriate units for conservation regardless of taxonomic status (Moritz 1994). In some respects the Gobi bear then represents an anomaly. It is a genetically unique entity on its way to extinction, which would seemingly call for extreme and urgent conservation measures, such as population augmentation with bears from nearby Tian Shan range, a possibility that has not been explored. Yet conservation biologists argue for preserving not just species, but processes, and the loss of the Gobi bear may be an example of such a natural process. The Gobi has existed in its present form for millennia and this remnant population may well reflect a natural shift in the species assemblage. The bear was tenacious enough to survive in low numbers, and the current lack of anthropogenic disturbances deep in the Park allow it to persist.

We believe that current supplemental feeding and the restrictions on human presence in Gobi bear range should be maintained. Non-invasive genetic appraisal of the population status should continue with modifications to overcome low success rates. Phylogenetic assessment of the Gobi bear's standing among other Ursids, particularly within the region, should be furthered and are essential to determine what additional conservation measures are appropriate.

Table 5-1. Success rates for determining microsatellite genotypes from Gobi bear hair samples, by oasis and for all oases pooled.

Oasis	Samples	Processed	PCR Failed	Incomplete genotype[a]	Typed at 3+ loci[b]	Genotypes seen
Baruun Tooroi	55	32	6	3	23	8
Shar Khulst	120	38	21	3	14	10
Tsagaan Bogd	22	5	3	2	0	0
All Oases	200	75	29	8	38	16

[a] Genotype determined at less than 3 loci.

[b] Three or more loci genotyped.

Table 5-2. Genotype, sex, number of appearances, and source oasis of sample.

	Microsatellite loci (size in bp)								
Genotype	GIA	G10B	G10C	G10L	GID	G10X	Sex	Prev.[a]	Oasis[b]
A	191/191	136/136	104/104	143/143	171/177	133/133	M	3	SK
B	191/191	136/136	104/104	143/143	177/177	133/133		2	SK
C	191191	136/136	104/104	143/143	177/179	133/133	F	3	BT
D	191/191	136/136	104/104	143/153	177/179	133/133	M	1	BT
E	191/191	136/136	106/106	143/143	171/171	133/133		1	SK
F	191/191	136/136	106/106	143/153	177/179	133/133		5	BT
FF	191/195		106/106	143/153	177/179	133/133		1	BT
G	191/191	136/144	104/104	143/143	173/173	133/133		3	BT,SK
Hm	191/191	136/144	104/104	143/153	177/177	133/133	M	6	BT,SK
Hf	191/191	136/144	104/104	143/153	177/177	133/133	F	5	BT
I	191/191	136/156		143/153	173/179	133/133	M	1	SK
J	191/191		106/106	143/153	177/177	133/133		1	BT
K	191/191			143/143	171/173	133/133		1	SK
L	191/191		106/106	143/153	171/177	133/133		1	SK
M	191/191		104/104	143/153	171/179	133/133		1	SK
N			104/104	143/143	171/171			1	SK

[a] Number of times genotype appeared in sample data.

[b] BT = Baruun Tooroi, SK = Shar Khulst

Table 5-3. Allele frequencies, measures of heterozygosity, and alleles per locus for Gobi bears in Mongolia.

		Allele Frequency			Expected Heterozygosity			Observed Heterozygosity			Alleles / Locus		
Locus	Allele	BT	SK	All	BT	SK	All	BT	SK	All	BT	SK	All
G1A	191	0.93	1.00	0.96	0.13	0.00	0.07	0.14	0.00	0.08	2	1	2
	195	0.07	0.00	0.04									
G10B	136	0.80	0.75	0.83	0.32	0.40	0.29	0.40	0.50	0.25	2	3	3
	144	0.20	0.17	0.11									
	156	0.00	0.08	0.06									
G10C	104	0.57	0.75	0.62	0.49	0.38	0.47	0.00	0.00	0.00	2	2	2
	106	0.43	0.25	0.38									
G10L	143	0.64	0.80	0.73	0.46	0.35	0.39	0.71	0.40	0.53	2	2	2
	153	0.36	0.20	0.27									
G1D	171	0.00	0.42	0.27	0.61	0.70	0.71	0.57	0.50	0.60	3	4	4
	173	0.17	0.21	0.13									
	177	0.50	0.26	0.40									
	179	0.33	0.11	0.20									
G10X	133	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1	1	1
Means					0.34	0.31	0.32	0.30	0.30	0.24	2.0	2.2	2.3

Table 5-4. Measures of genetic diversity in various populations of brown, polar, and black bears.

Species	Population	Alleles per locus[a]	Expected heterozygosity[b]
Brown bear	Kodiak Island	2.1	0.265
	Pyrenees	2.0	0.330
	Gobi	2.3	0.337
	Yellowstone	4.4	0.554
	N. Continental Divide	6.8	0.702
	Kluane	7.5	0.763
Polar bear	W. Hudson Bay	5.4	0.626
	N. Beaufort Sea	6.4	0.643
Black bear	Terra Nova Nat. Park	2.6	0.428
	E. Slope Canadian Rockies	8.8	0.819

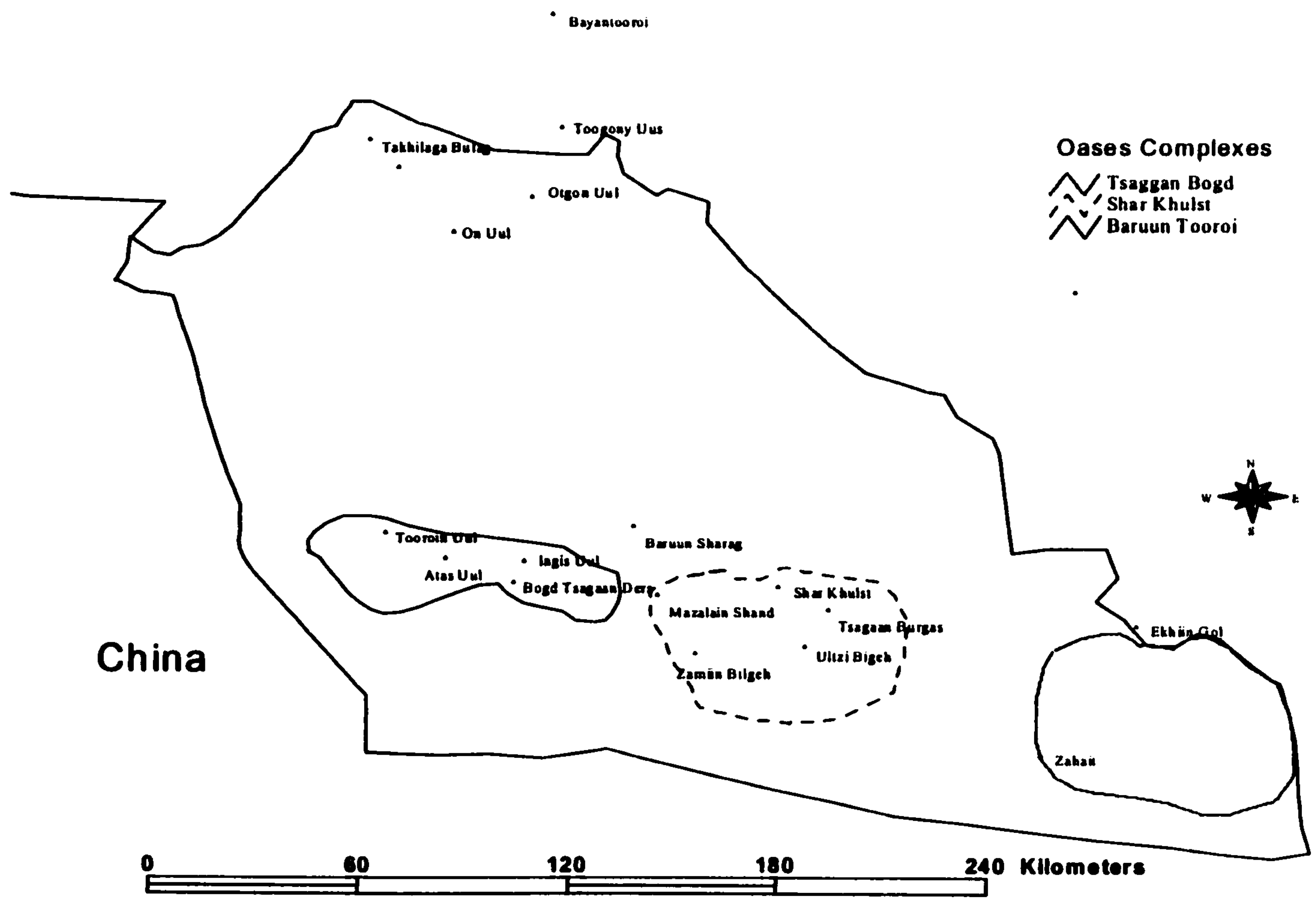


Figure 5-1. Oases complexes used by Gobi bears in the Great Gobi Strict Protected Area, Mongolia.

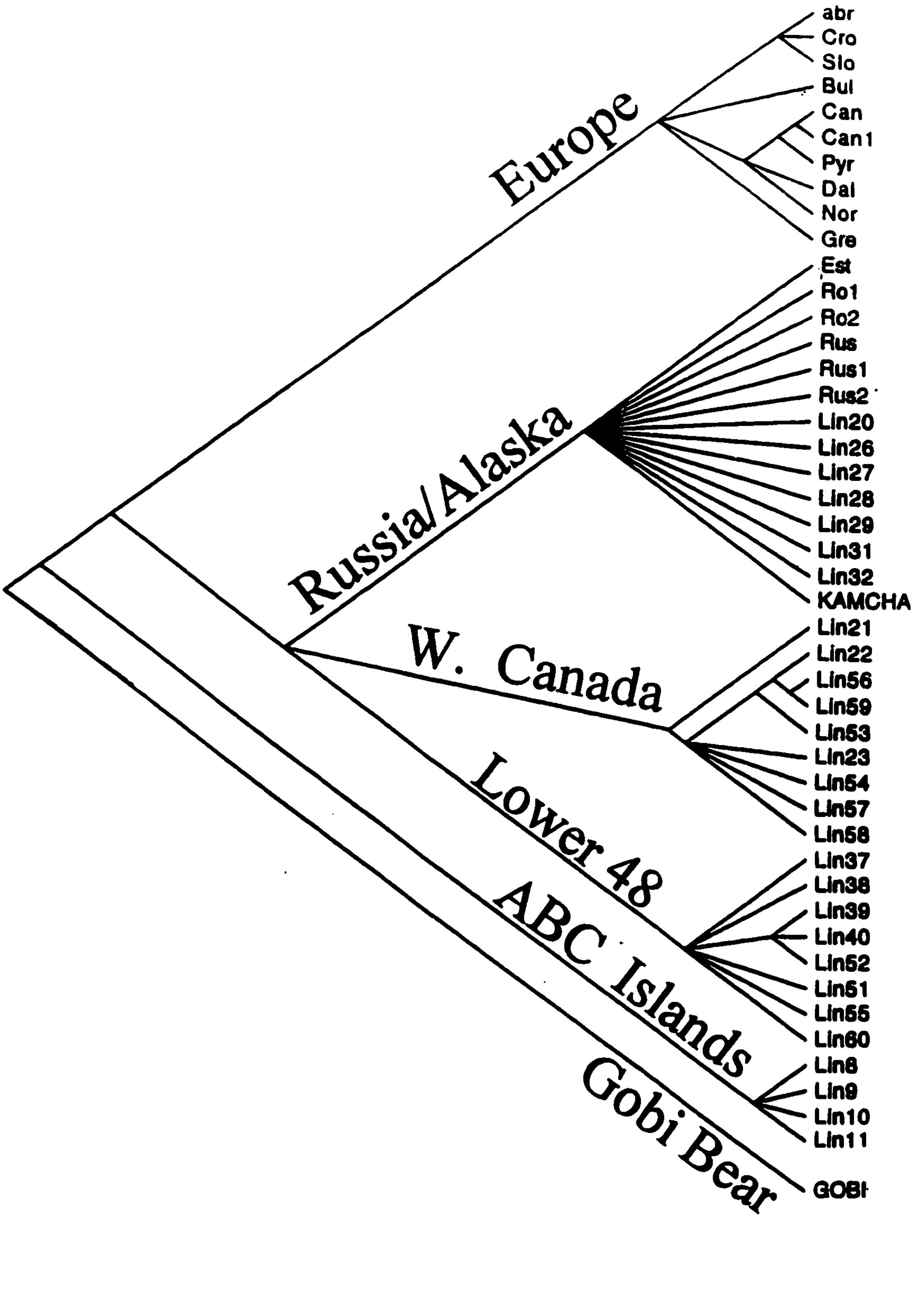


Figure 5-2. Cladogram comparing known brown bear clades and Gobi brown bears.

CHAPTER 6

CONCLUSIONS

This study sought to answer several basic yet pressing questions on the status and ecology of 3 of Mongolia's rarest species; snow leopards, wild Bactrian camels, and Gobi brown bears. Substantial new information on each species has been gained that will be valuable for conservation planning. Data gaps remain, and these have been identified along with suggestions for further research. Particular findings or accomplishments stand out and it may be useful to reiterate these.

The Gobi bear is perhaps the rarest animals in Mongolia, yet one of the least understood. In this study I made the first attempt to scientifically enumerate the population and detect population isolates within the GGNP. Noninvasive genetic techniques proved useful and minimized potential impacts on bears, but needs to be improved and ambiguities reduced. For two of the three activity centers a minimum population size has been established. Movement between activity centers appears to be limited. This bear exhibits characteristics of a highly inbred population and is among the least genetically diverse groups of bears worldwide for which data are available. Phylogenetically the bear is unique among Ursids, and appears distant even to its Asian relatives. The outlook for the bear is poor. Its continued existence may rest on maintaining the current management practices of supplemental feeding and nearly complete protection from human impacts.

Wild camels in the Gobi face only a slightly less uncertain future. A valid population estimate has yet to be made, but the survey system I established with the GGNP staff will allow trend monitoring in a systematic fashion. I verified the lack of young in the herds, but the reasons for such low recruitment are unclear. Population demographics were estimated from limited data, including skulls and tooth ages. Using these and other estimates, a population model was produced that indicates extinction for the species in a short time unless recruitment is improved. However, camel population estimates have remained relatively constant for more than a decade, despite low apparent recruitment. Additional research is urgently needed.

Snow leopards were the primary focus of this study and I determined aspects of their ecology in Mongolia that are unique for the species. Of particular note are the vastly larger individual range sizes and large-scale movements across expanses of open lowland steppe and desert. Snow leopards in Mongolia appear to exist on the ecological fringe of their range and, as prey densities would predict, require much larger home large-scale movements across expanses of open lowland steppe and desert. Snow leopards in Mongolia appear to exist on the ecological fringe of their range and, as prey densities would predict, require much larger home ranges to meet their needs. I refined the estimate for current range in Mongolia and determined that areas in which it was recently reported to occur are now devoid of the cat, or greatly reduced. From a conservation-planning standpoint, leopard use of travel corridors between mountain ranges is of particular importance.

Snow leopards are currently protected in Mongolia, but in practice there was much room for improvements in laws, education, and enforcement. The understanding of leopard ecology and human-leopard interactions gained in this study allowed me to propose a comprehensive conservation management plan for the country. This plan was adopted by government in December 1999, and is the first such species plan to be established in Mongolia. An implementation schedule was approved by relevant agencies and a review board was appointed to monitor progress.

In addition to the publishable findings and management plan, this project provided capacity building at several levels. Long-term monitoring programs for bears, camels and snow leopards are now in place in the Great Gobi National Park (now Great Gobi Strict Protected Area). Park staff have received exposure to the international scientific community and literature, and are co-authors of several of the papers (chapters) presented here. Biologists and managers from most protected areas in Mongolia where snow leopards occur are now skilled at conducting systematic surveys for leopards and prey, and a national database for those results has been established. Over the course of this study, several ecology students from Mongolian universities have been allowed participate, adding much needed practical field experience to their training.

Mongolia, the Gobi in particular, has a unique and rich natural heritage and the three species studied here represent world-class treasures. Their future is contingent upon responsible management based on a sound scientific understanding of each species' status, ecology, and threats. This study was designed and conducted to contribute to that understanding, and it has gone beyond the basic research to implement conservation actions.

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