What Are Snow Leopards Really Eating?

Using Genetics to Reduce Bias in Food Habit Studies

by

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A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Honors Bachelor of Science in Wildlife Conservation with Distinction

Spring 2014

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ACKNOWLEDGMENTS

This publication was made possible by the National Science Foundation EPSCoR Grant No. EPS-0814251 and the State of Delaware. I would like to thank Shannon Kachel for his collaboration and support in designing a method to identify prey species from hair samples and Dr. Kyle McCarthy for his guidance in this project. I would like to thank my other committee members, Dr. Deborah Delaney and Dr. Mark Parcells. I also would like to thank the field crews in Tajikistan and Kyrgyzstan for all their help with scat collection and Dana Goin for all her help in the lab. I would also like to thank Panthera for the scat samples and camera images that made this project possible and the University of Delaware for their support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Food availability is widely recognized as a primary threat to snow leopard (*Panthera uncia*) populations throughout their range. Effective conservation of snow leopards therefore depends upon reliable knowledge of their food habits. Unfortunately, past food habit studies may be inherently biased by the inclusion of non-target species in fecal analysis. Differentiation between snow leopard and sympatric carnivore scat is now cost-effective and reliable using genetic tools. In this study, we leverage fecal DNA analysis to both assess and remove bias in snow leopard food habit studies. We first analyzed presumed snow leopard scats collected from Central Asia, using standard microscopy methods to identify prey species based on medullar and cuticular characteristics of guard hairs found in the scats. We then estimated food habits for each study site under the assumption that all collected feces were of snow leopard origin. We then subset the data to include only snow leopard scats, as verified through fecal DNA, allowing us to compare results and estimate bias. Fecal samples from the four study locations ranged from 21-64% snow leopard. Analyzing all collected scats overestimated the percent occurrence, biomass, and number of small mammals consumed and underestimated these measures for large ungulates in snow leopard diet. Our results show that, lacking genetic analysis of collected fecal samples, scientists likely include a large percentage of scats originating

from other predators, thus altering the results of their studies. This could erroneously shift the target of conservation to more small mammals and fewer ungulates than truly required for a snow leopard population.

Chapter 1

Introduction

Lack of knowledge regarding the life history of a species is a common obstacle in creating conservation measures (Cisneros-Mata et al. 1995). For the snow leopard (*Panthera uncia*), knowledge of dietary habits is one such life history component needed for effective conservation (Shehzad, Mccarthy et al. 2012). By studying snow leopard diet, we can learn which species constitute the most important food source, allowing wildlife managers to design informed conservation initiatives.

Informed conservation strategies are important for snow leopards, as it is estimated that there are only 4,500 -7,500 snow leopards in the wild, and their effective population size is believed to be less than 2,500 (Mccarthy & Chapron 2003). Snow leopards have been considered endangered by the IUCN Red List beginning in 1986, and populations are believed to have declined 20% in the last sixteen years. They are also listed on CITES Appendix I, and most of the 12 countries in which they occur have banned hunting (IUCN 2013).

One major reason for the decline is a decrease in natural prey availability due to hunting, poaching, and competition with livestock (Shehzad, McCarthy et al. 2012). When natural prey populations are low, snow leopards have been found to turn to domestic livestock as a food resource. This can lead to retribution killing of snow leopards by herders, further exacerbating the strain caused by the low food supply

(Mishra 1997). Sharma et al found that 51% of the local population in Langtang National Park, Nepal, held a negative view of snow leopards because of livestock depredation (Sharma et al. 2006). If more wild prey was available, it is likely that predation on domestic livestock would decline (Kachel 2014), decreasing human - wildlife conflict. This would aid in snow leopard conservation, as conservation programs are most effective when the surrounding human population is inclined to protect the species (Treves & Karanth 2003). This further highlights the need for a sound understanding of snow leopard food habits, because knowledge of the most important prey species and the quantities needed to support a snow leopard population are essential for maintaining adequate numbers of prey on the landscape.

Previous studies have examined food habits by analyzing suspected snow leopard scat (Bagchi & Mishra 2006; Jackson et al. 2011; Oli 1994; Shehzad, McCarthy et al. 2012; B. Shrestha 2008). Methods for determining prey composition have included identification of teeth and bones, as well as examinations of hairs extracted from the scat (Bagchi & Mishra 2006; B. Shrestha 2008). Although these studies have provided a baseline for snow leopard prey preferences, their validity has relied heavily on the researcher's ability to discriminate snow leopard feces from that of other species in the area, mainly by using color, shape, location, pugmarks, scrapes, or remains of prey species near the feces (Shehzad et al. 2012*a*). However, many sympatric carnivore scats have similar visual and physical characteristics (Hansen & Jacobsen 1999; Shehzad, McCarthy et al. 2012; Spiering et al. 2009), and thus researchers likely inadvertently included erroneous scat in their diet analysis, altering their results. Shehzad and McCarthy et al. (2012) conducted a study examining the dietary habits of snow leopards in South Gobi, Mongolia in which only 43.3% of samples contained snow leopard DNA sequences. Another study conducted by Jackson et al. (2011) collected only 51.6% genetically confirmed snow leopard scat for their study. This inaccuracy in scat identification has also been found in diet studies for other species. In a diet study for leopard cats in Pakistan, only 21% of collected scats were confirmed to be leopard cat after genetic analysis (Shehzad, Riaz, et al. 2012), while a diet study of common leopards collected only 43.3% genetically confirmed common leopard scats (Koirala et al. 2012). Previous studies that may have a similar amount of bias have found that snow leopards eat large ungulates (*Ovis spp. and Capra spp.*) most frequently, but that they will also consume smaller mammals such as marmot (*Marmota spp.*) and pika (*Ochotona spp.*; Oli et al. 1993).

In this study, I assess the collection error bias in a series of scats that were collected from Central Asia. I leverage genetic sequencing to determine which scats actually came from snow leopards and then compare both naïve and informed snow leopard food habits. This allows me to gain insight into how bias may have impacted previous studies and to discuss how conservation measures can be updated.

Study Sites

Tajikistan: There are an estimated 180-300 snow leopards in Tajikistan, although these numbers are far from certain (McCarthy and Chapron 2003). The single greatest threat to snow leopard survival in Tajikistan is considered to be reduction in habitat quality due to depletion of available wild ungulate prey (McCarthy and Chapron 2003). I used fecal samples collected from two study sites in the Pamir mountains, Madiyan-Pshart and the Murghab Hunting Company Concession (Figure 1).

Madiyan-Pshart is an area roughly encompassed by 73°30'E to 73°45'E, 38°00'N to 38°20'N. The landscape is characterized by the broad river valleys of the Murghab and Pshart drainages, surrounded by steep, nearly vertical, broken terrain, which is dissected by numerous sub-drainages. There were herders camps spaced about 5 km apart along the lengths of the central drainages, and in summer, livestock operations may have extended to well above the 4,000 m in elevation. The town of Murghab, population 4,000, lies approximately 15 km East of the site.

The Murghab Hunting Company Concession in Jartygumbez lies approximately within the coordinates 74°15'E to 74°45'E, 37°30'N to 38°00'N. The Murghab Company uses the area for guided commercial trophy-hunting. Like the Madiyan area, the topography is defined by alternating broad valleys and steep mountains. Human settlements and seasonal camps, and associated livestock management, are far less common in the Jartygumbez area.

Kyrgyzstan: Snow leopard populations in Kyrgyzstan are estimated to be between 150 and 500 individuals (McCarthy and Chapron 2003). Both study areas in Kyrgyzstan are characterized by central river valleys rising steeply to peaks over 4000 m tall. Vegetation in the two areas was similar, consisting mostly of zerophytic grass and barren rock (McCarthy et al. 2008). The SaryChat Ertash Zapovednis study site was a

720km^2 protected area that was part of the Issyk Kul Biosphere Reserve (McCarthy et al. 2008) (Figure 1). The Jangart study area is located about 80 km southeast of SaryChat and is very close to the border with China. For many years, access to this politically sensitive border area was highly restricted, and thus it functioned similar to a protected area. At the time of sample collection, Jangart had recently become a hunting preserve. Although there were no permanent human settlements, hunting camps were set up by local guides and their clients (McCarthy et al. 2008).

Methods

I analyzed suspected snow leopard scat samples previously collected from Tajikistan and Kyrgyzstan. Suspected snow leopard scats from Tajikistan were collected opportunistically as they were encountered. Small portions of each scat were placed in a 10 ml vial with 6 ml of silica desiccant (Kachel 2014). These vials were sent to the Center for Conservation Genetics at the American Museum of Natural History, where genetic sequencing was performed. Suspected snow leopard feces in Kyrgyzstan were collected along SLIMS transects. Scats were collected based on their size, shape, location, and surrounding signs (McCarthy et al. 2008). They were placed in 4mL of 90% ethanol. Genetic analysis was conducted by the Laboratory for Conservation and Ecological Genetics at the Center for Research on Invasive Species and Small Populations, University of Idaho.

I used the portions of the scats that were not sent for genetic sequencing to conduct the diet analysis. Most carnivores ingest at least a small quantity of hair with every meal, while bones and other indigestible structures are often avoided. Even when these structures are consumed, they generally become disrupted, and hair is the only prey remnant that remains intact enough for species identification (Brunner & Coman 1974). For this reason, I used hair features to identify prey.

The most important hair identification characteristic used was the medulla appearance. The medulla is the central core of the hair, and different species produce medullas that look quite different (Figure 2). As a secondary resource, I also examined the scale pattern left by the outer layer (the cortex) of the hair. While scale patterns aid in hair identification, there is greater intraspecific variation and interspecific similarities than there is in medulla appearance (Brunner Coman 1974). To enable comparison of medulla and scale pattern characteristics, I first removed hair samples from the scats with tweezers. I then ran the hairs slowly between the thumb and index finger of my nitrile glove to remove any dirt and debris. If any debris remained attached to the hairs, I rinsed them with water and repeated the process, then allowed them to dry. To aid in microscopy of the hair samples, I painted microscope slides with clear nail polish and allowed them to dry for ten minutes. I then placed the hairs on the slide. This allowed the nail polish to set just enough that the hairs would not stick too tightly but were still able to leave an impression. I next placed a cover slide over the hairs, and applied pressure to the slides overnight using c-clamps and wooden boards. The slides were examined using standard microscopy techniques. I first examined the actual hairs under the microscope to see the medulla pattern and then peeled the hairs off of the slide to examine the scale pattern. Scale and medulla patterns were compared against photographic keys (Brunner and Coman 1974, Shrestha 2008, Anwar et al. 2012) as well as scale patterns from known reference hairs. This allowed me to determine the prey composition of each scat.

To assess how bias may have affected previous snow leopard food habit studies I used a suite of prey composition metrics matched to those from the literature (Chundawat 1992, Oli 1994, Bagchi and Mishra 2006, Shrestha 2008, Prasad Devkota et al. 2013). I first applied these metrics to all samples, i.e., those which were naïvely considered to be snow leopard upon collection. I then applied each metric to our informed dataset of true snow leopard samples. In both cases I assessed food habits at each study site separately, as differences in available prey likely influence the results.

The most basic metric I calculated is the frequency of occurrence of prey items in the scat data. This was found by dividing the number of scats in which an item appeared by the total number of collected scats and multiplied by 100 (Oli et al. 1993). The sum of all frequency of occurrence calculations may be over 100 in some cases, because several scats contained hair from more than one prey species. We also calculated percent occurrence by dividing the total number of scats in which an item was found by the total number of items found multiplied by 100 (Anwar et al. 2011).

Frequency of occurrence or percent occurrence alone are not necessarily accurate measures of relative biomass of prey items consumed. This is because smaller mammals, such as rodents and lagomorphs, have a larger surface area to volume ratio, and thus a greater percentage of the animal is not digestible (Jethva and Jhala 2004). When carnivores eat larger prey items, they can selectively consume the parts of the animal that are more digestible, and thus fewer scats are produced per amount of biomass consumed (Jethva and Jhala 2004). Additionally, consuming greater amounts of meat and smaller amounts of hair or bones produces more liquid scats that would not be collectible in the field (Marker et al. 2003). Therefore, only looking at percent occurrence would overestimate both the biomass and the number of small mammals consumed and underestimate the amount of larger mammals consumed. To account for this problem, several previous studies performed feeding trials, in which they fed a carnivore specified amounts of prey items and counted the number of field collectible scats produced. Using these data, they created an equation that related biomass of the prey species to the number of field collectible scats produced per kg of prey species consumed, and discovered that the larger the prey biomass, the less field collectible scats were produced per kg consumed (Ackerman et al. 1984). Although this type of study has not yet been performed for snow leopards, Bagchi et al. (2006) assumed that biomass of prey consumed to produce a single field collectible scat was similar to cougars (*Felis concolor*), as their body sizes are very similar.

To compare to snow leopard food habits studies which included a biomass consumed formula I followed the methods of Bachi et al. (2006). I used the average biomass of prey species to determine the kg of prey that would produce a single field collectible scat, using the equation $Y=1.98+.035X$, where X=average body weight of prey species involved and Y=biomass of prey consumed to produce a single field collectible scat (Ackerman et al. 1984). Average body weights of prey species were obtained from the literature (Table 1) (Oli 1994, Shrestha et al. 2005, Bagchi and

Mishra 2006). I then determined the amount of biomass of specific prey species consumed by snow leopards by multiplying the calculated Y value by the number of scats found to contain that prey item. I further determined the percentage of the diet by weight each prey species contributed by dividing the biomass of prey eaten by total biomass consumed.

Bagchi et al. concluded that large cats the size of snow leopards require 1.5 kg of food per day, and hence 548 kg per year. However, as about 1/3 of ungulate biomass is inedible, they must actually kill 822 kg of biomass per year (2006). I used this corrective factor to calculate the number of individuals of each prey species required per year by snow leopards by multiplying 822 by the product of the percentage of biomass consumed and the biomass of the prey species and dividing it by 100.

Initially, all of these data were calculated for individual prey species found in the scats. However, species composition varies between different snow leopard habitats, and thus to make this study more widely applicable, I combined prey into two groups: rodents and lagomorphs, and large ungulates. By categorizing prey into these groups, we were able to compare results with studies performed in locations with different prey species.

Results

I analyzed a total of 198 scat samples collected from Tajikistan and 56 collected from Kyrgyzstan. Tajikistan samples were collected during the summer of

2012 and the Kyrgyzstan samples were collected between June and December of 2005. Fecal samples from the four study locations ranged from 21-64% snow leopard, and the overall percentage of snow leopard feces was 36.1% (Figure 3). Fecal samples were most often confused with red fox scat, which comprised an overall 39.6% of collected samples (ranging between 28.6% and 44.7%). 18.4% of the collected samples could not be identified down to predator species using DNA analyses; the majority of these were from the Madiyan study site. This is potentially due to rainy weather conditions at the time of collection, which may have degraded the DNA. Unidentified predator scats were included in the analyses of all scats but were removed when analyzing only snow leopard scats.

Ten different prey species were found in the scats (Table 2). Most scats (78.3%) contained hair from only one prey species, although several had two or even three prey species (18.5% and 3.1% respectively). When more than one species was detected, it was predominately hair from an ungulate species plus hair from a small mammal or lagomorph. One scat sample contained hairs that were too degraded to be identified, and this sample was not included in any analysis. Seven scat samples contained only snow leopard hair, presumably from grooming, and these were excluded from further analysis as well. Many of the scats contained vegetation. Most of the prey species were mammalian, although seven scats contained bird feathers. For comparisons of all collected scats versus snow leopard scats, I focused only on mammalian prey and categorized prey species into two categories: large ungulates, and small mammals and lagomorphs.

Analyzing all collected scats overestimated the frequency of occurrence (Figure 4), percent occurrence (Figure 5), percent biomass consumed (Figure 6), biomass consumed per year (Figure 7), and number of small mammals consumed (Figure 8) and underestimated these measures for ibex and other large ungulates in snow leopard diet. Removing non-snow leopard samples caused an average 42.6 percent decrease in frequency of occurrence of rodents and lagomorphs consumed (ranging from 24.4 - 55.5 percent) and an average 39.2 percent increase in the frequency of occurrence of ungulates consumed (ranging from 12.4 - 59.9 percent). This trend was mirrored in the percent occurrence, with an average 38.7 percent decrease in rodents and lagomorphs consumed (ranging from 27.8 – 48 percent) and an average 51.1 percent increase in ungulates consumed (ranging from 27.1 - 76.8 percent). The same trend was seen in the percent biomass consumed and the biomass eaten annually, with an average 41percent decrease in rodents and lagomorphs consumed (ranging from 29.0-55.9 percent) and an average 20 percent increase in ungulates consumed (ranging from12.9-35.2 percent). There was also an average 59.8 percent decrease in the relative number of rodents and lagomorphs consumed (ranging from 50.0-67.3 percent) and an average 20.4 percent increase in the relative number of ungulates consumed (ranging from 1.2-43.8 percent).

Discussion

Our results show that, lacking species validation of collected fecal samples, e.g., via genetic analysis, scientists likely include a large percentage of scats originating from non-target predators, thus altering the results of their studies. This would potentially shift the target of conservation to maintain more small mammals and fewer ungulates than truly required, and could result in underestimating the yearly availability of ungulate biomass required for a snow leopard population to persist. For example using biased results suggests that a snow leopard population of 10 individuals in Tajikistan would require the biomass equivalent of 42 ibex and 24 argali per year. Using unbiased results, that same population would require the biomass equivalent of 57 ibex and 30 argali (Figure 9). Given that these ungulates need to be surplus animals, the actual total ungulate population size required is even greater.

Given our high error rate in targeted fecal collection there is a high potential that previous studies which did not genetically test scat samples may have skewed results for their diet analysis of snow leopards. For example, Oli et al. (1993) studied snow leopard diet in Nepal. Scats were collected whenever they were found and identified using the same criteria utilized in this study (size, shape, and nearby snow leopard signs such as scrapes or pugmarks). Oli stated that there were “no other predators of similar size to cause confusion” in regards to which scats were being examined, however he did report the presence of red fox (*Vulpes vulpes*) and stone martens (*Martes foina*). In this study, we collected a greater amount of red fox scat than snow leopard scat, and this could significantly alter results. Oli found that blue sheep were the most frequently consumed prey, but that Himalayan marmots also constituted a significant portion of the diet. When marmots were hibernating during the winter months, the snow leopards ate greater numbers of Royal’s pika and domestic livestock (Oli et al. 1993). Because of the lack of genetic testing, this study may have overestimated the importance of marmot and pika in snow leopard diet.

Bagchi et al. (2006) studied snow leopard diet in the Spiti region of the Indian Trans-Himalaya. Scats were identified as snow leopard based on size, shape, and associated signs such as scrapes or pugmarks. The authors found nine different prey items in collected scats. Small mammals comprised 1.8 to 3.4 percent of the diet at the two study sites, while the rest was composed of large ungulates. The authors also mentioned that the only other carnivores active in the region are wolves, which do not utilize the same habitat as snow leopards and thus are not likely to be confused with snow leopard scat. This is consistent with the results of our study, in which *Canis lupis* scats composed only 2.4%. Therefore, there is a higher likelihood that the results of this study are accurate and that little scat misidentification took place.

Chundawat (1992) studied snow leopard dietary habits in Hemis High Altitude National Park, Ladakh, India. Scat samples were collected randomly throughout the study area. Scats were identified based on associated marking signs and were not collected if the author was unsure of the predator identity. Chundawat found that blue sheep was the dominant large mammalian prey item, and that domestic sheep and goat were also common. During the summer, the amount of large mammals found in the scats decreased and small mammals, lagamorphs, and birds comprised the majority of the diet. Marmots were the most common prey during this time, followed by blue sheep. Chundawat reported the presence of several other predators in the study area, including red fox (*Vulpes vulpes*), stone marten (*Martes foina*), Himalayan weasel

(*Mustela siberica*), wolf (*Canis lupus*), and wild dog (Coun alpinus). Since several of these species were confused with snow leopard scat in our study, especially red fox scat, it seems likely that confusion took place in this study as well. Therefore, it is possible that small mammals and rodents are not as significant in the summer diet as concluded by Chundawat.

Shrestha studied snow leopard dietary habits in the Sagarmatha National Park in Nepal (Shrestha 2008). Once again, scats were identified using size, shape, and associated snow leopard signs such as scrapes and pugmarks. This study found that small mammals comprised 7.2% of the diet. The authors reported the presence of hill fox (*Vulpes vulpes*), golden jackal (*Canis aureus*), stone marten (*Martes foina*) and Yellow-throated Himalayan Marten (*Martes flvigula flavigula*). Both fox and stone marten were confused with snow leopard scat in our study, thus the 7.2% reported may be an overestimate of the importance of small mammals in the diet of snow leopards in this region.

Prasad Devkota et al (2013) studied snow leopard dietary habits in Shey Phoksundo National Park, Nepal. Suspected snow leopard scats were collected and identified based on size and associated signs such as scrapes and pugmarks. Predator identity was further corroborated by the presence of snow leopard hairs in the scats. Seven different prey items were found in the scats. The authors found that blue sheep were the dominant prey species consumed, comprising 30% of the diet. Rodents were the second most important prey items, followed by Himalayan marmot and domestic sheep (contributing 17.5%, 15%, and 15% respectively) (Prasad Devkota et al. 2013).

Although the authors do not mention all the predator species present in the park, they do state that 32 species of mammals, including wolves, are known to inhabit the area. Other predator species that have been reported to be in the park are leopards (*Panthera pardus*), small cats, and Himalayan weasels (*Mustela sibirica*) (Prieme and Oksnebjerg 1992). While wolves were not often confused with snow leopards in our study, it seems plausible that the other predator species reported here could have been mistakenly collected as snow leopard, possibly overestimating the importance of rodents and small mammals.

In order to better understand how these previous studies may be biased, it may also be necessary to examine the prey densities in these study areas and determine the prey levels at which snow leopards change their feeding habits (i.e. when do prey densities become low enough that snow leopards may actually switch to eating more small mammals). Moreover, identification of prey species by hair inspection may be an additional source of bias, as hairs from different species may look alike (Shehzad et al. 2012*a*). Therefore, future snow leopard diet studies might also consider conducting genetic analysis on prey hairs removed from collected scats to obtain even more accurate results.

Accurate knowledge of snow leopard diet is essential for effective management programs. If managers do not maintain adequate populations of prey species, it could lead to declines in the snow leopard population, or cause the snow leopards to turn to domestic livestock to fulfill their dietary needs, thus inciting conflict with local populations. This study not only provides a more accurate picture of snow leopard diet, allowing managers to create more targeted and effective conservation programs, but it also has broad implications for other research, as it is likely that many dietary studies conducted on other cat species have had similar scat misidentifications.

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Appendix

Tables and Figures

Table 1 Average Body Weights of Prey Species Used to Calculate the kg of Prey Consumed to Produce a Single Field Collectible Scat

Prey Species	Average Body Weight (kg)
ibex	76
marmot	5.3
bird	1.5
small mammal	0.5
domestic sheep	35
goat	34
hare	3
argali	93.7
pika	0.2
yak	250

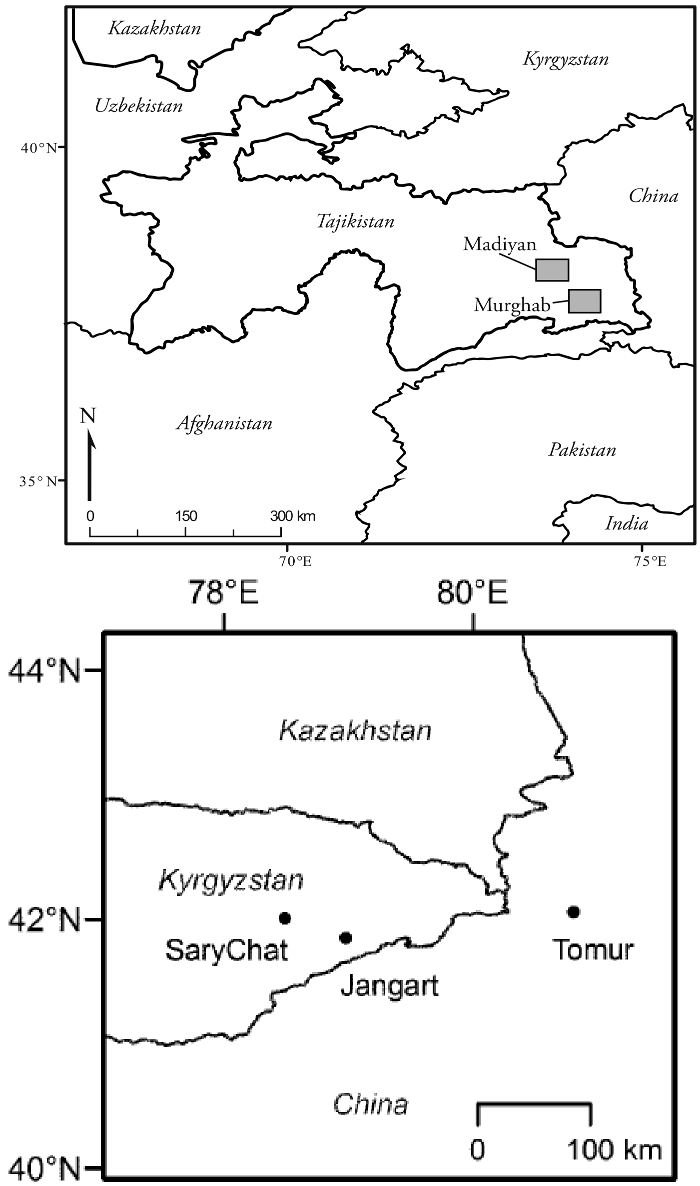

Figure 1 Maps depicting the locations of the study areas. The top map shows the locations of the Tajikistan study areas (Kachel 2014) and the bottom map shows the locations of the Kyrgyzstan study areas (McCarthy et al. 2008).

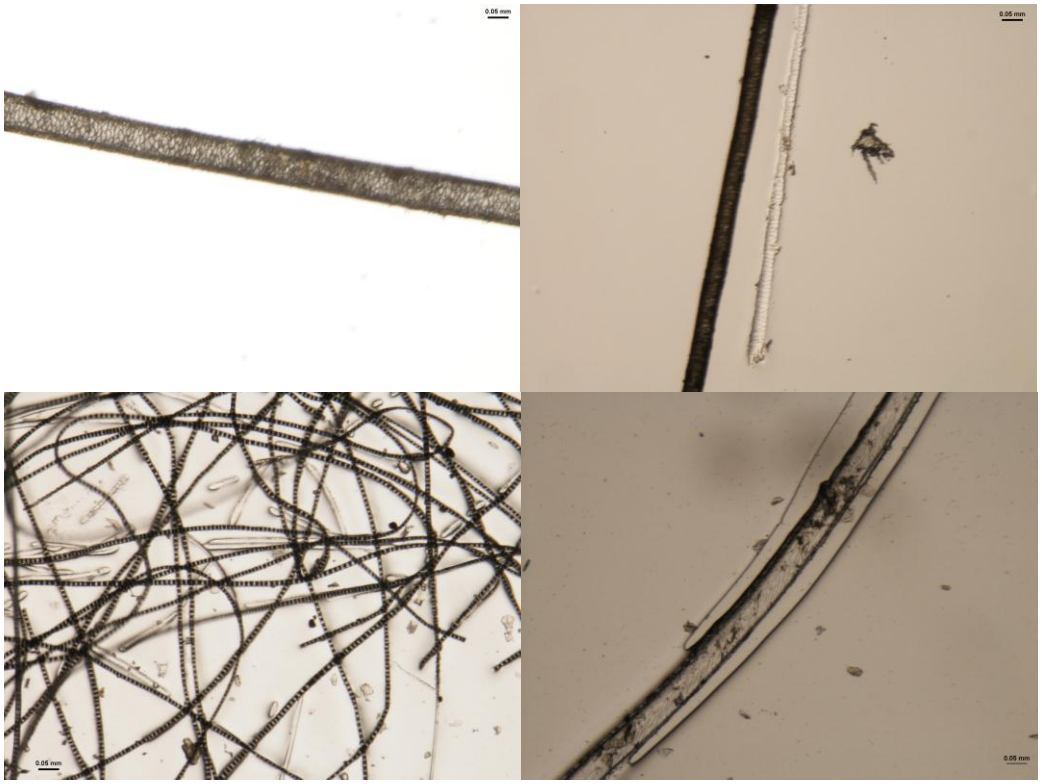

Figure 2 Examples of hair medullas and scale patterns taken with a microscope camera. Top left: ibex medulla. Top right: ibex medulla and ibex scale pattern. Bottom left: pika medullas. Bottom right: hare scale pattern

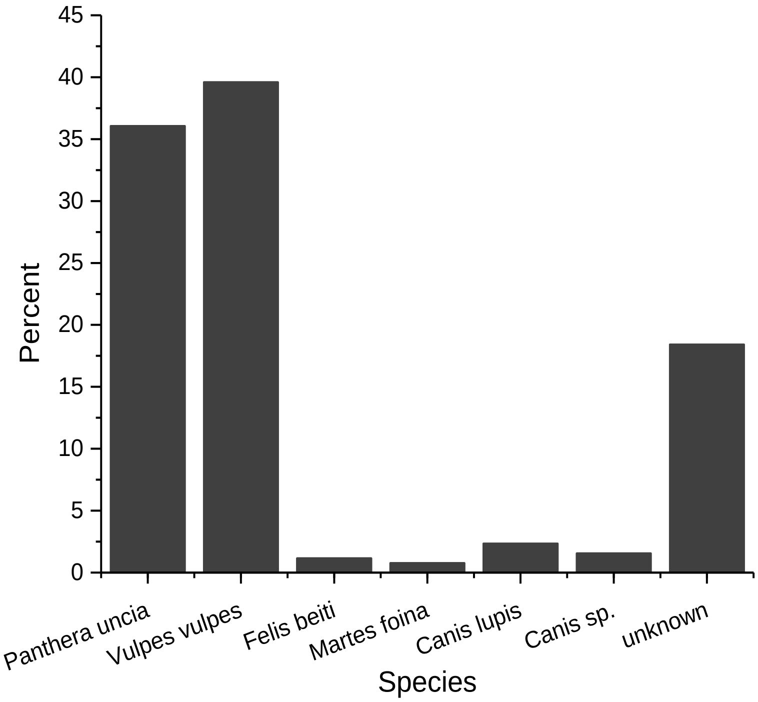

Figure 3 Actual species composition of scat collections from four study areas in Tajikistan and Kyrgyzstan thought to be snow leopard upon collection.

Table 2 Prey Species Found in All Collected Scats and in Snow Leopard Scats from Each Study Area

Species	Scat Type	Site			
		ATO	MAD	JAN	SCE
Ibex	All	29	28	12	5
	SL	18	10	9	3
Marmot	All	39	35	5	10
	SL	13	9	1	4
Bird	All	2	5	1	0
	SL	0	0	1	0
Small Mammal	All	7	17	3	3
	SL	1	0	1	0
Domestic Sheep	All	0	0	2	6
	SL	0	0	2	6
Goat	All	0	9	1	1
	SL	0	1	0	0
Hare	All	9	12	2	6
	SL	2	1	1	1
Argali	All	19	5	0	0
	SL	11	1	0	0
Pika	All	9	7	0	2
	SL	0	0	0	0
Yak	All	3	5	0	0
	SL	0	2	0	0

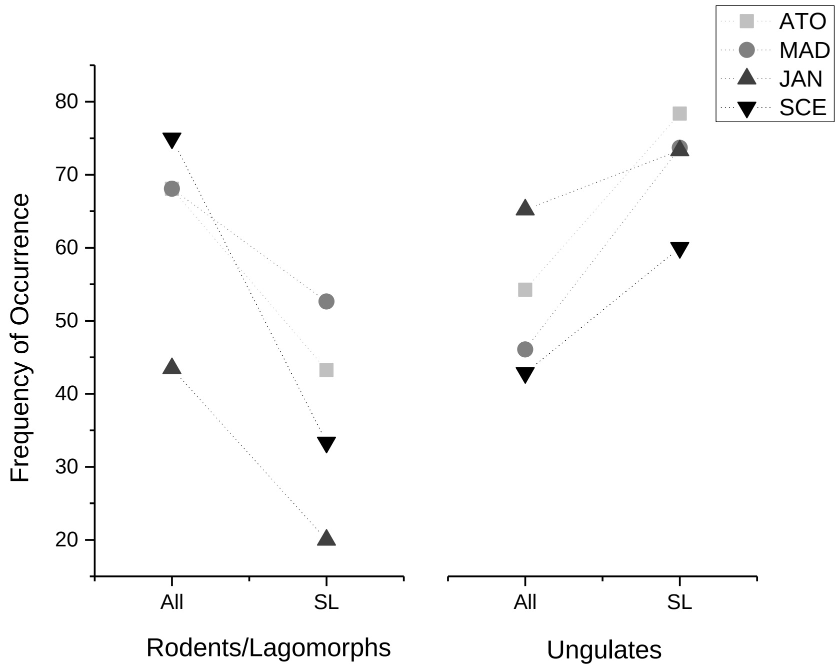

Figure 4 Frequency of occurrence of ungulate species and small mammal species found in all collected scats versus verified snow leopard (SL) scat from four study areas in Tajikistan and Kyrgyzstan. Dotted lines connect study sites for easier display of differences.

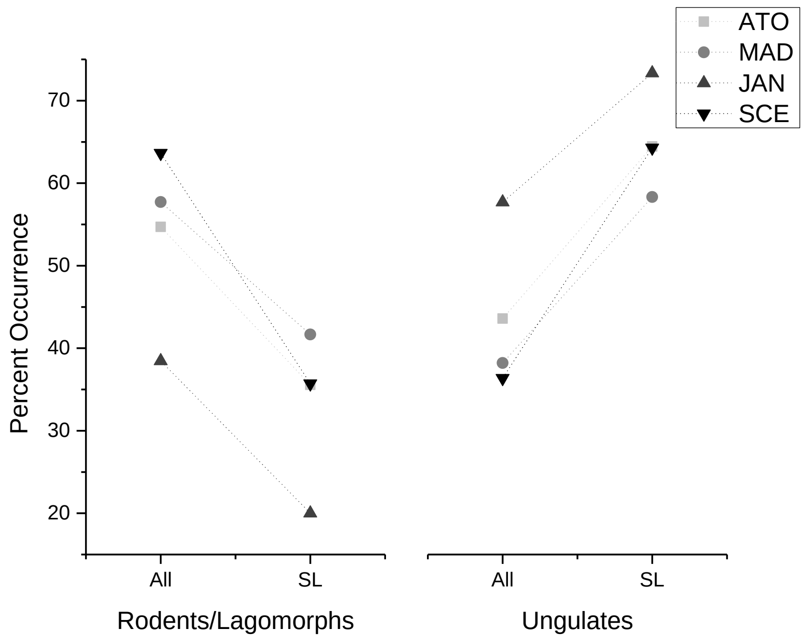

Figure 5 Percent occurrence of ungulate species and small mammal species found in all collected scats versus verified snow leopard (SL) scat from four study areas in Tajikistan and Kyrgyzstan. Dotted lines connect study sites for easier display of differences.

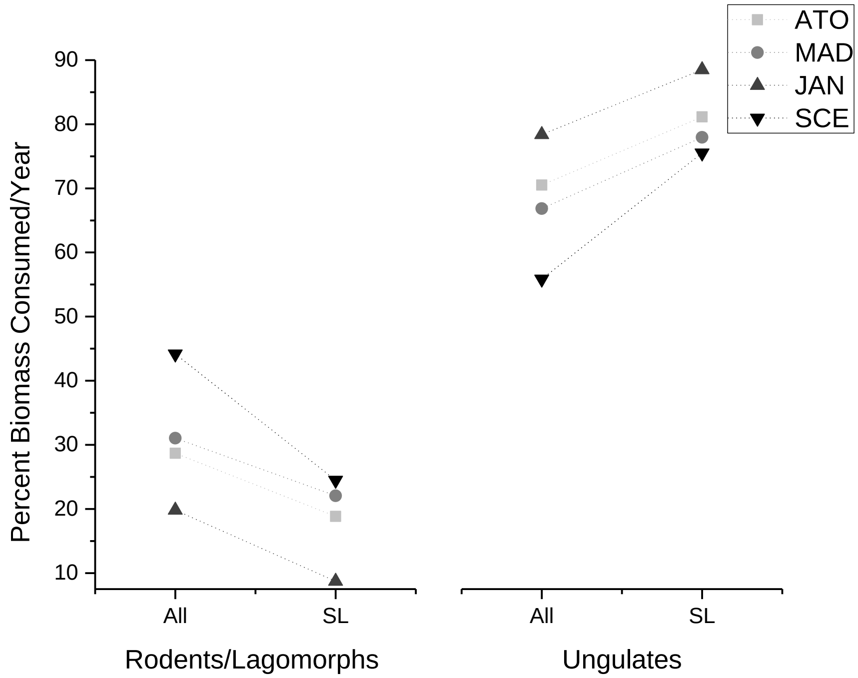

Figure 6 Percent Biomass Consumed/Year of ungulate species and small mammal species found in all collected scats versus verified snow leopard (SL) scat from four study areas in Tajikistan and Kyrgyzstan. Dotted lines connect study sites for easier display of differences.

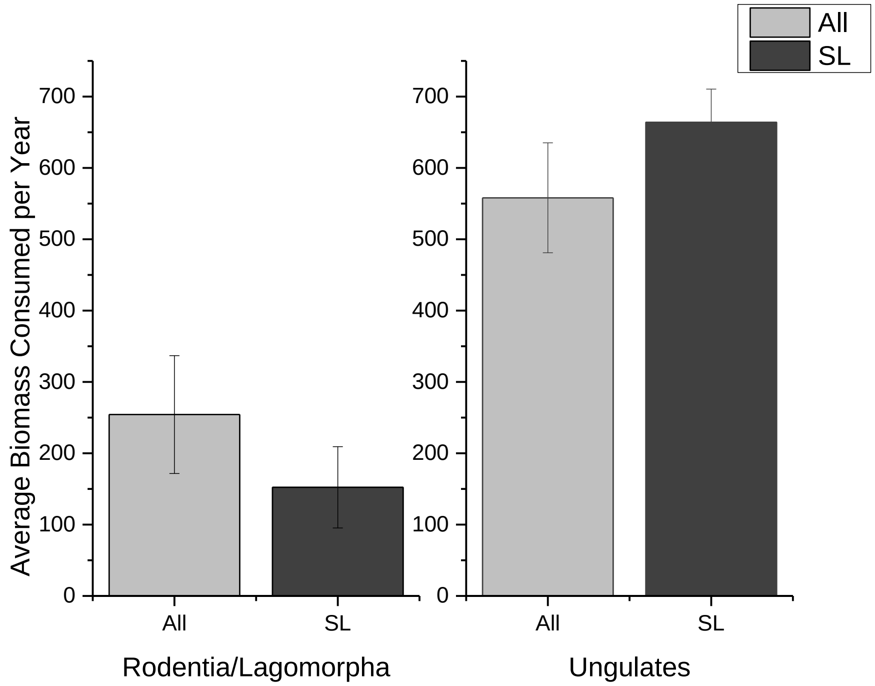

Figure 7 Average biomass consumed per year of ungulate species and small mammal species found in all collected scats versus verified snow leopard (SL) scat from four study areas in Tajikistan and Kyrgyzstan.

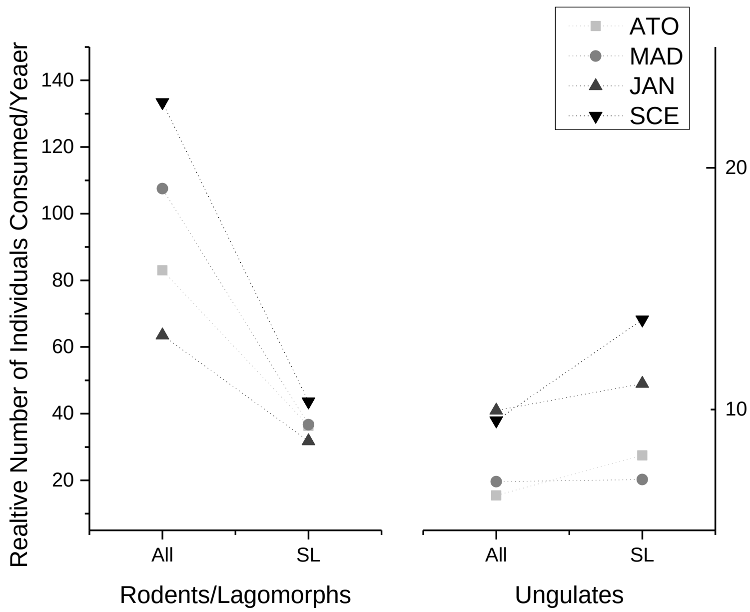

Figure 8 Relative number of individuals consumed per year of ungulate species and small mammal species found in all collected scats versus verified snow leopard (SL) scat from four study areas in Tajikistan and Kyrgyzstan. Dotted lines connect study sites for easier display of differences.

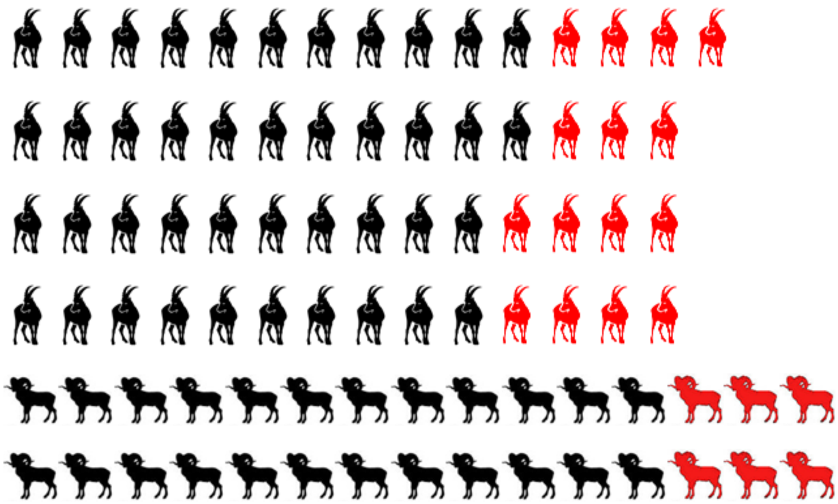

Figure 9 The effect of using biased food habit results in management plans. Black symbols represent the estimated number of yearly surplus prey animals needed by a population of 10 snow leopards based on biased food habit results. The red symbols show the additional number of surplus animals needed when bias is reduced by removing scats from non-target predators through genetic ID.