A Range-Wide Model of Potential Snow Leopard Habitat

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Introduction

The snow leopard (Uncia uncia) inhabits the largest collection of high mountains in the world. Its range, an area about the size of India, extends in a 6,000-km arc along the borders of 13 central Asian countries. Divisions among dozens of mountain ranges create an exceptionally fragmented population, or in today's terms, a metapopulation. Both an indicator of ecological health and a wildlife ambassador, the snow leopard unites conservation programs among countries with disputed borders and contentious politics. Specialists on snow leopard, however, agree that its numbers, overall, are declining. Rugged terrain and solitary behavior make the snow leopard a difficult animal to study - perhaps the least studied of the large cats. Scientific data are scarce and incongruent among range countries, while field studies are expensive, arduous, and politically sensitive, especially along border areas.

We hold the view that a landscape assessment of available habitat can propitiate field studies and help direct the programs of government and non-government organizations (NGOs). As with most other wildlife, snow leopard conservation centers around habitat protection: provide and safeguard ample, suitable habitat and the species will thrive with minimum human intervention. Over the past two decades a small number of field surveys have produced very localized snow leopard habitat maps that cover a small fraction of total range. Since range-wide ground surveys are not practical, we describe the use of geographic information system (GIS) tools to model potential snow leopard habitat from map-based suitability criteria. The GIS model produced a map of potential snow leopard habitat, revealing a new picture of the physical and political landscape upon which the species depends. Merged with other data such as country and protected area boundaries, the model can aid managers and scientists in the artful craft of snow leopard conservation. We use the map and concomitant data to comment on (i) new discoveries about snow leopard habitat, (ii) gaps in protected area coverage, (iii) priority areas for research and surveys, (iv) management recommendations, and (v) future improvements to the model.

The Habitat Model

Modeling potential snow leopard habitat is a geographic or spatial exercise dependent upon maps. For ecological studies, the larger the map scale the better. In Asia, good quality, large scale maps are often classified, locked away by government officials especially fearful of studies in border areas (a seemingly inane concern given the global availability of high resolution satellite data). There is no large-scale map series, however, that covers the entire range of snow leopard. Even if large-scale maps were available, a high quality, large-scale habitat mapping project for snow leopard would require the cooperation of 13 countries and innumerable government departments. We therefore turned to readily available data, eliminating the need for the initial participation of range countries. The Operational Navigation Chart (ONC) 1:1,000,000 series, produced by the United States Defense Mapping Agency, is a worldwide map series; the Digital Chart of the World (DCW) is a commercially available product that is the digital equivalent of the ONC maps, including topographic data

(ESRI 1992). The ONC maps and DCW data formed the geographic foundation for the modeling exercise presented in this paper.

Using ONC paper maps as a base, we hand-drew polygons around the major mountain ranges in central Asia - a key habitat requirement for snow leopard presence (Jackson and Ahlborn 1984). The lower elevation limit of the mountain range polygons varied, following a general north-south vertical gradient. For example, in Mongolia the lower elevation limit was around 1,219 meters (4,000 feet); in Pakistan below 2,743 meters (9,000 feet); in Nepal below 2,743 meters in the west and 3,353 meters (11,000 feet) in the east. Originally, 5,182 meters (17,000 feet) was used as the upper limit throughout the range, but this excluded much of the high plains of the Tibetan Plateau, an area used by snow leopard, so the upper limit in China was extended to 5,486 meters (18,000 feet).

These polygons were then digitized and the resultant map was modified and updated over a two-year period of peer review. Likewise, the boundaries of protected areas were drawn onto the ONC maps and digitized. Green's (1992) Nature Reserves of the Himalaya and the Mountains of Central Asia was the primary reference source for protected areas. Some protected areas (term includes parks, reserves, wildlife sanctuaries, and so forth) lack spatial boundaries, and are thus noted geographically by a point rather than a polygon. Point data were not included in the model described in this paper.

The mountain range polygons and protected area boundaries were combined with the country boundaries from the DCW database to create an initial range map. This map showed the geographic extent of snow leopard range but included areas of unsuitable habitat such as water bodies, glaciers, roads, and population centers. We systematically excluded unsuitable habitat that could be discerned from the geographic database, using the following exclusion parameters:

* areas above 5,182 meters (17,000 feet) - except in China
* permanent snow fields
* permanent water bodies
* areas below lower elevation exclusion zone

Once these areas were extracted (about 500,000 km2), the resultant map portrayed a more accurate picture of potential snow leopard habitat. Since the DCW database contained topographic data it was possible also to model qualitative categories of habitat based largely on slope. Slope is a crude index to ruggedness, another key feature of snow leopard habitat suitability: here higher or steeper slopes equal more rugged and thus better habitat. Habitat quality was modeled into two subjective categories. Fair habitat included areas from 0-30 degrees, and good habitat areas greater than 30 degrees. Marginal use areas such as population centers and transportation corridors were left in the habitat map but included in the fair category based on the following criteria: 10-km buffer around large cities and 5-km buffer around small towns or villages; 2.5 km on each side of major roads and 1.0 km on each side of minor roads. Table 1 portrays the potential habitat of snow leopard separated into two quality categories.

Results

GIS tools were used to produce tables for each country, showing the amount of snow leopard habitat in each quality category and the percent that is included or protected within a park, reserve or wildlife sanctuary (see Table 1). All areas are reported in square kilometers. The numbers in parentheses are earlier estimates of snow leopard habitat derived from smaller scale maps (Fox 1994).

The model revealed two new areas of potential habitat that have, to our knowledge, either not been reported previously or are poorly documented as potential habitat: northern Myanmar (Burma) and Yunnan province in western China. Myanmar raises to thirteen the number of countries with potential snow leopard habitat. These sites were overlooked in previous studies and in the first generation, hand-drawn map. Although the presence of snow leopard has not been verified in Myanmar and possibly also Yunnan, the model suggests both locations may have suitable habitat. The model also shows China, Afghanistan, Mongolia, and Russia to have significantly greater amounts of habitat than previously thought. And China, with 60% of the total potential habitat within its borders, assumes a new level of importance in the overall scheme of snow leopard conservation.

According to the new map, only 6% of total potential snow leopard habitat lies within protected areas. Many countries in central Asia have only recently initated protected area programs, particularly in mountain areas, which have traditionally been under less population pressure than lowlands. As this situation is changing, central Asian governments are attempting to establish new protected areas, striving toward the general target of 10% of each unique biogeographic zone (McNeely and Miller 1984). Thus far, India, Nepal, Bhutan, and Tajikastan are the only countries to meet this target for mountain ecosystems. The other former Soviet republics and Mongolia have substantial snow leopard habitat but have only small percentages protected.

The model suggests the extent of potential snow leopard habitat (approximately 3 million km2) is larger than previous estimates (Fox 1989, 1994). This might be perceived as good news since available habitat may be correlated with population abundance. Yet, as mentioned earlier, the snow leopard population is evidently declining in many areas. We suggest that the higher estimates of available habitat point to the importance of habitat quality, supporting the notion that the snow leopard decline is linked to the loss of suitable habitat, not available habitat. ÿDeclines in prey species, illegal hunting, and human encroachment make habitat fragments less suitable. These figures point to the need for a broader protected areas network and imply a failure in protected area management: "paper parks" may appease western sensibilities but they protect nothing if not actively managed. And while transborder parks sound like good ideas, there are few successful examples.

Discussion

The results of this study must be interpreted with care. Even though a larger-scale map series was used in the model than in previous estimates of habitat, 1:1,000,000 scale is still quite small for wildlife studies. At this scale, and given the vast extent of the map coverage (6,000 km through 30 degrees of latitude), spatial

calculations are affected by the map projection used. In an area this expansive, total area calculations can vary thousands of square kilometers by simply changing the map projection. For this study, the Alberts Conical Equal Area projection was used after preliminary tests rejected Lambert Conformal and Lambert Azimuthal Equal Area projections.

Size and distribution of protected areas, including buffer zones, corridors, and border reserves are too often set by bureaucrats without considering the ecological requirements of the target species. From the map, it is obvious that snow leopard habitat is highly fragmented. Research is needed to establish minimum viable population size and the effects of a fragmented landscape structure on survival and reproduction. The potential habitat map can help prioritize site-specific research and target on-the-ground surveys, for example resolving the status (presence-absence) of snow leopard in Myanmar and Yunnan province, China. With the dissolution of the former Soviet Union, data from the new republics are very rare. The narrow stretch of mountains bordering Kazakstan and China form a fragile connection between Russia-Mongolia populations and those of the southern countries. Field surveys are needed to verify presence along this corridor, thus inferring the potential for genetic mixing across the full range of the snow leopard.

The data for Bhutan are suspect due to blanks in the ONC maps and DCW database. The blank areas could not be reconciled for this or for similar gaps in southeastern China. With no topographic data, slopes could not be calculated, but since the blank areas were clearly in mountainous regions they were put into the fair category rather than being excluded from the model. Protected area boundaries were hand-drawn from imprecise sources, thus introducing another possible source of error. Also, the model contained only the habitat requirements of snow leopard that could be extracted from the geographic database, omitting other criteria such as prey species distribution, competition, grazing pressure, and other potentially important ecological parameters.

The new data presented in this paper can help NGOs and in-country conservation organizations; by establishing a common reference for snow leopard habitat, it makes it easier to communicate and coordinate activities among many different countries. Organizations like the International Snow Leopard Trust (ISLT) and World Wide Fund for Nature (WWF) help turn world attention to the plight of rare species like the snow leopard. For more than a decade, ISLT's conservation programs have helped the snow leopard attain the status of "megaspecies," a transcendent symbol for conserving central Asia's high mountain biodiversity. Under the aegis of snow leopard conservation comes greater protection and attention to many other endangered species, focusing light on the need to protect ecosystems, not just species. Spearheaded by ISLT, Project Snow Leopard (PSL) is a model program (Hunter et al. 1994) for species with large, multinational home ranges. PSL promotes standard survey methods and a common data-sharing network to help unify the conservation measures of many countries, keeping the snow leopard and other rare species thriving for generations to come.

We view this study as a step in an evolving process to build a clearer picture of snow leopard ecology. We hope to correct the geographic

discrepancies mentioned earlier and add the range of prey species such as wild sheep and goats. As the database improves, more sophisticated models will be used to evaluate the spatial distribution of habitat fragments and protected area coverage. We appeal to each country with snow leopards to continue working toward the goals of Project Snow Leopard and ask biologists and managers to correct and add to the potential habitat database maintained by ISLT as errors or new data are found. Queries can be made to this internet address: http://detox.mesc.nbs.gov or email: don_o_hunter@nbs.gov or islt@serv.net

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Table 1. Potential Snow Leopard Habitat (square km) by Country and Quality Category and Percent Protected

Country	Total Habitat	Good	Fair	Percent Protected	Earlier Estimates
Afghanistan	117,653	32,748	84,905	0.3	(50,000)
Bhutan	7,349	1,269	6,080	57.4	(15,000)
China	1,824,316	290,766	1,533,550	6.3	(1,100,000)
India	89,271	33,996	55,275	14.4	(75,000)
Kazakhstan	71,079	14,775	56,304	1.7	(50,000)
Kyrgyzstan	126,162	32,783	93,379	1.1	(105,000)
Mongolia	277,836	21,180	256,656	2.5	(90,000)
Myanmar/Burma	4,730	3,094	1,636	0.0	(0)
Nepal	27,432	12,388	15,044	26.7	(30,000)
Pakistan	81,016	32,348	48,668	6.6	(80,000)
Russia	302,546	41,166	261,380	4.5	(130,000)
Tajikistan	78,440	27,337	51,103	13.3	(100,000)
Uzbekistan	13,834	5,083	8,751	5.8	(10,000)
Disputed Areas	3,064	773	2,291	0.0	
All Countries	3,024,728	549,706	2,475,022	6.0	(1,835,0000)