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REMOTE SENSING SNOW LEOPARD HABITAT IN THE TRANS-HIMALAYA OF INDIA USING SPATIAL MODELS AND SATELLITE IMAGERY PRELIMINARY RESULTS

S.N. Prasad*
R.S. Chundawat*

D.O. Hunter
U.S. Fish and Wildlife Service
National Ecology Research Center
4512 McMurray Avenue
Fort Collins, Colorado USA 80525-3400

H.S. Panwar*
G.S. Rawat*

ABSTRACT

The snow leopard (Panthera uncia) is a flagship species for conservation in the high mountain regions of central Asia. It is endangered throughout its range in Afghanistan, Bhutan, China, India, Mongolia, Nepal, Pakistan, and the Soviet Union. All of these countries are attempting conservation measures that call for new protected areas in representative ecosystems harboring snow leopard. High altitude (mainly above 3,000 m), rugged terrain, and extensive distribution (approximately 1,230,000 km²) make conventional habitat suitability surveys difficult, expensive, and time consuming. This study investigates the use of satellite imagery and geographic information system (GIS) modeling techniques to locate suitable snow leopard habitat in the Zanskar range of the Ladakh district of Jammu and Kashmir state, India. Data on snow leopard predation, habitat conditions, and range of main prey species were gathered by Chundawat (1987-1989) in a study site of 98 km² in the Rumbak valley south of Leh, in the Zanskar range. While in the field, Chundawat prepared thematic maps of the study area for elevation, snow cover, sighting data, kill data, blue sheep use areas, and vegetation data. These data were entered into a GIS and used to help delineate surface features from a satellite image. Using GIS, spatial models of snow leopard habitat suitability were tested and compared against habitat features verified on the ground, and features delineated in a satellite image. Preliminary results show that general physiographic features of snow leopard habitat can be detected using satellite imagery and that GIS cartographic modeling techniques can improve this delineation.

INTRODUCTION

The snow leopard is a rare and endangered felid of high altitudes and steep rugged terrain. Its distribution in India ranges from the northwest Himalayas of Jammu and Kashmir to Himachal Pradesh, Uttar Pradesh, and Sikkim; and to Arunachal Pradesh in the east. At the top of the food chain, the snow leopard is considered an indicator species of high altitude ecosystems (Chundawat et al. 1989). Its primary prey species are blue sheep (Pseudois nayaur) and Himalayan marmot (Marmota bobak) which are found at altitudes ranging from 3,000 to 5,000 m in

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*Wildlife Institute of India
P.O. New Forest
Dehradun - 248 006, INDIA

extremely rugged and precipitous country. Snow leopard home range varies considerably with location and prey density. In Nepal, for example, estimates vary from 5-10/100 km² (Jackson and Ahlborn 1989), to 1.2/100 km² (Schaller 1977). Field ecological studies on snow leopard or its prey species in the Himalaya are daunting tasks because of the vastness of the area involved, hostile weather conditions, and high costs of logistic support (Jackson and Ahlborn 1989). More efficient methods are needed which can help identify potential snow leopard habitat and help manage protected areas once they have been set aside.

Satellite imagery has helped remotely sense earth surface features for more than 20 years. In the United States, Landsat proved very useful in locating grizzly bear habitat in the remote regions of the west (Craighead et al. 1982). Little work has been done, however, in the extremely rugged areas of the world like the Himalayas. Ground truthing is needed to refine the image classes. In the French and Italian alps Landsat was used with moderate success to locate habitat for the alpine ibex (<u>Capra ibex ibex</u>) (Wiersema 1983). Steep, rugged, terrain with ice or snow cover present problems with satellite image interpretation. Shadows, glare, bare ground, and rock are easily misidentified. GIS can help improve the usefulness of satellite imagery for delineating wildlife habitat. Broad habitat features detected in a satellite image can be refined using GIS models of an animal's habitat requirements such as proximity to human habitation, preferred vegetation, seasonal use areas, and prey species use areas.

STUDY AREA

Ladakh is a region of high desert plains and rugged mountains north of the main Himalaya range in India. The average elevation in the eastern plains is over 5,000 m and the region includes mountains with heights ranging from 6,000 to 7,000 m. Temperatures range from -25 °C in the winter to 25 °C in the summer. In the rain shadow of the main Himalaya, this arid region is in the trans-Himalayan physiographic zone. The study area occupies 98 km² in the northern part of Hemis National Park which is situated 27 km to the south of Leh, Ladakh district of Jammu and Kashmir. The satellite image covered a larger area of 100 km² composed of five major drainages that feed into the Indus River: Rumchung, Jingchen, Husing, Rumbak, and Choksti. For GIS analyses, only the Rumbak drainage was mapped. The Rumbak area was intensively studied from 1987 to 1990 (Chundawat et al. 1989). In addition to snow leopard, the mammalian associates of the study area include a diverse assemblage: blue sheep, great Tibetan sheep, Ladakh urial, Asiatic ibex, Tibetan wooly hare, mouse hare, Himalayan marmot, wolf, wild dog, red fox, stone marten, and Himalayan weasel.

METHODS

Thematic data of the study area such as elevation, contours, vegetation, and blue sheep use areas were digitized and entered into a GIS. Cost of digitizing limited contour intervals to 200 m. Vegetation and blue sheep use areas were entered as polygons. Two GIS programs, ArcInfo (Environmental Systems Research Institute, Redlands, California) and EPPL7 (Land Management Information Center, St. Paul, Minnesota) were used to capture and analyze the mapped data. ArcInfo software was used to digitize the map data which was later converted to EPPL7 so that GIS analyses could take place using both programs.

The remote sensing data consisted of a 3-band SPOT satellite image taken in October 1988. The image was obtained from the National Remote Sensing Agency, Hyderabad on floppy diskette medium in a 512 x 512 bytes format. Two image analysis systems were used: ISROVISION, a PC based digital image processing system which operates under Xenix O/S; and, Image Display and Analysis (IDA), a system developed by the U.S.

Agency for International Development to help predict famine in the arid regions of Africa.

Using EPPL7, an aspect map was created for the study area which helped delineate possible snow leopard habitat based on elevation and aspect. The aspect map was found to be accurate but coarse in scale when compared to a topographic map. Vegetation data were overlaid on elevation contours to create another map showing the relationship between altitude and vegetation (Figure 1).

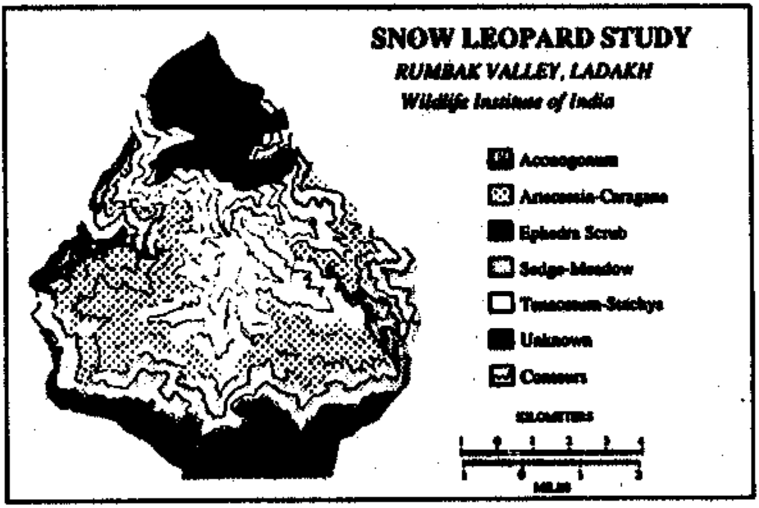

Figure 1. GIS map showing vegetation types and elevation contours for the Rumbak Valley.

To arrive at terrain features and vegetation types from the satellite image, enhancement techniques were used, such as density slicing and principal component analysis (PCA). An unsupervised classification was carried out on the imagery since the number of classes to be delineated was small due to seasonal snow cover. To delineate vegetation, the "normalized different vegetation index" (NDVI) was computed using the band ratio technique:

$$NDVI = \frac{\text{Band 3} - \text{Band 2}}{\text{Band 3} + \text{Band 2}}$$

Band 3 represents the near infrared, the red region was covered by band 2.

False color composites were generated from the three band data corresponding to the first, second, and third principal components generated in the PCA. The analyzed data consisting of 512 x 512 byte scenes were brought together using the IDA system.

RESULTS

A site visit to the study area was conducted in August 1990 to verify the preliminary results of GIS and remote sensing analyses. GIS map products and hard copies of the satellite image were carried into the field for ground truthing. Because of a critical time window for this field trip most of the GIS and image analyses planned for the study were incomplete. The following reports on the GIS and remote sensing analyses results that were substantiated in the field.

GIS Analyses

Once elevation contours were entered into the GIS, it was very easy to produce a new map showing aspects. It was observed that of the 98 km² study area 14.3% faced north, 21.9% northwest, 7.9% east, 10.5% southeast, 6.1% south, 14.5% southwest, 9.3% west, and 15.1% northwest. Ground observation and reference to a topographical map verified these calculations. Aspect above 3,500 m is an important consideration for vegetation which correlates to snow leopard prey availability. The vegetation map overlaid on elevation contours (Figure 1) was accurate given the general classes of vegetation. Like aspect, vegetation at different altitudes is important for modeling the location and habitat of blue sheep.

Remote Sensing Analyses

Density Slicing. The results of density slicing of band 3 SPOT data was found to be suitable compared to Gaussian or linear stretching in identification of various features. Further, the density sliced image in the color coded mode enabled identification of different classes more clearly. Primarily the classes were found to be of various snow melt stages, hard snow, snow-free areas and very highly broken terrain. Jackson and Ahlborn (1989) noted terrain ruggedness as one of the most important habitat requirements of snow leopard.

Principal Component Analysis. Three principal components corresponding to band 1, band 2, and band 3 were obtained with percentage variation 68%, 20%, and 12%, respectively. On assessing principal components 1, 2, and 3 to the image planes red, blue, and green, the resulting image did not show any more detail than was seen by density slicing.

Unsupervised Classification. Unsupervised spectral classes were verified on the ground and found to correspond to the features of interest as far as the general habitat requirements of snow leopard and blue sheep: highly broken terrain, snow cover, aspect, and blue sheep forage.

DISCUSSION

For physiographic spatial analyses involving aspect and elevation, GIS is indeed a rapid tool. However, as expected, a good data set is essential, otherwise, the results obtained are not that accurate. Aspect computation is a case in point. Since the contour data were digitized at only 200 m intervals, the resulting aspect computation missed the smaller aspect sites in the study area. Aspect computation accuracy could have been enhanced by digitizing intermediate contour intervals or by using GIS to interpolate the missing contours. This would have improved the usefulness of the aspect map since small south-facing sites are preference areas for blue sheep and therefore snow leopard. With EPPL7, this was not possible. Some computations aimed at modeling other habitat features such as buffering high relief areas took several hours on a 386 machine with a coprocessor.

Snow cover was easily delineated into snow melt classes. This helps identify habitat during the crucial period of autumn and spring sessions. As far as the terrain analysis is concerned, identification of steep and broken terrain helps in demarcating crucial snow leopard habitat. Shadows in the steep valleys, however, limits the accuracy of classification. The vegetation analysis using NDVI is again an indicator of habitat for blue sheep. Combining these three measures: degree of snow melt, availability of broken terrain, and NDVI, it appears one can predict the general extent of suitable snow leopard habitat in rugged, high altitude environments. However, time series (each season) satellite data is needed to fully exploit the technology. Integration of GIS and remote sensing software on one computer was not achieved. This was due to limited time and technical reasons rather than incompatibility per se.

CONCLUSIONS

The preliminary results were positive for using GIS and remote sensing to identify potential snow leopard and the blue sheep habitat in high altitude ecosystems. Satellite imagery still requires ground truthing to be useful. GIS can help refine the general surface cover features detected in satellite imagery, and while not demonstrated in this study, the ability to develop more sophisticated models of snow leopard habitat using GIS are possible. In principle, the image classes and GIS models in this study should hold for adjacent drainages, or possibly other regions of the Himalayas.

The Himalayas pose a great challenge to biological study. Extreme slopes, poor soils, and increased human encroachment jeopardize the future of this fragile environment and its wildlife denizens. Only about 5.5% of the Indian Himalayas has been set aside as protected areas. An additional 4.5% is planned. Are existing protected areas adequate to preserve the snow leopard? Where should new protected areas be located? Does the spatial distribution of protected areas make sense biologically? These are a few of the urgent questions that stand before biologists and managers concerned with the fate of the endangered snow leopard. GIS and remote sensing are technologies that hold promise--maybe the only promise--for answering some of these questions in time to turn the tide on this noble Himalayan cat.

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