Ecology of the Snow Leopard and Associated Prey in Central Ladakh

INTRODUCTION

The snow leopard (Panthera uncia) is one the least known and most endangered of the world's large cat species (Simon 1970). Within India, the snow leopard occurs along the northern border regions in Arunachal Pradesh, Sikkim, Uttar Pradesh, Himachal Pradesh, and Jammu and Kashmir (Prater 1980, Dang 1967, Osborne et al. 19_3, Mallon 1984). Snow leopard populations have been depleted due to a) hunting for pelts and as retaliation for predation on livestock, b) hunting of the major wild ungulate prey species of snow leopard, and c) the displacement of these prey species from preferred grazing areas by livestock. With continued pressure on the snow leopard from these factors, it is doubtful that it can survive except in a few isolated areas or in captivity.

Recently, India has taken a major step In Identifying the current national conservation status of snow leopard with the initiation of *a* survey project on snow leopard and its prey, which was conducted in 1985-86. The results of these surveys indicate that, although there are still some areas In northwestern India that have what appear to be viable snow leopard populations: 1) some further surveys are required to assess the degree of isolation of these populations and to recommend locations for the further establishment of protected areas, and 2) a research study Is needed to determine the basic biological requirements of snow leopard and Its prey in northern India, to be Incorporated In conservation management programmes for the region. Whereas the proposed research is centered on the snow leopard, the studies are aimed at providing conservation information for all major wildlife species in the high altitude ecosystem of the northwest Himalaya.

Based on snow leopard and prey abundance, as well as logistics and accessibility, the survey project identified the Hemis High Altitude National Park In central Ladakh as the best area for conducting an Intensive research study. A three-year investigation of the snow leopard and its major ungulate prey In central Ladakh, the blue sheep (Pseudois nayaur), is proposed In order to provide basic information on home range, movement patterns, habitat use, food habits, and population structure for these species. A parallel Investigation of human land and natural resource use patterns will provide the basis for determining the type and degree of interaction between man and wildlife in the area. More general surveys of the status of snow leopard, other predators (especially lynx and wolf), and prey species will continue on a more limited scale in several selected sites not yet surveyed in northern India. These studies are designed to be instrumental in building *a* framework for high altitude wildlife conservation research in India.

The studies proposed here will provide important comparative data building upon initial snow leopard research work (Jackson and Ahlborn, in press) recently completed in Nepal. The Nepal study was in an area with dense prey populations, and was generally free of human disturbance. The more desertic conditions and sparser wild prey populations in Ladakh will make useful contrasts with the Nepal study site, and indicates that the India study is essential to estimating snow leopard carrying capacity in the trans-Himalayan region. In addition, the proposed Ladakh study is located in inhabited areas, which will enable investigation of snow leopard interaction with human activities. And this information is basic to the development of wildlife management programmes appropriate to the socio-economic development of the region.

Study Area

Ladakh is the northernmost district in India (33-35° N, 76-79°E), situated between the Himalaya and Karakoram Ranges in the state of Jammu and Kashmir. The region is characterized mostly by high elevation desert, with moister alpine zones in the higher ranges, both north and south. Elevations range between 2700 m and *7300* m, with irrigated

cultivation present in the valley bottoms below 4000 m. The main crops are barley, wheat and vegetables. The population is predominantly Buddhist, with Muslim communities in the towns and predominating in the western portions.

The main study area is located on the south side of the Indus valley in the northwestern corner of the Hemis High Altitude National Park (34 5'N, 77°Z0'E), about 25 km southwest of Leh (the administrative center for Ladakh). Elevations in this part of the park range between 3300 m and 5600 m. The climate is dry (annual precipitation about 10cm); summers are mild with highs near 25 degrees C and winters are cold with highs near 0 degrees C and lows commonly below -20 degrees C. Vegetation is predominantly desert grass and herbaceous communities on the hillsides, with shrub thickets and cultivated willow, poplar, and apricot along the valley bottoms. There are three villages north of the Markha valley in the study area portion of the park, with a population of 94 people and 450 domestic animals (sheep, goats, yak hybrids, horses, donkeys), and small areas of agriculture land.

Snow leopard is the major predator in this area, although wolves (Canis lupus) occur in the open valleys and occasionally enter the rugged mountains. The blue sheep is the most common ungulate, with lesser numbers of Ladakh urial (Ovis orientalis vignei) occurring near the main Indus valley, and a small population of Tibetan argali (Ovis ammon hodgsoni) present on the watershed divide into Markha valley:-Snow leopard tracks were commonly found (and one individual observed) in this area during surveys in 1986.

If the initial research methods prove successful in the small area proposed here, work will probably be extended into nearby areas within the Markha valley to the south. Additional sites for continuation of snow leopard surveys and investigation of other predator and prey occurrence will be selected in consultation with the J&K Department of Wildlife Protection officials in Ladakh.

Objectives

1. Determine snow leopard home range, movement patterns, habitat use, food habits, and population structure.
2. Evaluate the Impact of other large predators on snow leopard land and resource use, including a determination of wolf and lynx distribution, habitat use, and food habits.
3. Determine population structure, distribution, habitat use, activity patterns and food habits of blue sheep a major snow leopard prey species.
4. Determine the prey base of snow leopard in study area (in cooperation with J&K Wildlife Dept.) - population size estimates for blue sheep. urial, marmot, domestic livestock.
5. Determine the effect of livestock on vegetation/ i.e., on forage resources for wild ungulates.
6. Assess snow leopard status in several areas not surveyed during the first year of the project.
7. Evaluate the interaction of human activities and snow leopard ecology.

Methods

1. Habitat classifications

Large scale habitat typing will be delineated from LANDSAT imagery (Fraser 1980, Wiersema 1983) or aerial photographs. if available for the study area. Vegetation

characteristics will be measured in a series of circular plots using a stratified random sampling design (Cochran and Cox 1957) where the strata are based on the large-scale vegetation types identified from LANDSAT imagery or photographs. Initial vegetation description in the Ladakh area has been carried out by Kachroo et al. 1977 and Hartmann 1983. In addition to the vegetation types. areas of steep, rugged escape terrain will be mapped from a combination of photographs. topographic maps. and on-site inspection.

Plant species composition and percent cover, along with exposed ground substrates (e.g., rock, bare ground) will be visually estimated using the relieve' method (Mueller-Dombois 1974). Associated with the vegetation measurements, other habitat variables including elevation, slope, aspect, terrain ruggedness, distance to water, and distance to human habitation will be recorded *for* use In a habitat classification based on Principal Components Analysis (PCA). The vegetation composition and terrain variables will be standardized and subjected to PCA, an ordination technique that can be used to delineate community patterns (Gauch 1982), thus defining distinct habitat components within the study area. These habitat types will be used in later analysis of carrying capacity and habitat use and suitability.

2. Range carrying capacity:

Estimation of range carrying capacity, *forage* production, and trends in range quality will involve the use of a variety of range evaluation methods. Range trend will be determined by changes in plant community composition over time. Permanent 30 m transects will be established in each of the gross vegetation types identified in the classification of habitats. Foliar cover will be measured along the transects using the line-intercept method (Canfield 1950), and plant species density will be measured by counting all plants within four 0.25 sq m rectangular plots placed at 6 m intervals along the transects. Permanent photo-points will be established associated with the transects in each vegetation type, so that changes in plant community characteristics can be documented in the future. Several fenced exclosures will be built in areas used by domestic livestock and/or wild ungulates, to determine the effect of various grazing regimes on vegetation production and species composition.

Forage production for each vegetation type will be measured using a modified double-sampling method (Wilm et al. 1944, Alaback 1982, Fox 1983). Annual production will be measured each year after termination of summer growth. Forage will be remeasured prior to winter snowfall to enable estimates of available forage in each vegetation type during winter (Fox 1983). Occular estimates of forage utilization will be made in each vegetation type. The carrying capacity of critical winter ranges will be estimated using a modification of the approach reported by Potuin and Hout (1983).

3. Habitat use:

Radio telemetry will provide the basis for determining seasonal habitat selection, activity patterns, and movements for the snow leopard and, to a *more* limited extent, the blue sheep. Monitoring 'of each species by radio will continue for at least two years to insure

adequate data on home range sizes, movements, food habits, and productivity. Snow leopards will be captured using either foot snares or box traps, immobilized, and collared. Attempts at capture will be both opportunistic, and associated with live baits, either in the box traps or in conjunction with snares. Local game guards will be consulted concerning areas where blue sheep aggregate, such as at salt licks. If

necessary salt sources will be provided to facilitate capturing. Animals will be captured by a rocket net or the remote injection of immobilizing drug. Five adult or yearling female blue sheep will be radio-collared and followed for the two years of study.

All radio-collared animals will be located at least two or three times each week on a randomly designed schedule. Where possible, all radiolocations will be verified by visual location. Locations will be assigned to an X-Y grid coordinate system accurate to 100 m. This grid coordinate system will be used for determining home range area and movements for each animal. Activity patterns will be determined from the radio-tracking data and from 24-hour tracking periods, using signal integrity to classify the animals as active or inactive at each radio fix. Radio telemetry studies of the mountain lion (Felis concolor) (Seidensticker et a1. 1973) and American mountain goat (Oreamnos americanus) (Rideout 1973, Schoen and Kirchoff 1982, Smith 1985) provide technical and analytical bases for these studies of ecologically similar species in India. Jackson and Ahlborn's (in press) recent radio-tracking study of snow leopard in Nepal provides a basic comparative study for the work outlined here.

Seasonal habitat selection will be determined by two approaches. For both approaches, a secondary level of habitat selection (location of home range within the study area) and a tertiary level (habitat use within an Individual's home range) will be determined (Johnson 1980). The first approach will involve the comparision of use versus availability to determine selection (Neu et al. 1974, Marcum and Loftsgaarden 1980). The percent of use for each habitat category is compared to the percent availability of that category to determine selection. Percent availability for each category will be determined from random sampling of a map of habitat types identified in the study area. Test hypotheses and statistical methods for this approach are detailed in Marcum and Loftsgaarden (198O).

The predominant method for determinations of ungulate habitat use will be based on visual observation through the daylight hours. However, for supplementary measurement of ungulate habitat use on a scale smaller than the accuracy of radio-tracking, pellet-group counts will be used to measure blue sheep and urial use within selected habitats that support measurable use. This will be done only within exclusive ranges of each species. unless discrimination between species' pellets is possible. The pellet-group technique (Neff 1968) is useful in inaccessible areas where there is substantial use and has proved successful in studies on mountain goat (Fox 1983) and Japanese serow (Morisita et al. 1977). For example, ungulate use of habitat in relation to distance from escape terrain should be important in explaining habitat *use* (Fox 1983), and is more accurately measured using pellet-group counts than radio-telemetry. Circular plots (3m diameter) will be randomly located within the habitat types previously identified. The plots will be swept clear of pellets, checked (pellet-groups counted) and cleared every three months.

For the snow leopard an additional approach to an assessment of habitat selection will involve the systematic documentation of travel routes (Hargis and McCullough 1984). Snow leopard tracks will be followed in snow, with randomly selected segments of the route characterized with respect to habitat variables. This technique gives a measure *of* habitat use, and when contrasted with available habitat, habitat selection.

The second overall approach to seasonal habitat selection is based on the radio-tracking data and will use Discriminent Function Analysis (DFA) to determine which habitat variables best discriminant between habitat and non-habitat for each species (Cooley and Lohnes 1971, Morrison 1976, Fox et al. 1982). The discriminant function coefficients produced will be used in construction of the habitat suitability models.

Whereas the blue sheep is relatively common throughout central Ladakh, the Ladakh

urial is more restricted in its distribution and is thus more venerable. An assessment of habitat separation between the blue sheep and urial is possible with *DFA*, and may facilitate identification of suitable areas for urial management or reestablishment. The *DFA* approach will also provide quantitative assessments of habitat quality for snow leopards and will be used in developing the habitat suitability model and identifying potential habitat for this species.

4. Population dynamics:

Initial population data on the snow leopard will be based mainly on indirect methods such as systematic counts of various sign. Presence *of* young and adults can be determined from track size, and characteristic variation in pug marks *may* allow individual identification. Transects through suspected snow leopard habitat will provide frequency estimates *of* pug marks, scrapes, and scats. Certain terrain features such as bluff-tops or cola along ridgelines appear to be heavily used by snow leopards traversing their home range (Schaller 1977, Jackson and Ahlborn in press), and commonly used routes are marked with scent, feces, and scrapes in the dirt, which are often left at prominent locations such as trail junctions or bends, ridge crests, and bluffs. Transects which incorporate these key terrain features and measure frequency of sign can be used as a relative index of snow leopard abundance in an area. Interviews with local inhabitants will supplement this data. along with any direct observation of snow leopards.

As the study progresses and captures are made. animals will be aged and sexed as they are caught. The captured snow leopards will be measured (standard museum measurements). weighed. and photographed. They will be individually marked with ear tags and fitted with radio collars. Age will be estimated in the field by teeth replacement and wear (Pocock 1916). Foot-pad characteristics will be recorded for possible individual identification of tracks. and a sample of ectoparasites will be taken when feasible. A blood sample will be taken for establishing baseline blood values for wild snow leopards.

Population dynamics of blue sheep and urial will be based on visual counts where classification by age and sex Is possible (Schaller 1977. Wegge 1979. Wilson 1981). The data on group size. sex and age categories will be collected using binoculars or telescope. Using marked animals in an intensively studied subpopulation. estimates of the accuracy of the visual counts is possible through tag-recapture methods (Chapman and Overton 1966). The pe1let-group counts used in assessing habitat use can also be used as an index of population size when correlated with known ungulate density or in conjunction with estimates of defecation rates (Neff 1968. Morisita et al. 1977).

All blue sheep captured will be weighed. sexed. and aged by incisor replacement (up to four years) and horn annuli. Physical condition will be determined and a blood sample will be collected for establishing population health characteristics (Seal 1978) and for genetic analysis. All captured individuals will be ear- tagged with a colored. numbered plastic tag. and each will be individually marked using color-coded ear-streamers. collars or by painting horns. Observations of marked and unmarked animals will be made from a series of transects that will be run over a three to five day period each month. Within the subpopulation that includes marked animals an estimate of visual count accuracy will be determined using mark-recapture methods (recapture will be by observation) (e.g. Stevens 1983).

Biological materials from leopard-killed blue sheep and urial will be collected (e.g... lower jaw. kidney with fat. femur. rumen contents) for determination of prey age and physical condition. Similar material from hunter-killed or accidental deaths of these

wild ungulates will also be collected for other baseline data on population health.

5. Food Habitats

Seasonal food habits for the snow leopard will be based on analysis of scats (Korschgen 1971. Grobler and Wilson 1972, Weingart 1974). and the examination of known or suspected kills. All scats identified as snow leopard will be collected from the study area at all times of year. Wolf scats will also be collected and analyzed for determination of diet overlap with snow leopards. A collection of hair samples from potential prey species will be prepared on microscope slides for use in identification of scat contents. Snow leopard kills will be examined for evidence of killing method (e.g... size and location of tooth punctures, claw marks. and presence of subcutaneous blood at wounds) and the parts and amounts of carcass eaten.

Seasonal food habits of the blue sheep and urial will be based primarily on microhistological analysis of composite fecal samples (Sparks and Malechek 1968, Vavra and Holechek 198O). A composite sample of fresh fecal material from 10-15 individual pellet groups will! be collected monthly for each species. Forage will be gathered, identified, and air-dried seasonally for use in preparation of reference slides for the microhistological analysis. Rumen samples will be collected from hunter-killed or other recently dead animals. Diet analysis will follow microhistological techniques described by Sparks and Malachek (1968).

6. Habitat suitability model:

A habitat suitability index model will be developed for the snow leopard, blue sheep and Ladakh urial. These models will utilize. expand upon, and adapt to Ladakh's environmental circumstances the preliminary efforts in developing habitat suitability index models for snow leopard (Jackson and Ahlborn 1984) and the American mountain goat (Fox et al... in prep.). Habitat characteristics used in such models include variables such as vegetation type and canopy coverage, slope angle and aspect, distance to cover (steep. broken terrain). and physical or ecological isolating barriers (e.g... a dense forest or a wide valley). Variables related to human activity include the pattern and density of human settlement, livestock grazing pressure, livestock depredation by snow leopard, and the hunting or trapping of snow leopards.

The models will be computer-based and will be used in the assessment of habitat quality for each species. The discriminant functions produced in explaining and predicting habitat use for snow leopard and blue sheep will be used in constructing the appropriate habitat suitability model (U.S. Fish and Wildlife Service 1981).

7. Wildlife and man

Local government officials and village leaders will be consulted to obtain data and information on human population, livestock numbers, pastoral and agricultural practices, and development programs in the study area. Inhabitants of the study area and vicinity will be interviewed with regard to their experience with and attitude toward wildlife species in the region. Questionnaires and interview formats were experimented with during the 1985-86 survey projects, and will be further developed in cooperation with wildlife extension personnel at the Wildlife Institute of India.

8. Surveys of snow leopard, other predators, and prey species:

A continuation of the surveys on snow leopard and associated species begun In 1985 (Fox et al. 1986) will be based on methodology developed in those surveys and by Alhborn and Jackson (in press).

Reports and Publications

Quarterly progress reports will be prepared for the Government of India and other cooperating agencies and supporters. Annual reports will summarize accomplishments and present data analyzed up to date of preparation. Several papers are tentatively planned for publication in international journals, as follows:

1. Ecology of the snow leopard in Ladakh. Wildlife Institute of India Monographs
2. Predator- prey relations for large mammals in Hemis National Park. Bombay Journal of Natural History
3. Status of the snow leopard in Northern India. Oryx, or Biological Conservation
4. Ecology of blue sheep in the Hemis National Park, Ladakh. Journal of Wildlife Management
5. Classification of wildlife habitats in Hemis National Park, Ladakh. Journal of Range Management
6. Human land use impacts on wildlife in Ladakh. Mountain Research and Development
7. Status of large predators and prey in Ladakh. Oryx.

Ahlborn, G., and R. Jackson. in press. Marking in wild snow leopards: a preliminary assessment. Int. Ped. Hook on Snow Leopards 5.

Alaback, P. 1982. Dynamics of understory biomass in Sitka spruce western hemlock forests of southeast Alaska. Ecology 63: 1932-1948.

Braden, K.E. 1983. The geographic distribution of snow leopards in the USSR: Maps of areas of snow leopard habitation in the USSR. IntI. Pedigree Book of Snow Leopards 3:25-39.

Canfield, R.H. 1950. Sampling ranges by the line interception method, plant cover, composition, density, and degree of forage use. U.S. Dept. Agric., For. Serv., Southwestern For. and Range Exp. Sta. Research Rep. 1. Tucson, Arizona.

Champion, H.G. and S.K. Seth. 1960. Forest types of India.

Crawford, A.R. 1974. The Indus suture line, the Himalaya Tibet and Gondwana land. Geo. Mg. - 111:369-383.

Chapman, D.G., and W.S. Overton. 1966. Estimating and testing differences between population levels by the Schnabel estimation method. J. Wildl. Manage. 30;173-180.

Cochran, W.G., and F.M. Cox. 1957. Experimental design. 2nd ed. John Wiley and Sons, New York.

Cooley, W.W., and P.R. Lohnes. 1971. Multivariate data analysis. John Wiley and Sons, New York.

Dabadghao, P.M. and K.A. Shankarnarayan. 1973. Grass Cover of India. Indian Council of Agriculture research, New Delhi

Dang, H. 1961. A natural sanctuary in the Himalaya: Nanda Devi and the Rishi Ganga basin. J. Bombay Nat. hist. Soc. 58:707-714.

Dang, H. 1967. The snow leopard and its prey. The Cheetal 10;72-84.

Dhar, U. and P. Kachroo. 1983. Alpine flora of Kashmir Himalaya. Scientific Publisher, Jodhpur.

Fox, J.L., C.A. Smith, and K.J. Raedeke. 1982. Mountain goat ecology on Cleveland Peninsula, Alaska 1980-1982. Final Rep. Coop. Agrmt. PNW-82-197 Pacific Northwest For. and Range Exp. Station and Univ. Washington. 41 p ((((Biblio incomplete))))