Snow Leopard Conservation on a Regional Basis: Elements in Planning Protected Areas

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Although snow leopards (*Uncia uncia*) are declining throughout most of their range, no country has developed a National Snow Leopard Protection Plan, or conversely, endorsed its extinction. Human impact on snow leopard populations, prey species and habitat has been due largely to independent, small decisions on the part of local people to increase grazing, hunting, poaching, and depredation. The cumulative effect of these actions are significant, and in fact many regional environmental resources may be adversely affected by such "small decision" effects (Odum 1982). This "invisible hand" policy, in lieu of positive action based on rational analysis, may not produce optimal or desired solutions for society (Hardin 1968).

Life-history statistics are needed to ascertain the requirements of populations, particularly rare species or those which need special habitat elements. Natural history information on snow leopards is limited, but accumulating. However, studies on other large, ecologically similar mammals may provide useful insights for management and augment the knowledge base available to decision-makers. In addition, conservation biologists need to preserve diversity on a broader basis. Island biogeography and landscape ecology (Forman and Gordon 1986) suggest strategies for conservation of preserve areas as well as the surrounding landscape. Both emphasize structural components which form interacting units. This integrated approach to preservation, highlighting ecosystem integrity, seeks to mitigate deterioration on the regional landscape (Noss 1983, Noss and Harris 1986).

As the human population increases in both number and influence, conflicts for alternative uses of the land become more severe. Governments, local peoples, and resource managers need accurate, timely, and sophisticated information upon which to base decisions, mediate conflicting demands, and to insure long-term integrity of ecosystems. Cooperation among these various groups to realize interdependent goals is becoming more crucial. Ideally, pure and applied science should augment each other in generating guiding principles, goals, knowledge, and options for long-term management. In practice, however, resource decisions must be made on the basis of limited knowledge. The cost of inaction may be high (Soule 1986), auguring for multi-faceted approaches to the problem. Conservation biologists could assist resource planners and managers in attaining societal goals by offering guidelines for rare species which are sensitive to biological, economic and ecological factors.

LIFE-HISTORY PARAMETERS

Delineation of home-range characteristics and dynamics, especially through radio-telemetry data, is essential for determining reserve size and the relation of snow leopard movements to surrounding areas. The concept of minimum viable populations (MVP) emphasizes that demographic, environmental, and genetic variability, and natural catastrophes have an effect on the long-term survival of isolated populations (Shaffer 1981). Preserves that are not designed and managed with various life-history parameters in mind increase the probability that these populations will not survive.

Home Range

Animals with large area requirements or special habitat needs are usually the most vulnerable to human-induced environmental change: their preservation is heavily dependent on a regional management system. Large contiguous areas are needed to protect snow leopards, but their habitat is increasingly fragmented by natural and human-caused barriers (Jackson and Ahlborn 1991). Home ranges of 12-39 km^2 have been reported for snow leopards in west Nepal (Jackson and Ahlborn 1986, 1989), 53-1,183 km^2 for Florida panthers (*Felis concolor coryi*) in southern Florida (Maehr et al. 1991), and 10-40 km^2 for jaguar (*Panthera onca*) in Belize (Rabinowitz and Nottingham 1986). This variety in home range size reflects differing food sources, social organization, habitat, and human impact on these different species. Generally, for many wide-ranging carnivore species, home-ranges are smaller in higher quality habitat or areas protected from human encroachment. As such snow leopards living in marginal habitat or unprotected areas likely require larger home-ranges and consequently a given population needs more space. Craighead (1980) reported on the large spatial requirements, seasonal ranges, travel corridors, and yearly variation in land-tenure for determining critical habitat for grizzly bears (*Ursus arctos*). Thus, designations of "enclaves" of critical habitat would be antithetical to the integrated use of the landscape by grizzlies. Until more radio-telemetry data becomes available on snow leopard populations in a variety of habitat conditions, we suggest that an average home-range of 75 - 100 km^2 is a reasonable estimate in determining preserve sizes. Preserve sizes of 5,000 to 10,000 km^2 are recommended for populations of 50-100 cats.

Seasonal Shifts

Although Jackson and Ahlborn (1989) observed no seasonal ranges due to a sedentary prey base, these movements may occur in other parts of snow leopard range where ungulates migrate (Roberts 1977, Novikov 1956). Whether seasonal movement patterns are important considerations in the design of preserves for snow leopards is not known at this point. However, seasonal patterns of foraging took black bears (*Ursus americanus*) out of protected areas in east Tennessee, which sometimes resulted in death for these individuals (Garshelis and Pelton 1981, Villarrubia 1982). During years of low food production, the availability of food resources surrounding preserves was important to bear survivability. Consideration of seasonal availability of ungulates and lack of human interference in using these areas, particularly when native prey species are low, is likely important in designing and managing sanctuaries and surrounding habitat for snow leopards.

Core areas

Many researchers, studying a variety of large mammals, report home-range overlap and use of limited core areas, especially where food is abundant and reliable (Villarrubia 1982, Rabinowitz and Nottingham 1986, Jackson and Ahlborn 1989). Rugged habitat, cliffs, and broken terrain also appear important to snow leopards as movement corridors, bedding sites, and hunting areas (Fox et al. 1986, Jackson and Ahlborn 1984). Available food sources and lack of human habitat and harassment appear to be essential elements of quality snow leopard habitat, both inside and outside of nature preserves. Identification of these areas, possibly using satellite and shuttle imagery, the delineation of other needed habitat elements, and connections among them is necessary to provide landscape heterogeneity for snow leopards and their prey.

Dispersal

Dispersal is another component to consider in preserve design and management. Movements of subadult animals, usually males, from natal areas to surrounding sometimes suboptimum habitat, is a prominent feature of many large mammal's life history. These travels, often exploratory in nature, enable young animals to find areas relatively free of competing resident adults in which to establish their own home-range. Decreased survivorship often occurs due to increased aggression with conspecifics competing for space and negative encounters with humans (Villarrubia 1982, Van Dyke et al. 1986, Maehr et al. 1991). Although no radio-telemetry data on snow leopard dispersal exists, studies on other large mammals provide some insight. In eastern Tennessee, subadult or male black bears were documented as moving out of more protected areas (national park, bear sanctuary areas) to less secure regions, indicating that sanctuaries provide a nucleus of breeding bears for dispersal (Garshelis and Pelton 1981, Villarrubia 1982). Studies on mountain lions also indicate dispersal of subadult animals, particularly males, from areas populated by resident adult lions. Uninterrupted reproduction of resident females is enhanced by transient animals which replace residents that have died. With more limited habitat and dispersal opportunities or changes in land-tenure of residents due to hunting, increased aggression among mountain lions occurs which may affect survivorship (Logan et al. 1986, Van Dyke et al. 1986, Maehr et al. 1991). A viable population of non-resident, transient individuals is important in maintaining optimum recruitment, breeding success, and long-term persistence of the population in sanctuary and non-sanctuary areas.

LANDSCAPE ECOLOGY

For practical reasons, many preserves are managed as if they exist apart from the surrounding matrix of disturbed and "semi-natural" ecosystems. Increasingly, however, formulations such as landscape ecology and empirical studies (Kushlan 1979, Craighead 1980, Maehr 1990) promote a regional basis for land-use and animal preservation practices. Island biogeography theory deals with the rates of colonization and extinction on islands and has been extended to isolated and fragmented habitats (Diamond 1975, Whitcomb et al. 1976). More specifically, this theory recommends large size, preservation of different habitats, and connections (corridors) among preserves to promote gene flow and recolonization. Forman and Gordon (1986) define landscape as "a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout". There are spatial relationships and interactions among the ecosystems comprising a landscape and this structure and function can change over time. Pickett and Thompson (1976) have suggested that nature reserve size be based on the minimum dynamic area, defined as "the smallest area with a natural disturbance regime which maintains internal recolonization sources and minimizes extinction." From this viewpoint, landscape heterogeneity and ecosystem integrity are important components to consider in preserve design and management. Disturbances to ecosystem function outside the preserve can adversely affect species inside protected areas. For example, changes in the amount and timing of water released to the Everglades National Park in Florida, despite its relatively large area, have adversely affected many species of wading birds (Kushlan 1979). This underscores limitations of using only life-history information and advocates regional planning and approaches emphasizing ecosystem integrity. Some important elements for planners to consider in designing preserves for snow leopards are given in Table 1.

Fragmentation

Fragmentation occurs when landscapes are broken up into smaller areas, and isolated from each other by dissimilar habitat. Some of the effects of fragmentation include reduction in population size, increased extinction rates, disruption of dispersal **TABLE 1. Design criteria for snow leopard protected areas and buffer zones (Adapted from Jackson and Ahlborn 1984, 1991)**

Protected (PA) and Core Areas (CA)

* Large tracts of mountainous land (5,000 - 10,000 km^2 or larger)
* Areas with no or few permanent human habitations (a density of 1 - 5 villages per 100 km^2 or less)
* Mixture of terrain types, with rocky slopes, cliffs, broken areas and gorges well represented
* Habitat for large ungulate prey species (e.g., blue sheep, ibex) over large areas
* Habitat for all seasons should be located within PA boundary

Buffer Zones (BZ)

* Limit expansion of human settlements near PA's
* Protect prey populations and critical wintering habitat
* Promote guarding of livestock and construct secure nighttime corrals
* Minimize hunting or disturbance of wildlife
* Manage and enhance natural resources, including forage, timber and fuel to decrease dependency of communities upon resources located within the PA
* Promote tourism development to strengthen PA and generate income for local people

and immigration, genetic deterioration, and social dysfunction (Wilcove et al. 1986, Wilcove 1987). Secondary extinctions due to reciprocal dependencies among species, shifting of populations and habitats over time and space, and changes in ecosystem function may occur.

Snow leopards, which roam quite widely, will likely be adversely affected by the insularization process. Loss or shifts in core area, travel routes, and hunting sites to more marginal habitat due to fragmentation are likely very detrimental to individual snow leopards and consequently to the population of a particular area. Snow leopards need rugged terrain near pastures or meadows for hunting cover and as travel corridors within home-ranges or along dispersal areas. Increased human use of hunting habitat may reduce a snow leopard's hunting success by directly competing for available prey or indirectly through habitat alteration and the modification of its or its prey's activity. Buffer areas may be needed to limit human activity around core areas of snow leopard habitat. Research in the Amazon (Lovejoy et al. 1986) is demonstrating the need for buffer areas to mitigate changes to stable, core areas from surrounding disturbed land.

Despite rationale and empirical data supporting the need for larger reserves for snow leopards, fragmentation and increased pressures on habitat will persist. As a result, resource managers need techniques, which, in-lieu of more optimal strategies (larger resources), mitigate population declines and disruption of ecosystem function. Alternative and conflicting demands are a reality of land-use. Flexibility in addressing these differing goals is paramount in the application of a land management strategy. An emerging construct, which encompasses both the preservation and consumptive aspects of land-use, is the multiple use module (MUM), and other related issues (Noss 1983, Noss and Harris 1986). This strategy seeks to preserve nodes of diversity at all biological levels, create networks of nodes and buffer zones, and promote long-term planning and ecological integrity (Figure 1). A node can be any element of a population or landscape which is threatened or in need of conservation. Core areas, cliff borders or non-resident animals are examples of nodes of diversity with respect to snow leopard ecology. Nodes may vary spatio-temporally as denning sites or hunting areas change seasonally or from year to year. Identification of nodes important to snow leopard survival is a high priority for their conservation. As noted above, dispersal is an integral aspect of the ecology of a wide-ranging species. Therefore connections or corridors among nodes to form networks of important habitat features should be a reasonable conservation strategy (Noss and Harris 1986, Burkey

FIGURE 1. Schematic relationship showing four core areas (CA), buffer zones (BZ) and corridors (CO).

1988). Maehr (1990, Maehr et al. 1991) noted that Florida panthers use connections among various habitat elements and these corridors may be crucial in maintaining populations levels. Multiple use modules, which consist of protected core areas with increasing levels of human use radiating from the center, are a management tool that can implement these conservation networks. Table 2 provides preliminary recommendations for locating and designing corridors to link snow leopard reserves.

Jackson and Ahlborn (1990) estimate that 65% of the snow leopard population in Nepal reside in unprotected areas. Consequently, including non-reserve areas in a regional conservation plan for snow leopards is imperative. Transborder parks, such

TABLE 2. Linking protected areas with corridors and minimizing barrier effects (Adapted from Jackson and Ahlborn 1984, 1991).

Corridors (CO)

* Locate along mountain ranges offering optimal snow leopard landscape, topography and habitat
* Implement land-use planning (multiple use modules) which keeps corridors intact
* Avoid reliance upon narrow corridors encumbered by "bottle-necks" or barriers (corridor should be wide enough to encompass home range of at least two individuals, or more than 20 - 40 km)
* If possible, select the most direct route to link neighboring PA's
* Provide economic and other incentives to pastoralists who protect snow leopards and their prey
* Promote development projects which are sustainable and that generate income for local people

Barriers to the dispersal of snow leopards

* Continuous forests, wide open plains and rolling hills *lacking* rocky outcrops or cliffs
* Large rivers or lakes

* Corridors which are too narrow to encompass at least one snow leopard's home range
* Extensive snowfields and terrain above 6,000 m in elevation
* Mountain ranges separated by wide, open low-elevation valleys
* Scarcity of natural prey requiring snow leopards to subsist on livestock
* Areas with many people and human settlements

as Sagarmatha and Makalu-Barun National Parks in Nepal and the Qomolangma Nature Preserve in Tibet, China serve as focal points of snow leopard survival and dispersal. As such, existing and new transborder preserves deserve special attention as significant sanctuaries benefitting snow leopards. Areas of ecological importance to snow leopards can be identified through standardized surveys (Hunter and Jackson 1992) or more intensive radio-telemetry studies. The multiple use concept can be used to protect, connect, and manage these areas in a manner more conducive to snow leopard survival (Miller and Jackson 1992). The problem of cumulative effects on habitat destruction could thereby be substantially ameliorated.

PEOPLE

Politicians and conservationists alike agree that preservation will not work if the day-to-day needs of people, especially the rural poor, are not taken into consideration. Furthermore, for any development activity to be sustainable, it must be based upon accepted conservation principles and ecological standards (Dasmann 1988). Achieving this admittedly idealistic, but imminently practical goal, however, is another matter. Identifying the conflicts between humans and wildlife is a necessary process in gaining understanding and implementing procedures to mitigate the problems. Some of these concerns are adequately documented for snow leopards. Major issues include grazing by domestic animals which compete for habitat and forage used by the leopard's natural prey, retaliatory hunting for depredations caused by leopards, and hunting pressures on leopards and their prey (Fox et al. 1991, Mallon 1991). Snow leopards seem to prefer areas of low village density (Jackson and Ahlborn 1991) and human presence. Increased accessibility through roads, hunting and other secondary impacts is known to adversely affect other large mammals (Schaller pers. comm., Van Dyke et al. 1986). Although black bears were tolerant of low intensity oil development, females (having a strong attachment to home ranges), could be displaced by such activity (Tietje and Ruff 1983). The multiple use concept helps to mitigate these conflicts by providing for the protection of ecologically significant areas and allowing appropriate uses by people in less sensitive habitat. Landscape ecology stresses the adjustment of human usage to the sensitivity of the habitat, maintenance of corridors, and natural disturbance regimes (Forman and Gordon 1986). To accomplish this, cooperation among national and regional governments, as well as the involvement of local peoples, is imperative.

In some way, peoples' and society's goals with respect to wildlife conservation must be made congruent if some degree of success is to be realized. The condition of local peoples and unprotected lands seem to be important considerations in this regard. Naess (1986) has argued that social conditions such as war and poverty usually consume peoples' attention more than an "identification with all life forms".

CONCLUSIONS

It is becoming increasingly evident that preserves alone are not the answer to conservation of wildlife and its habitat. In addition, involvement of local peoples in conservation efforts through training and empowering communities to manage their resources more effectively will lessen pressures upon natural resources. Benefits to the local economy through tourism, livestock management, or controlled trophy hunting seem to be necessary for a change in attitude from a basic survival approach to occur. Development projects must be sustainable and directed toward alleviating poverty. With an improved standard of life, people can better afford to embrace nature conservation. Techniques, such as the MUM strategy, which addresses both snow leopard and human needs, may help in the integration among snow leopards, preserves, and people.

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