Snow leopard conservation in the wild - a comprehensive perspective on a low density and highly fragmented population

Full Text:

Since the First International Snow Leopard Symposium in Helsinki in 1978 heralded a critical mass of professional interest in the conservation of snow leopard, participation has been increasing and broadening. The first several symposia dealt almost entirely with the health, breeding and organized conservation of snow leopards in captivity, and while this important focus continues, there has in recent years been an initiation and rapid increase in studies and information from wild populations. Largely due to the efforts of the International Snow Leopard Trust (ISLT), initial thoughts on the possible imminent need for reintroduction of captive animals to native ranges has given way to an agreed priority on conservation in the wild, complemented with zoo-based captive breeding and conservation education programs. Resolutions agreed on at the symposium held in India in 1986, for example, include the pronouncement that captive population size is currently sufficient, given the inevitable occasional unplanned additions (e.g., chance capture of cubs or adults), to preclude the need for supplementation by deliberate capture from the wild. That conclusion has now also been accepted within China as indicated in the resolutions of the present symposium. The last three symposia (India, Kazakhstan, China) have now been held in countries with native snow leopard populations, the primary objective of which has been to both inform and to enhance in-country conservation initiatives regarding snow leopard and the ecosystems they symbolize.

As we have more clearly realized that sufficient populations remain in the wild to allow recovery of the species there without reintroductions, the focus of wild conservation efforts has concentrated on the protection and study of these populations. Recent detailed studies and field surveys (Chundawat 1992, Fox et al. 1991b, Jackson and Ahlborn 1988, Koshkarev 1989, Oli 1991, Schaller et al. 1988a, 1988b) have greatly increased our knowledge of snow leopard ecology, distribution and abundance, and with field studies currently under way or being initiated in China and Mongolia (Hillard 1992, Schaller et al., this symposium) the development of a required data base by ISLT (see Hunter et al., this symposium) for determining critical habitat and other conservation requirements for the snow leopard is progressing.

With current estimates of overall snow leopard numbers in the range of 4,500-7,500 (see below), we may rightly begin to ask whether the snow leopard is really in danger of extinction. As there is no consistent limit to the population size that determines viability and threat of extinction across species (Soulé 1987, Boyce 1992), specific information on habitat requirements, breeding habits and population biology are essential for effectively determining such threat. And where the overall population is disjunct, as is clearly the case with snow leopard, the size of subpopulations, dispersal patterns and genetic diversity all strongly affect extinction probability. As data on snow leopard demography, life history characteristics and habitat requirements improve, we are in an increasingly better position to utilize modern techniques in conservation biology to evaluate the status of snow leopard. Management initiatives regarding snow leopard must be rooted in human considerations, as the "parks, people and snow leopards" theme of this symposium highlights, but whatever actions are taken require a scientific background based on the best possible use of available biological information for the species.

CURRENT DISTRIBUTION AND POPULATION

Range

The snow leopard is restricted in its distribution to the mountain regions of central Asia. Thus delimited, its range is a mix of long narrow mountain systems and islands of mountain habitat scattered throughout a vast region surrounding the central Asian deserts and plateaus. Core areas of snow leopard habitat are present around the periphery of the Tibetan plateau and Taklimakan desert in the Himalaya, Karakoram, Hindu Kush, Pamir, Kun Lun, Tien Shan, and Altay mountain ranges. Such separation into pockets and long fingers of habitat isolates populations and naturally predisposes the snow leopard to extinction processes associated with further fragmentation.

In an attempt to illustrate on a large scale the tenuous and patchy character of snow leopard occurrence, I have taken the regions reported as snow leopard range (Schaller 1972, Green 1988) and used more recent and detailed information on distribution (Schaller et al. 1988a, 1988b, this symposium, Fox et al. 1991, Buzurukov, pers. comm., Koshkarev 1990, pers. comm.) to map our current knowledge of snow leopard range (Figure 1). In areas where detailed information is lacking, good habitat is assumed to be associated with rugged mountain terrain, using satellite imagery and space photographs where maps are

poor. Areas are also identified where substantial uncertainty still exists regarding the continued presence of low density snow leopard populations. The entire range of snow leopard, based on this map and calculated by image analyzing computer, is approximately 2,300,000 km^2. Eliminating the areas of high uncertainty where large gaps in distribution or very low numbers are suspected (e.g., parts of the Tibetan plateau), total snow leopard

FIGURE 1. Distributional range of the snow leopard. Lightly shaded areas indicate regions where substantial uncertainty still exists regarding the presence or absence of low density populations.

range is about 1,600,000 km^2. It should be clearly understood that this is still a preliminary evaluation of snow leopard distribution and further refinement of boundaries may either expand or diminish ranges in different areas.

Such mapping greatly enhances our conception of the narrow and isolated character of snow leopard range, notably when compared to the earlier maps (e.g., Schaller 1972) and especially in areas such as western China. This patchy distribution of appropriate habitat for snow leopards over much of their range has thus become quite clear in recent years. For example, the most recent snow leopard distribution map for Mongolia (Schaller et al., this symposium), shows a much more fragmented distribution as compared to maps of only a decade ago (e.g., Mallon 1984a), a result both of better knowledge and current trends toward additional fragmentation. Furthermore, as stated in relation to the recent distribution map for Mongolia, in part of the country "the snow leopard's range is highly fragmented even in continuous mountain tracts" (Schaller et al., this symposium). The natural topographical separation of snow leopard habitat into islands and narrow peninsulas, and the further fragmentation of populations as a result of hunting, trapping and the effects of human disturbance is of great concern when considering the continued persistence of small resident populations in many parts of snow leopard range.

Population

The snow leopard was originally considered endangered, for example on Schedule I of the 1972 Convention on International Trade in Endangered Species of Flora and Fauna (CITES), on the basis of very conservative estimates and very large gaps in information on populations throughout its range, as evidenced in IUCN Red Data Book reports of that time. Early CITES estimates of snow leopard status were based on the only published information available on populations, for example the claim by Dang (1967) that there were only about 200-600 in the entire Himalayan region. Thus, one of the major advances of the past 15 years has been the improvement in our information on current distribution and abundance, with the realization that there actually remain in the wild substantially more snow leopards than was originally suspected.

Based on published figures from the past 15 years Fox (1989) suggested a minimum estimate of 1,200,000 km^2 for overall snow leopard range and Green (1988) and Fox (1989) compiled overall population estimates of at least 2,000 to 4,000 snow leopards throughout this range, while at the same time acknowledging that numbers from significant portions of know distribution were lacking. More recent population estimates from areas previously without data (e.g., 2,000 in China, Schaller 1990), plus conservative numbers for countries without published estimates (e.g., Bhutan, 100-200; Afghanistan, 100-200), indicate that total numbers throughout all of snow leopard range may be somewhere between 4,500 and 7,500 (Table 1). Published distribution maps for snow leopard are not always in close agreement with areal distribution figures given, and this discrepancy accounts for the difference between the 1,600,000 km^2 from Figure 1 and the total in Table 1. At any rate, based on **TABLE 1. Distribution area and population estimates for snow leopard in the various countries throughout its range.**

Country	Area of habitat (km^2)	Estimated population	Source
Afghanistan	50,000	100-200	area-based estimates (low density)

Bhutan	15,000	100-200	area-based estimates (moderate density)	
China	1,100,000		2,000-2,500	Schaller 1990, Jackson 1992
India	75,000	200600	Chundawat et al. 1988, Fox et al. 1991	
Kazakhstan		50,000	180-200	Annenkov 1990, Zhirjakov 1990
Kyrgyzstan		105,000	800-1400	Zhirjakov 1990, Koshkarev *pers. comm.*
Mongolia		90,000	5001000	Green 1988, Schaller et al., this symposium
Nepal	30,000	350500	Jackson *pers. comm.*	
Pakistan	80,000	100250	Schaller 1976, 1977	
Russia	130,000	50-150	Smirnov et al. 1990, Koshkarev *pers. comm.*	
Tajikistan		100,000	120-300	Sokov 1990, Buzurukov *pers. comm.*
Uzbekistan		10,000	10-50	Braden 1982, Koshkarev *pers. comm.*
TOTAL	1,835,000		4,5107,350	

regional estimates and current knowledge of distribution, a total figure of approximately 6,000 snow leopards does not appear unreasonable.

Given the indications we have of snow leopard disappearance for some areas and decreasing trends in other populations (e.g., Koshkarev, this symposium, Schaller, this symposium), the more critical it becomes to obtain information on demography, dispersal patterns and genetic diversity to assess risks to isolated populations. Recognizing the relatively low density of snow leopard that has been reported over large areas of good habitat (<1/100 km^2) (Fox et al. 1991b, Koshkarev 1989, Mallon 1984b, Schaller 1988b), fragmentation may be an especially critical problem, and such data, especially dispersal behavior (Burkey 1988), will be important in assessing viability (extinction probability) of the various subpopulations that encompass snow leopard range.

With intensively studied snow leopard populations in prime habitats displaying overlapping home ranges estimated at 10-30 km^2 and population densities of 5-8 per 100 km^2 (Jackson and Ahlborn 1989, Chundawat 1992, Schaller et al., this symposium), and with an average density of 1/270 km^2 over their entire distribution, it is apparent that snow leopards have a significantly clumped pattern of distribution throughout their already fragmented range. Thus, significant parts of snow leopard range shown in Figure 1 must constitute areas of density less than the average 1/270 km^2, suggesting that occurrence is probably very patchy in these areas also. Although Figure 1 provides an indication of the attenuation and fragmentation of populations and represents more realistically than previous maps the reality of snow leopard distribution today, both the accuracy and stability of patch location and boundaries in the figure will require substantial checking and revision over time.

There has been much recent discussion regarding the number of individuals required in a population to ensure its viability over time (Soulé 1987, Boyce 1992), and "rule of thumb" numbers of 50 for short term genetic viability and 500 for longer-term viability related to environmental variation have been suggested as appropriate order-of-magnitude minimum viable population thresholds for many species. Mace and Lande's (1991) suggested criteria for IUCN categories of extinction threat also utilize these figures, while clearly emphasizing that they refer to N_e or "effective population size" of breeding individuals which correspond to actual field populations (N) of approximately 250 and 2,500, respectively.

With a population of say 6,000 individuals, is the snow leopard really in danger of extinction? Compared with the "guesstimates" of 10-25 years ago which led to its placement on the endangered species list, this is a substantial number and the species as a whole is apparently not in immediate danger of disappearing. If 6,000 snow leopards constituted one interbreeding population its foreseeable viability would be relatively secure, however, as our discussion of fragmentation indicates, this is not the case. In addition to population size, factors such as both fragmentation and area-specific evidence of decreasing trends in population must also be considered in assessing threats to populations. Using these criteria as suggested by Mace and Lande (1991) in their recommendations for evaluation of IUCN threatened species status, it is clear that the snow leopard should continue to be listed as endangered.

Size of Protected Area Required

Based on an assumption that an average home range size of 75-100 km^2 is reasonable over large areas, Villarubia and Jackson (this symposium) suggest that protected area sizes of 5,000 to 10,000 km^2 are required for preserving snow leopard populations of 50-100 individuals. Green (this symposium) suggests that protected areas of 500-1000 km^2 are required to maintain populations of 50 effective breeders. Both of these estimates fail to clarify the relationship between N_e and N, and if we use the critical minimum actual field population of 250 individuals as suggested by Mace and Lande (1991), the required protected area size in good habitat increases to nearly 25,000 km^2. Actual populations of 250 individuals in regions of average snow leopard density would require areas approaching 70,000 km^2, and even so would be subject to relatively high extinction threat just on the basis of demographic and environmental stochasticity.

When we include the effects of environmental variation on population viability, the long-term viability requirement for an effective population (N_e) of 500, or an actual population (N) of 2,500 animals, requires an area of 250,000 km^2 of good habitat. Even using the less conservative (risky) lower limits of Mace and Lande's (1991) actual population estimates (N), we are still dealing with at least 100,000 km^2 of good snow leopard habitat to encompass an effective population of 500. Areas of such size set aside for protection of snow leopard and other species are generally unrealistic, and such extrapolations of habitat requirements puts sharp focus on the problems associated with setting aside sufficiently large protected areas today or in the future. Although large protected areas should be created where possible, efforts should also be concentrated on both conservation efforts in the substantial areas of good snow leopard habitat outside of reserves and on effective means of linkage between existing reserves (see Jackson and Ahlborn 1990). One further approach is to take advantage of international cross-border connections between protected areas, and make allowances for corridors between reserves wherever possible, thus enlarging the effective size of areas receiving some protection (Villarubia and Jackson, this symposium). In addition to the protection of selected prime core habitats, as subpopulations become more isolated smaller populations may perhaps be maintained with human-aided translocation of animals to maintain genetic diversity. Given the large areas required to maintain viable snow leopard populations, regional and international cooperation in research and management is essential.

CONSERVATION STATUS

Recent reevaluation of the taxonomy of the Felidae (Wilson and Reeder 1993) acknowledges the placement of snow leopard in its own single species genus, *Uncia uncia*. This decision stresses even further the genetic uniqueness of the snow leopard and thus the importance of conserving this endangered genus. We must then ask, what has been the effect of recent legal protection, increased research, and national or international conservation actions with regard to the status of the snow leopard in the wild. As indicated above, research has shown us that there is apparently a larger overall snow leopard population, but with a much more fragmented distribution than we thought 20 years ago. On the other hand, populations of snow leopards appear to be decreasing in many areas.

The number and areal extent of protected areas encompassing snow leopard range has greatly increased within the past two decades (Green 1988, this symposium). Most countries have at least one snow leopard conservation area of greater than 1,000 km^2, encompassing a total of 12 such areas, but with only China having areas (4) of greater than 10,000 km^2, the largest being an exceptional 300,000 km^2 (Schaller 1993, Green, this symposium). The 300,000 km^2 reserve, recently designated in Tibet, encompasses large areas of high plains so that a substantial portion consists of relatively unsuitable or uncertain quality snow leopard habitat, so indicated within the lightly shaded area of Figure 1. The majority of reserves encompass areas of less than 500 km^2, clearly very marginal with regard to snow leopard population protection without access to interchange with other areas. In border regions between countries the largest conjunction of several adjacent protected areas is in the Mount Everest region of Nepal and China (Tibet) and encompasses an area of some 40,000 km^2, and between Pakistan and China there exist adjacent reserves totaling an area of 16,000 km^2. One such cross-border reserve has also been proposed between Russia and Mongolia, as indicated in the resolutions of this symposium. If we assume that protected areas encompass good habitat with average snow leopard densities of 1 per 75-100 km^2, today there are only 4 reserves (or adjacent combinations) that may encompass populations of 150-500 individuals.

It is thus abundantly clear that conservation efforts must also be pursued in regions outside of protected areas. Relatively undisturbed mountain corridors exist today between many protected areas, and while little effort has been made to formalize a modified protected status for any of these corridors, they continue to act as important habitats as well as dispersal avenues between reserves. Limited conservation initiatives in some of these corridors can be important in lessening threats to snow leopard populations associated with increased isolation.

Whereas we have greatly improved our knowledge of the numbers and distribution of the snow leopard throughout its range, we are also more keenly aware of the threats to this species. Enforcement of conservation laws is often less than effective, even within many of the designated protected areas in central Asia. There are areas where, regardless of legal protection, open public sale of snow leopard products continues, the region around Kashgar in far western China is but one example. Reduced supply and increased demand for tiger bones and their medicinal products have increased the value and demand for similar species such as snow leopard, and today this is probably the primary commercial value of snow leopard. International trade in snow leopard skins has apparently decreased as a result of CITES, although illegal sale continues to a limited extent (Barnes 1989). Mongolia, the only snow leopard country which has not signed CITES, has recently suspended its trophy hunting program on snow leopard (Tserendeleg, pers. comm.). Cessation of trade in snow leopard body parts is important, but probably more basic to the future conservation of this species is confronting the issue of predation on livestock within the pastoralist grazing ecosystems that encompasses its entire range. Snow leopards continue to be killed as predators of livestock and as development of livestock industries accelerate large predators will be subject to increased persecution (Fox et al. 1994, Miller and Jackson, this symposium). Accommodation with pastoralists and their developing livestock industries needs to be addressed now before conflict becomes too intense.

RESEARCH DIRECTIONS

As we obtain more and better information on snow leopard populations in the wild, assessment of trends will become more practical and reliable. Population data will also help us to delineate the core areas of viable subpopulations that may require additional protection measures to ensure the species' survival.

It is possible that our estimates of total snow leopard population may actually continue to increase somewhat as better information comes in from all parts of the species range. It is also possible that overall known distribution area will decrease somewhat as the patchy nature of snow leopard range becomes better documented and mapped. If so, the average densities thus portrayed will increase and probably more realistically reflect populations in typical snow leopard habitat. In any case, the reports of decreasing range and increasing habitat fragmentation emphasize the need for periodic estimates and continued improvements in population and distributional data.

We must continue to update population estimates and reevaluate the degree of extinction threat for the snow leopard. Although at present the compiled estimates of total population lie somewhere between 4,500 and 7,500, caution is required in accepting such figures because none of the estimates upon which these figures are based are precise enough to even incorporate sample variation, and thus we have no confidence limits to our estimates. Improvement and standardization of population estimation is thus an important goal for the near future. Strong justification for management actions will require a soundly-based indication of population viability and possible extinction threat. A detailed determination of a minimum viable population is not possible today for snow leopard because of the dearth of precise data on its demography and life history characteristics in the wild. Nevertheless, as Boyce (1992) argues, the use of population viability analysis, even where necessitating the use of general rules of thumb for minimum viable population, and its heuristic value in an adaptive management approach (Walters 1986) is a practical first step, which should be taken for snow leopard.

Some of the questions mentioned above regarding snow leopard dispersal behavior and degree of population isolation can be addressed with well conceived and executed radio-telemetry investigations, using both conventional and new satellite receiving transmitters. In short, the most important demographic data will come from long-term studies of known individuals in the wild, and this will only be possible with the aid of telemetry techniques. Thus, where such studies are successful, efforts should be made to continue them for reasonable periods of time.

We currently have virtually no information on the genetic diversity among snow leopard subpopulations, how isolated (and extinction prone) some of the small populations may be, or how much

dispersal there is between habitat patches. As is clear from Figure 1 there is a substantial spatial gap between the northern quarter of snow leopard range in Mongolia/Kazakhstan and the main distribution to the south, a situation which may possibly have led to genetic distinctions in snow leopard populations between the two regions. Such genetic questions should be addressed with a coordinated system of tissue and blood collection from snow leopards captured or killed in the wild, for example in studies requiring capture or in the removal of livestock killers. A start can be taken, and is apparently underway with cooperation from some zoos, for DNA analysis of wild-caught snow leopards (where capture location is well-known) to begin a database on genetic markers for the species.

A major concern with regard to persistence of snow leopard populations is the concomitant continued viability of populations of their prey, the wild ungulates of the central Asian mountains and steppe. There have been recent drastic reductions in wild ungulate populations on the steppelands of western China (Rowell 1983, Schaller 1990), Mongolia (Mallon 1984a), and Transhimalayan India (Fox et al. 1991). It is conceivable that these ungulates' predators (wolf and snow leopard) have turned to domestic livestock as prey, and thus become more persecuted as a nuisance to humans, but it is also probable that predator populations have been reduced as a consequence of the reductions in wild prey. Hunting of mountain ungulates continues, in some areas on a commercial basis, and threats to prey populations in some mountain regions are important factors affecting snow leopard conservation. Monitoring of mountain ungulate populations, which is considerably easier than that for snow leopard, needs to be improved and expanded to more areas to provide better estimates of densities and population trends of snow leopard prey.

In some areas snow leopard populations appear to be stable and healthy. Continuation and improvement of management regimes associated with these areas can be instructive regarding successful reinstitution of conservation in other areas. A flexible region-specific management approach, which includes foresight in adapting to changing human land uses must be emphasized where snow leopard conservation is an important concern. Basic knowledge of ecosystem interactions in snow leopard habitat will also be important in conserving such processes over time.

We easily acknowledge that the snow leopard is a magnificent symbol of the high mountain ecosystems of central Asia, and the health and viability of its populations is a prime measure of the maintenance of intact ecosystem processes within this region. The theme of this symposium is "parks, people and snow leopards", thus stressing the inclusion of local people's needs and aspirations within the context of endangered species and biodiversity conservation. Can we realistically speak of a "sustainable development" within the typical pastoral ecosystems of snow leopard range which occurs in concert with the maintenance of many of today's isolated populations of a predator on livestock such as the snow leopard? Because these questions involve ethical and political determinations, as well as biological ones, they will not be solved simply with better scientific or biological data on the snow leopard or its prey (see Miller and Jackson, this symposium). Little sociological or anthropological research has been carried out that is useful in integrating local development with conservation objectives, and emphasis should be placed on such studies, for example as is incorporated in ISLT's Project Snow Leopard (Freeman et al., this symposium).

Clearly, better population and distribution data on snow leopard and their prey species is required as part of the foundation for human initiatives to try to manage a coexistence of pastoralism and large predators in the highlands of central Asia. Conserving a widely dispersed and low density endangered species such as the snow leopard requires both effective use of such basic scientific information as well as a commitment to international communication and cooperation regarding research and management alternatives and initiatives over the large expanse of this species' range.

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