Snow Leopard Conservation: Accomplishments and Research Priorities

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Introduction

The first international symposium devoted to snow leopard, held in 1978 in Helsinki, Finland, concentrated on the management and breeding of the species in captivity. In 1960 there were only 22 captive snow leopards held in Europe and North America, but by 1976 the population had reached 167 animals, in some measure due to the acquisition of wild-caught animals (Blomquist 1984). Although the captive population still exceeded 150 in 1978, breeding success was low and only 54% of cubs reached the age of six months (Blomquist 1978). Subsequent triennial symposia, held in Switzerland, USA and West Germany, helped reverse this trend and by 1983 the captive population had increased ten times to 292 animals in 73 zoos around the world (Blomquist 1984). Although 141 snow leopards had been taken from the wild to zoos during the period 1960-1983, the bulk of which came from the former Soviet Union, the number of captive-bred animals increased dramatically over the same period. With survival rates greatly improved, delegates at subsequent symposia turned their attention more toward the welfare of the wild population.

The Fifth International Snow Leopard Symposium (Freeman 1988) was held within 50 miles of "occupied snow leopard habitat," in Srinagar (India). During the closing session the Government of India announced the initiation of "Project Snow Leopard," modelled along the lines of Project Tiger - at the time considered one of the great conservation successes of the decade. Likewise, the next two symposia were convened in range countries, in Kazakstan in 1989 (Blomquist 1990) and China in 1992 (Fox and Du 1994). Delegates to the 1989 and 1992 symposia also approved resolutions aimed at: (a) establishing new protected areas (including transboundary parks and reserves); (b) strengthening breeding efforts in range country zoos (which rely upon wild-caught animals because of extremely poor captive breeding records), and (c) increasing our understanding of the snow leopard's natural history, including its movement patterns, home range, food requirements, and social organization.

Clearly, these symposia have provided a useful forum for researchers, park managers and others from snow leopard range countries and elsewhere to share information on the cat's status, distribution and population trends, and its ecological and conservation role in the high mountain ecosystems of Central Asia. The information produced in these symposia proceedings provided important source material in international compendia on species status and conservation, including IUCN's Cat Action Plan (Nowell and Jackson 1996). The purpose of this paper is to review where we stand after nearly twenty years of formally addressing snow leopard conservation, to highlight focal areas of research and conservation action, and to recommend, in broad terms, where we should go from here.

Current Status, Distribution and Survey Approaches

At the last symposium, Fox (1994) mapped snow leopard distribution using large-scale published range and topographic maps, literature and known sightings, and estimated their current range at about 2.3 million square kilometers. After eliminating areas of "high uncertainty" with large gaps in distribution or areas suspected of supporting very few cats, Fox reported the total snow leopard range at between 1,600,000 km2 and 1,835,000 km2, based on country-by-country estimates (see Table 1, Fox 1994). The twelve countries (with population estimates indicated in parentheses) are Afghanistan (100-200), Bhutan (100-200), China (2-2,500), India (200-600), Kazakstan (180-200), Kyrgyzstan (800-1,400), Mongolia (500-1,000), Nepal (350-500), Pakistan (100-250), Russia (50-150), Tajikistan (120-300) and Uzbekistan (10-50). The total estimated wild population was placed at 4,510 - 7,350 snow leopards. In the absence of new surveys, this remains our best answer to the general public's most often asked question: "How many snow leopards are there in the wild?" While we cannot refine or update population projections made by Fox (1994), we do note that the species evidently continues to decline in large parts of its range.

Symposium participants rightly query, "How have things changed since we last met?" We continue to be severely hampered by lack of reliable data on the status and distribution of the wild snow leopard population. To our knowledge, there have been about six status surveys and studies of snow leopard since 1992; all but one focused on areas where presence had been previously confirmed. Few status surveys have provided reliable density or total population size estimates. Virtually no attention has been devoted to mapping the cat's distribution along the edges of its range, or in areas of marginal habitat, save for the efforts by researchers Koshkarev, McCarthy and Munkhtsog, who reported at this symposium. Given the justifiably high priority placed on the identification, establishment and management of protected areas, most surveys have been conducted in known population hotspots or established reserves. However, there are many reserves where information is essentially non-existent.

As these proceedings were being edited, Wang and Schaller (1996) reported that the snow leopard was on the verge of extinction in Inner Mongolia (China), with "just a few surviving in the Lang Shan." They documented the disappearance of snow leopard from eight of the nine isolated mountain ranges formerly occupied in Inner Mongolia, although it persists widely on the other side of the border in the People's Republic of Mongolia (Schaller et al. 1994; R. Jackson unpub. data). Although figures cannot be cited, it is quite clear that Afghanistan's wildlife, including its snow leopard population, have suffered greatly from several decades of warfare (Adil, this symposium). Snow leopard numbers have also suffered from the breakup of the USSR in the Central Asian republics Kyrgyzstan, Tajikistan and Uzbekistan, due largely to widespread poaching and depletion of the wild sheep and goats which constitute critical prey to snow leopards. Most delegates from these countries voiced their deep concern about the rapidly dwindling wildlife populations and decreasing biodiversity in high mountain regions, as illustrated in presentations made to the Special Session on Biodiversity in Central Asian Regions that took place immediately after this symposium.

On the other hand, it appears that snow leopard numbers have increased in some areas. For example, there is some evidence to indicate a population recovery from conditions prevailing in the early 1970's in Pakistan's Khunjerab National Park (Iftikhar et al., this symposium).

Unfortunately, current information is lacking for China (other than Inner Mongolia), India, Nepal, and Russia, although circumstantial evidence in the form of increased livestock predation may suggest increases in some protected areas like the Annapurna Conservation Area of Nepal and the Qomolangma National Nature Preserve of Tibet (S. Ale pers. comm. and R. Jackson unpub. data). Whether this pattern holds for small, isolated pockets only or broader regions is not known. However, given the widespread regional conversion to market economies (former USSR, Mongolia and China), the growing human and livestock populations in most range countries, and the widespread tendency of livestock herders to displace and deplete prey species, it is clearly reasonable to assume that snow leopard numbers are continuing to decline - we simply cannot quantify this trend. Clearly, more effort needs to be placed on delineating distribution patterns and monitoring selected core and corridor areas.

Several factors have not changed since the first symposium in 1978. Population estimates from the wild remain hostage to the extremely rugged, remote and inhospitable terrain, and the snow leopard's almost legendary elusiveness (which makes them virtually impossible to spot or locate). Instead, we have to rely upon pugmarks, scrapes or other irregularly distributed sign that is detectable only by an informed observer. Given the cats' rarity and sparse distribution, finding its sign takes perseverance, knowledge and skill. Census techniques employed to estimate population sizes vary widely according to the particular observer, and it is thus not surprising that population estimates vary so widely, even for the same country. In recognizing these factors, the International Snow Leopard Trust (ISLT) initiated development of a standardized survey and database procedure known as SLIMS (Snow Leopard Information Management System) in 1989. Delegates to the 7th International Snow Leopard Symposium (1992) urged all countries having snow leopard populations to join SLIMS for "gathering fundamental data that could then be used in critical and crucial decisions regarding the conservation and management of snow leopard reserves." Although three training workshops have been convened, in Pakistan and China in 1993 and Mongolia (1994), with over 26 biologists and park managers trained, very few surveys have been undertaken. The most notable constraints are the lack of funds, a paucity of trained or motivated personnel willing to work under the difficult conditions prevailing in the field, and the low priority placed on baseline information gathering and monitoring by senior management (Jackson et al., this symposium). In the case of China, there is little or no contact between wildlife management agencies in the five autonomous regions which contain snow leopard; this is very unfortunate, for China contains 60% of the world's total snow leopard habitat.

Following the initial snow leopard studies (Ahlborn and Jackson 1988, Fox et al. 1991) in which the SLIMS survey protocol was developed, Fox and Chundawat (this symposium) evaluated snow leopard sign surveys in the Ladakh region of India. Their results confirm the importance SLIMS has always placed on linking sign with specific topographic features and factors, such as precipitation, flooding and livestock movements, that may affect sign visibility and survey comparability between different seasons or regions. McCarthy and Munkhtsog (this symposium) are the first investigators to systematically apply SLIMS protocol on a country-wide basis (Mongolia), and they offer valuable recommendations for its improvement and application in an area that differs significantly from the more rugged terrain (Himalaya) where the technique was originally developed (Ahlborn and Jackson 1988, Jackson and Hunter 1995). They suggest field surveyors gather additional information on terrain characteristics, while emphasizing the importance of having a common understanding of landscape categories and other terms involved. Also, little attention has been focused on the power of fecal, track and scrape surveys to detect change in snow leopard populations, clearly a high priority from a monitoring viewpoint (Kendall et al. 1992, Smallwood and Fitzhugh 1995).

Remote cameras have been used to photograph such species as tiger (Karanth 1995) and grizzly bear (Mace et al. 1994) in an effort to more precisely estimate population size based upon capture-recapture statistics, but this technique has yet to be used for snow leopard. Unfortunately, it is both cost- and time intensive, and relies heavily upon one's ability to detect individuals using differences in physical characteristics, such as pelage patterning and coloration. Facial or frontal pictures would have to be taken for this method to work with snow leopard, which of course cannot be guaranteed, for this depends upon the direction the subject approaches the camera (which has to be placed unobtrusively along a well-used trail). Nevertheless, it is a technique worth testing in continued efforts to assess the status of various predators in central Asia.

An exciting development since the Seventh International Snow Leopard Symposium is the introduction of new tools in the effort to delineate snow leopard range. Thus, considerable dividends may be realized when information from standardized status and distribution surveys are combined with computerized geographical or spatial data-sets. Hunter and Jackson (this symposium) mapped potential snow leopard habitat utilizing GIS (Geographical Information System) technology and public-domain geographic information. These investigators estimated the total amount of habitat historically or potentially available to the species at about three million square kilometers, somewhat larger than the 2.5 million square kilometer estimate of potential range by Jackson and Ahlborn (1984), and considerably larger than previous estimates of current range by Fox (1994), Green (1988), and Schaller (1972). The fragmented nature of snow leopard habitat, especially along the Tien Shan range in China and the Altai and trans-Gobi ranges of Mongolia and adjacent parts of China are clearly illustrated (Hunter and Jackson, this symposium). This GIS exercise also indicated the presence of potentially suitable habitat in Myanmar, formerly Burma. Whether snow leopards are actually present is not known, for no surveys have been conducted. However, blue sheep (Pseudois nayaur), a species closely associated with snow leopard over much of its range, is known to occur in the mountains in the extreme north of Myanmar (A. Rabinowitz pers. comm.).

Metapopulations, Movements, and Significance of Marginal Habitats or Corridors

In many animal populations, individuals occupy habitat patches of differing quality, a fact that has far-reaching implication for the management and conservation of a rare species like the snow leopard. An understanding of basic demographic processes at the landscape level helps provide the necessary perspective to identifying and prioritizing conservation actions. Meffe and Carroll (1994) wrote: "Individuals in highly productive habitats are successful in producing offspring, while individuals in poor habitats may suffer poor reproductive success or survival. The fate of a population as a whole may depend on whether the reproductive success of individuals in the good habitats outweighs the lack of success by individuals in the poor areas." The concept that population dynamics may depend upon the relative quality and amount of good and poor habitats is known as source and sink dynamics, and is probably one of the most significant ideas emerging from conservation biology. In essence, animals tend to disperse outward from good or source habitats (which harbor source or more productive populations) into surrounding areas, some of which offer inferior or poor habitat (population sinks), where the long-term survival of the species is questionable. The role of source and sink habitats is best viewed in light of the metapopulation concept, a term used to describe a collection of sub-populations of a species that each occupy habitat patches of varying suitability in a landscape of otherwise unsuitable habitat. Wells and Richmond (1995) defined a metapopulation as a set of spatially disjunct populations among which there is some immigration. The rate of colonization of empty patches depends on the dispersal ability of the species and the spatial location and size of suitable habitat patches across the particular landscape.

Although we have no definitive proof that the metapopulation concept applies to snow leopard, its habitat is highly fragmented (Fox 1994, Hunter and Jackson, this symposium). We should not find this surprising for a species which lives in mountain massifs that are often disjunct from one another. In fact, in many parts of the snow leopard's range, the typical habitat distribution pattern consists of weakly or strongly linear mountain ranges separated from adjacent massifs by low-lying valleys, desert basins and high plateaux that offer inferior and often very poor habitat. Under this situation, corridors, which link separated habitat enclaves (each with their sub-population of snow leopard) are vital elements to the maintenance of a low density species across a patchy landscape. Given the small size of most reserves or core population areas, corridors are especially important in demographically and genetically linking separate sub-populations. Models of sources and sinks constructed by Pulliam and Danielson (1991) suggest that most individuals of a species may exist in habitats or sub-populations that cannot maintain the overall population without periodic reproductive infusions from source areas; furthermore, the more a resident individual can tolerate conspecific immigrants, the greater the chances that a small population can survive during times of low numbers. Thus, large carnivores may require relatively large amounts of good habitat to remain stable (Doak 1995), and even small amounts of habitat degradation can result in rapid change in population growth rates according to simulated demographic models. Beier (1993) provided an excellent example of a metapopulation analysis for puma (Puma concolor) inhabiting fragmented habitat in southern California, in which he attempted to identify critical sub-populations, habitat patches or links that are vital to the maintenance of the overall metapopulation, an exercise with clear analogy to snow leopard.

Until this symposium, nothing was known about the dispersal abilities of snow leopards, yet the very future of the species probably hinges upon the ability of animals to emigrate and reoccupy depopulated enclaves which may occur at some distance from a core or source population. McCarthy and Munkhtsog (this symposium) reported the exciting and astonishing finding of snow leopards moving across extensive expanses of flat or "unsuitable" terrain, as they moved from one isolated mountain range or massif to another. They reported snow leopard sign in numerous small massifs (3 - 35 km2 in size) that lie between occupied ranges, including situations where cats had to have crossed 20 - 150 km of open steppe or desert to reach a small mountain massif. McCarthy and Munkhtsog term these "corridor sites," noting that the snow leopard sign (scrapes, feces, scent-sprays and pugmarks) found there tended to be notably denser, older and more relic (a site that has been repeatedly re-marked over long periods of time) in nature than that found in permanently occupied ranges. Feces comprised most of the sign compared to scrapes which predominated in occupied or "core areas." Thus, 78% of corridor sign consisted of feces, compared to only 23% in non-corridor or occupied range (see Table 4, McCarthy and Munkhtsog, this volume). Such social marking may help orient migrating animals with respect to conspecifics, and prey and habitat suitability. Small, isolated, but topographically prominent massifs may funnel a relatively large number of individuals through a single area, but at different times so that such use is temporally spaced. Jackson and Ahlborn (1989) noted similarly high marking use of common core areas within more densely occupied range in Nepal, indicating similar patterns but on different spatial scales.

Satellite telemetry offers the best option for studying dispersal and migration, although ground-based tracking of standard UHF or VHF radio-transmitters can suffice where there is good access and less severe topography. We therefore hope that McCarthy and his Mongolian associates will employ both technologies as part of their on-going radiotelemetry studies.

Sign surveys enabled Koshkarev (this symposium) to verify snow leopard presence in several parts of the Eastern Sayan of Russia and the Hovsogol region of Mongolia, where they were thought to have been extirpated. Specifically, he verified a small breeding population at the very edge of the snow leopard's distribution, and speculated that animals moved out from a few small core populations into more marginal habitat where they were difficult to detect and their persistence was judged as tenuous. Overall, he estimated the snow leopard density in this region at 0.3 to 0.5 animals per 100 km2, which he attributed (in part) to high precipitation and deep snowfall.

Very little is known about what constitutes effective barriers to movement in snow leopard, although these likely consist of major rivers, well-traveled roads, expansive habitats lacking in either food or cover, and areas of intensive hunting and extensive human disturbance. Landscape-scale studies are needed to determine dispersal rates and to establish natural birth and death rates in snow leopard occupying habitat of differing quality. Without a basic knowledge of where the population "hotspots" and source areas are located, it is impossible to assess potential gaps in the existing protected areas coverage, or to recommend the best locations for new reserves. Therefore, we must yet again highlight the critical importance of population status and distribution baseline surveys using standardized or comparable methods.

Genetic Considerations

As noted, conservationists are becoming increasingly aware that habitat fragmentation is potentially a key factor in the survival of large carnivores (e.g., Maehr and Cox 1995, Paquet and Hackman 1995). To what extent the sub-populations of snow leopard differ genetically is unknown. Indeed, almost nothing is known about geographic variation in snow leopard based upon either genetic or morphological characteristics; museum collections are too limited or incomplete to offer much insight. Given the prevailing low densities, a relatively vast area will be required to maintain a viable population of snow leopards to protect against any potential long-term loss of genetic variability and to mitigate the effects of in-breeding. Although there are over 100 existing or proposed protected areas within the snow leopard's range, most are small, with over 68% being less than 1,000 km2 (Green 1994); many are less than 500 km2, especially in parts of India, Pakistan and Sichuan Province, China. Even large reserves that exceed 45,000 km2, such as China's Changtang (Tibet) and A Er Jin Shan nature reserves (Xinjiang), may actually contain relatively little suitable snow leopard habitat (Figure 1, Hunter and Jackson, this volume; G.B. Schaller, pers. comm.). The amount of habitat required to meet commonly accepted Minimum Viable Population (MVP) criteria could exceed 30-50,000 square kilometers, assuming a MVP size of 500 breeding adults. MVP is defined as the minimum viable isolated population size having a 99% chance of remaining extant for 1,000 years despite the foreseeable effects of demographic, environmental and genetic stochasity, or natural catastrophes (Soule 1987). Other factors may also be important, such as human disturbance. A model developed by Kenney et al. (1995) suggested that poaching could contribute significantly to a species' genetic demise, adding to the difficulty of conserving an isolated, wild population of economically valuable species like the tiger.

Besides constraints on size and habitat quality, most Central Asian parks must accommodate human habitation or livestock herders within their boundaries, and since the amount of new area that can be set aside for wildlife is limited, it is imperative that we have a good knowledge of existing population hotspots, sources and sinks, and linking corridors. From a conservation perspective, therefore, we urgently need information on such aspects as:

* How genetically different (or similar) are different individuals and sub-populations from each geographic region?

* What are the demographic characteristics (number of individuals, their sex and ages) of the typical emigrating cohort?

* What is the potential for loss of genetic variability, especially along critical "bottlenecks" linking "hotspots" and key protected areas (taking into account all primary factors affecting reproductive success, including dispersal capacities and mortalities due to poaching)?

* Where are the best locations for new reserves and where should we place our limited resources to maintain critical functional linkages and corridors?

The most feasible means for accruing such demographic and genetic data lies in a combination of field-based, non-invasive DNA studies and numerically reliable censusing using strategically placed field surveys and studies. Recent efforts at extracting DNA from fecal material appear most promising (S. Wasser pers. comm.). Fecal DNA measures are particularly valuable here because of the extreme difficulty in obtaining blood or tissue samples from a free-roaming animal. The number of snow leopards in an area can possibly be determined by individually recognizable DNA acquired in their relatively accessible feces. This information, coupled with data on suitable habitat, prey species abundance and distribution patterns, and human-livestock activity, can help determine those areas most in need of enhanced protection.

Besides answering questions of taxonomic and theoretical importance, such techniques could offer direct practical applications and benefits in snow leopard conservation. For example, the trade in furs, bones and other body parts poses a threat to snow leopards, especially in China and the newly independent republics of Central Asia, but baseline information is sorely lacking (Nowell, this symposium). As tiger bone becomes increasingly scarce, trade in snow leopard parts for traditional medicines and aphrodisiacs will increase. DNA analyses could play a pivotal role here as well, by helping to locate "poaching hotspots." By first using the relatively accessible fecal DNA to develop "geographic maps" of snow leopard gene frequencies, DNA from seized body parts could be matched to geographic maps of gene frequencies, thus making it possible to identify the geographic origin of seized materials. This information could, in turn, be used to strengthen law enforcement efforts in areas where poaching is most concentrated.

Livestock predation by snow leopards is yet another key factor in snow leopard conservation, particularly in areas where prey species have been depleted by poaching. Fecal DNA analysis would make it possible to determine whether a particular individual or a given sex more often kills livestock and whether particular individuals become habitual killers of valuable livestock. Such information has significant implications for developing management specifically adapted to pastoralists living in areas with livestock-predating snow leopards.

As the first step in the development of such genetic techniques to conservation efforts in the wild, the International Snow Leopard Trust is cooperating with Dr. Sam Wasser (University of Washington) to develop the necessary methodology. The first step will validate that gene frequencies as measured from tissue samples match with those of fecal samples from the same individual. These studies are vital to show that the DNA being measured from feces is from the snow leopard itself, as opposed to something the animal may have ingested. They are also important to verify that the techniques designed to preserve samples collected in the field will work on snow leopard feces, and that possible contamination from DNA ingested in hair can be controlled. Samples from captive animals will be used to identify hyper-variable gene loci among snow leopards, each containing several different alleles, to optimize discriminations between individuals and regional sub-populations, and to establish if the species has or has not suffered from a genetic bottleneck like that suspected to have occurred in cheetah (Acinonyx jubatus). Immediate applications of study results include measurements of heterozygosity from the captive snow leopard population in North America. In addition to providing the foundation for utilizing this technology in wild populations, these measurements will be important for captive breeding aimed at maximizing genetic diversity, and will give a first estimate of likely geographic allelic variation among snow leopards.

Predator-Prey Relationships

Snow leopard conservation will be greatly affected by the status and management of its prey species, both wild and domestic animals and primarily mammalian herbivores. Because the major prey species of snow leopard are wild sheep and goats and their relatives, efforts to conserve and manage members of this taxonomic group are also of special concern to the conservation of the snow leopard. The International Union for the Conservation of Nature and Natural Resources (IUCN) is preparing, as part of a series of species-specific conservation status and action plans, a compendium on the conservation and management of the Caprinae, the wild sheep and goats of the world (D. Shackleton pers. comm.). Preparatory work indicates that quantitative information on the population status of many Caprinae species is relatively little known, despite the fact that some Caprinae species are still widespread within the snow leopard's Central Asian range. Therefore, efforts by range countries to improve this knowledge are greatly needed.

The continued existence of healthy populations of Caprinae species like the blue sheep (Pseudois nayaur) and ibex (Capra [ibex] sirbirica), as well as that of marmots (Marmota spp.) in some areas, are critical to snow leopard survival in the wild. In turn, the conservation of these prey species will be greatly affected by the development of livestock industry and animal husbandry throughout the mountains of Central Asia (Miller and Jackson 1994; Fox, in press). Some of the factors affecting conservation of snow leopard prey include:

* competition (direct food-related or disturbance) between livestock and wild herbivores;
* disease transmission between domestic livestock and wild ungulates;
* removal of herbivore pests (e.g., marmots and pikas) due to their perceived "degradation" of pastures for livestock;
* maintenance of wild stocks of ungulates as a source of genetic diversity for domestic breeds.

With regard to the prey species of snow leopard that include domestic animals, primarily livestock, efforts to understand and coordinate rangeland management on a regional scale in Central Asia will be very important in developing strategies to incorporate effective wildlife conservation into the modernization of pastoralism. Within snow leopard range, pastoralism is the primary way of life and changes in rangeland management are thus a critical factor in snow leopard conservation (Miller and Jackson 1994). Within the Hindu Kush - Himalayan region, for example, the International Centre for Integrated Mountain Development (ICIMOD), based in Kathmandu, Nepal, has recently established a new focus on range management, affecting over 60% of the region's land area (Miller, in press). One of the tasks of this new program is to address issues of livestock husbandry in relation to wildlife conservation; with a significant number of national parks and other types of reserves being created in the mountainous areas, the interface between pastoralism and wildlife is of increasing concern.

Other factors affecting wild herbivore conservation not directly related to livestock management include the hunting of wild herbivores for food, skins, medicinal uses and trophies, and the impact of wild herbivores as crop pests. As indicated above, conclusions from a meeting on biodiversity conservation in the former Soviet republics, held immediately following this symposium, clearly emphasized the dramatic increase in hunting of large herbivores for meat and commerce (in the form of trophy hunting), activities with clear consequences for snow leopard conservation. There is strong interest in the commercial trophy hunting of various Caprinae species, for example in China and the former Soviet republics, and to a lesser extent elsewhere. Because of the potential competition for ungulate prey, such programs must be incorporated into overall strategies for snow leopard management. In general, the pasturelands of western China and the mountainous margins of the Tibetan plateau are only beginning to see changes from the traditional and long-established practices of nomadic and semi-nomadic animal husbandry. Nevertheless, the fencing of pastures, increasing domestic herds in some areas, efforts to maximize forage exploitation, the introduction of new breeds, changes in herder vigilance, and mammalian pest control are affecting snow leopards and their prey over increasingly larger areas. The incorporation of wildlife management goals into general rangeland management throughout the snow leopard's range is thus crucial to its long-term conservation.

A knowledge of prey density and predator-prey ratios would help to set limits for validating snow leopard numbers in a particular area: clearly, there must be sufficient prey to support the predicted predator population. Dietary studies seem to suggest that livestock and/or marmots are important in sustaining a high density of snow leopard, even when good numbers of blue sheep are present (e.g., Chundawat and Rawat 1994; Oli et al. 1993). Field studies should be mounted to determine how many blue sheep or similar-sized (large) prey are needed to sustain varying densities of snow leopard, with or without the presence of a buffering species like the marmot (summer) and domestic stock (especially during winter months.)

Conservation Strategies and Priorities

Conservation of the snow leopard, its prey and habitat is hardly an easy undertaking, a fact explicitly demonstrated by the general lack of progress made toward fulfilling the clearly ambitious resolutions passed at all symposia held to date. Few of the reserves recommended have in fact been established, and the vast majority stand as "paper parks," most of which lack management plans to guide the staff in their daunting task. The ambitious in-country research programs recommended at the fifth, sixth and seventh symposia have generally failed to come to fruition. For example, India's "Project Snow Leopard," which was announced with much fanfare at the 5th International Snow Leopard Symposium in 1986, remains essentially a "paper project," in sharp contrast to the broad-based and well-funded conservation initiative targeted at tigers in the same country. Similarly, the extent of baseline information gathering, including systematic and standardized population-habitat surveys, which are so essential to effective conservation planning, has been disappointingly weak. Commonly cited reasons are the lack of funding, epitomized most conspicuously by the decline of the formerly highly active scientific institutions in the former Soviet Republics and Mongolia - but also echoed by limited follow-through from other organizations elsewhere in Asia, US, and Europe.

There are some notable exceptions, however. Ferguson's paper (this symposium) reviewed collaborative snow leopard projects and suggested that projects are more likely to succeed if they are flexible, respond to local needs and are long-term in nature. He observed that international collaboration has played a key role in promoting snow leopard research and conservation, and emphasizes the catalytic role of the U.S. Fish and Wildlife Service in India and Pakistan over the past twenty years.

The question of how to ensure that symposia resolutions are more achievable merits special attention. Freeman (this symposium) argues that the International Snow Leopard Trust and range countries should adopt a workshop rather than symposium format and hold smaller, more focussed meetings which target key conservation issues and include those individuals most directly involved in the proposed outcome. She submits that the goal of each workshop should entail the development of an action plan that identifies agency and individual responsibilities, prioritizes implementation steps and specifies funding mechanisms or sources. In recognizing the importance of ensuring adequate follow-through, delegates to this symposium recommended that, "ISLT should monitor the progress made in implementing these resolutions and report successes and failures to the next symposium." However, this resolution failed to specify how monitoring should be conducted: one option would be for the Trust and the snow leopard conservation community to establish a contact person or organization for each country (A. Ahmad, pers. comm.). Under this arrangement, the country-based "conservation action monitoring committee" would be responsible for incorporating, promoting, coordinating and implementing those activities approved at the symposia or workshops. ISLT would then play a coordinating or facilitating rather than decision-making, unilateral role, which is far more in keeping with its mission statement.

The generally accepted conservation target for protected areas coverage is 10% of each unique biogeographic zone (McNeely and Miller 1984). As of early 1995, about six percent of potential snow leopard habitat was located within existing protected areas, including proposed reserves (Table 1, Hunter and Jackson, this volume). Bhutan leads with over 50% of its potential habitat protected, followed by Nepal (27% including conservation areas), India (14%), and Tajikistan (13%). China, containing over 60% of the world's potential range for the species has just over six percent under park or reserve land-use. Coverage is especially low in Afghanistan, Kyrgyzstan, Kazakstan and Mongolia, although several countries, including Mongolia and Kyrgyzstan, have expressed keen interest in expanding their protected areas coverage.

As previously stated, most reserves are too small to harbor significant populations of snow leopard, and even when nearby protected areas are linked, there is not enough space to support even 50 to 100 breeding adults, the very minimum population target. In fact, most theorists argue for maintaining a much larger interbreeding population comprising

500-1,000 breeding adults. In a study of Nepal's protected areas network, Jackson and Ahlborn (1990) noted that only a few parks were large enough to support more than 50 individuals and that fully 65% of the country's projected snow leopard population likely lived outside of its national parks - leading to the conclusion that habitat located outside of a park or reserve is vital to maintaining a genetically viable population. Green (1994) and Fox (1994) reviewed this issue throughout snow leopard range, suggesting that this pattern probably applies to virtually all of the other 12 or 13 snow leopard countries.

How can we ensure that protected areas, their buffer zones and the intervening corridors become more effective conservation tools? The best option for managing a large carnivore at a regional or landscape level probably involves a series of protected areas located and designed to serve as core areas with source populations, but which are linked through a strategically-placed network of corridors of suitable habitat, such that the full range of montane ecological conditions are covered (Noss 1995). Management initiatives should be designed to ensure adequate numbers of large and small natural prey species, sufficient breeding sites, dispersal corridors, and other important life-history requisites are provided by protected areas and intervening corridors acting in concert. This approach has been proposed for tigers in India and jaguars in Brazil (e.g., Quigley and Crawshaw 1992).

Green and Zhimbiev (this symposium) consider transboundary or transfrontier protected areas as vitally important for the future survival of the snow leopard and other widely-ranging mountain species, by virtue of offering an effective means of increasing the size of individual protected areas. They reported a total of five transfrontier protected areas (comprised of 13 individual reserves) exist across the snow leopard's range, and noted the potential for creating many more. Thus, 36 protected areas lie on international borders with nothing comparable on the neighboring side. Green and Zhimbiev concluded that the greatest potential for new transfrontier protected areas lay along the borders of Kazakstan, Nepal and Bhutan. In fact, delegates to both the Sixth and Seventh International Snow Leopard Symposia recommended the establishment of several transfrontier reserves in these areas, but these have either not been developed, or there is little cooperation across the border in terms of collaborative management. A notable exception is the transfrontier complex of the Qomolangma National Nature Preserve in Tibet and the Makalu-Barun, Sagarmatha and Langtang National Parks in Nepal.

Given the rapid depletion of prey populations through much of Central Asia, conservation initiatives must seek to ensure an adequate population of wild ungulates, especially blue sheep and ibex. Similarly, marmot, pika and small rodents help buffer domestic livestock from predation by snow leopard, and should not, therefore, be depleted through over-exploitation or widespread poisoning such as occurs in some parts of China and Mongolia. Observations by Chundawat and Rawat (1994) that livestock are vital to the maintenance of snow leopards even in a national park like Hemis highlights the valuable ecological service that herders may unwittingly provide, and for which they should receive appropriate recognition - provided, of course, they agree to protect and enhance the wild prey numbers. Special management problems result from conflicts with herders, which can threaten to undermine snow leopard conservation, unless these are specifically addressed by resource managers, community leaders and pastoralists (Miller and Jackson 1994). Classic examples of herder-predator conflict are reported by Oli et al. (1994) and Ahmad (1994). Animal husbandry is vital to the welfare of many mountain peoples, and the loss of even a few animals may result in significant impact. Thus, conservationists are faced with a basic dilemma: how to encourage local people to protect an animal that kills their valuable livestock? Potential solutions fall into two broad categories: (1) educate herders on ways of better guarding their livestock and on the importance of not decimating the natural prey base for snow leopards or other rare predators like brown bear and wolf, and (2) Direct or indirect compensation for those herders who lose livestock to wild predators. Many sheep and goats are lost simply because of poorly constructed night-time enclosures or because they are allowed to roam freely without a tending shepherd. Cash-based compensation programs may lead to abuse and fail to address root causes for livestock depredation (Jackson et al. 1996). Besides, such programs are costly, rarely equitable (most funds are captured by well-to-do households) and difficult for a government to sustain for long. Subsidizing community development projects, in full or in part, may constitute a more satisfactory "reward" or community incentive for wildlife stewardship in the face of periodic livestock depredation or crop damage.

People-wildlife conflict is often associated with the establishment of a park or reserve (Wells and Brandon 1993), for wildlife may leave the protected area to damage nearby cropland or kill livestock. Such problems only serve to undermine public support for protected areas in general, which are undoubtedly the primary repository of biological diversity in all countries. New management models which satisfy people's legitimate concerns while also addressing root causes of depredation - overgrazing, habitat degradation, hunting and poaching of prey species - are urgently needed. These must foster biodiversity conservation, enable community-based resource management and stewardship, and educate mountain residents on the benefit of ecologically sensitive and socially responsible land-use and development.

Many lessons have been learned from ongoing community-based conservation (CBC) initiatives (Western and Wright 1994). Brown (this symposium) poses a number of questions that could be asked of local communities, the government and conservation NGO's, while Ahmad (this symposium) offers invaluable lessons and recommendations from WWF-Pakistan's projects in Bar Valley and the Khunjerab National Park. Ale (this symposium) introduces new management concepts from the Annapurna Conservation Project, one of the first community-oriented initiatives of its kind in the world. The most important points arising from these and other community-based conservation programs can be encapsulated as follows:

* Commitment and long-term sustainability is best achieved by promoting the communities' sense of ownership through involving them in project design, implementation, monitoring and evaluation, using participatory and transparent processes targeted at all segments of the community, development agencies, government management agencies, and NGO's (i.e., the primary stakeholders or beneficiaries);

* Grass-roots participation improves park-people relations and enables rural communities to assume greater resource management responsibility, thus stretching precious agency or donor funding. When programs are carefully designed, with an effective means for objectively monitoring progress, local communities can be empowered to ensure that valuable resources are not knowingly mismanaged or over-utilized;

* Community-based conservation initiatives should be bottom-up rather than top-down, technologically appropriate, small scale, low-budget rather than extravagant, and "do-able" by community members with a minimum of outside inputs and resources;

* Project activities should establish clear linkages between their input (often income-generation or economic enterprises aimed at improving the local standard of living) and the desired environmental or resource conservation actions. These are best achieved through implicit village-based agreements, preferential hiring or training of local residents, participatory park management planning and monitoring systems, and other devices;

* Understanding and consensus can be enhanced if traditional land rights are recognized and if a constructive dialogue on the factors leading to environmental degradation or conflict is promoted;

* Buffer zone development projects are only likely to succeed if they continue well beyond the five-year life span characteristic of most existing conservation-development projects, and

* Conservation-development projects must be flexible and responsive to changing conditions, best detected through on-going participatory monitoring and evaluation using sensitive indicators for measuring project outputs and success.

Conclusions: Where should we go from here?

Resolutions made by delegates to the Eighth International Symposium cover much the same ground as previous symposia. Presentations and discussion centered on the importance of collaboration with respect to the exchange of information and ideas, the sharing of skills and "know-how," and the need to bring local people into the mainstream of conservation. Many expressed deep concern regarding the lack of current data on the species' status, distribution and trend, and therefore again urged range countries to mount systematic status surveys. These need to be followed up with regionally based conservation plans identifying key snow leopard areas, reserves and corridors that permit inter-refuge movement. Scarce skills and resources are best gained through a network of partnerships between communities, NGO's and government (Management Institute for Environment and Business 1993). Freeman (this symposium) poses the question whether issue-targeted workshops may not be a more effective means for mobilizing such resources than symposia.

The major requirements for the maintenance of a healthy snow leopard population include the provision of a patchwork of areas offering suitable habitat, the presence of corridors to accommodate dispersal, and security from poaching or unregulated hunting for an adequate population of breeding adults. "Single-species" efforts are justifiably criticized if they become too narrowly-based or singularly focussed; we therefore emphasize that management and conservation should occur at the ecosystem and landscape levels in order to benefit all mountain biodiversity, not just the snow leopard. As noted, it is also imperative that management embrace the principles of community-based conservation, in which the general public serve as guardians of the particular region's wildlife and biodiversity.

Conservation initiatives must also address the rapidly intensifying demand for snow leopard body parts used in traditional Chinese medicine. Profit from the sale and trade of snow leopard bones and organs is a seductive attraction to any mountain dweller, especially those living in extreme poverty. Snow leopards need to be worth more alive than dead, but how this can be achieved is unclear; tourism may represent one option, but long-term subsidies for "biodiversity maintenance" may be necessary on the part of affluent urban residents or nations from outside the snow leopard's range. In any event, ensuring that local communities serve as effective stewards for snow leopards and other rare wildlife is critical to curbing the decline in their numbers. However, these and other consequential measures are contingent upon the extent of political will governments and the public are willing to muster for the cause of conserving their rich mountain biodiversity. Significant progress has been made in making the snow leopard known as Asia's "Imperiled Phantom" (Schaller 1971), but much work remains to ensure its future as a revered and secure phantom of Asia's mountains.