THE SNOW LEOPARD DILEMMA: WILL THEY PERSIST?

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With their splendor and elegance, snow leopards (*Uncia uncia*) have become the focus of zoo visitors around the world and also have attracted considerable attention of the international conservation community. They have been recognized as the symbol of the fragile high-altitude ecosystems of the central Asian mountains (Anonymous 1988), a 'flagship' species (Green 1994), an indicator species, and a "conservation ambassador" with a potential to transcend geo-political boundaries for the cause of conservation (Freeman et al. 1994). Unfortunately, they also attract the attention of fur-lovers willing to pay thousands of dollars for their luxuriant coat, of the manufacturers of traditional Chinese medicine for which snow leopard skeletons are an important ingredient, and of local pastoral communities who lose their livestock to predation. These and other threats have taken their toll. Snow leopards are considered an endangered species by the International Union for Conservation of Nature and Natural Resources (IUCN) and are listed in Schedule I of the Convention on International Trade in Endangered Species of Flora and Fauna (CITES) which prohibits international trade of the leopard's body parts.

While the remoteness of their rugged mountainous habitat has positively contributed to leopard survival, it also has hindered research efforts to improve our knowledge of this species. Consequently, snow leopards remained a mystery to the scientific community until recently; only in the 1980's did systematic scientific investigations of this species begin. Since then, substantial progress has been made, and the air of mystery that surrounded snow leopards in the past has been partially dispelled.

In this paper, I critically review recent literature on snow leopard ecology, identify threats, and discuss conservation measures essential for ensuring the long-term survival of snow leopards. The role of zoos in achieving this objective also is discussed.

STATUS AND DISTRIBUTION

The geographic range of snow leopards is restricted to the Altay, Hindu-Kush, Himalayas, Karakoram, Pamir, and Tienshan mountain ranges of central Asia (Table 1). Although estimates of snow leopard populations are available from only a small portion of their range, it is generally believed that their numbers are declining. Habitat fragmentation is severe, and the leopards continue to face a multitude of threats which render the species' long-term survival questionable (Fox 1994, Oli 1994c, Schaller et al. 1994).

The most recent estimate indicates that 4,510-7,350 leopards occupy 1,835,000 km^2 habitat area in their range (Table 1). These estimates are based primarily on habitat area or expert opinion (Fox 1989, 1994) and their accuracy is unknown. It is evident, however, that there are more snow leopards in the wild than early estimates indicated and that they are not at immediate risk of extinction as previously believed (Fox 1994).

Snow leopards reportedly occur in 50 protected areas (3 in Mongolia and 47 elsewhere; Green 1994, Schaller 1994). This list also includes protected areas (e.g., Langtang National Park and Sagarmatha National Park, Nepal) from where no credible evidence of leopard presence has been reported (M.J.B. Green, Pers. comm.). Also, only few of these protected areas are of adequate size to support viable leopard populations (Green 1994, Jackson and Ahlborn 1990). Densities vary from 0.4-0.5/100 km^2 in the Taxkorgan Reserve, China (Schaller et al. 1987), 5-7/100 km^2 in Manang (Oli 1994b), to 5-10/100 km^2 in Langu, Nepal (Jackson and Ahlborn 1989).

ECOLOGY

Food habits - Snow leopards generally are opportunistic carnivores, but field studies indicate that wild goats and sheep consistently form the major portion of the diet. Blue sheep (*Pseudois nayaur*) have been reported to be the main prey in Shey and Lapche (Schaller 1977), and Manang, Nepal (Oli et al. 1993, Oli 1994b), Ladakh, India (Chundawat and Rawat 1994), and Qinghai and Gansu provinces (Schaller et al. 1988b) and Taxkorgan Reserve, China (Schaller et al. 1987, 1988a). Other large wild caprids were more important elsewhere: ibex (*Capra ibex*) in Tomur Feng, China (Schaller et al. 1988a), Altai-Transaltay, Mongolia (Schaller et al. 1994), and Zailisky Alatan (Zhirjakov 1990), and markhor (*Capra faconeri*) in Chitral, Pakistan (Schaller 1977). Small mammals, particularly marmots (*Marmota* spp.) were important in the summer diet of snow leopards in China (Schaller et al. 1987, 1988a, b), Manang, Nepal (Oli et al. 1993, Oli 1994b) and Ladakh, India (Chundawat and Rawat 1994). Other prey types known to form a part of snow leopard diet include argali (*Ovis ammon*), urial (*Ovis orientalis*), tahr (*Hemitragus* spp.), goral (*Naemorhaedus goral*), takin (*Bubrocas taxicolor*), musk deer (*Muschus chrysogaster*), roe deer (*Capreolus capreolus*), kulan (*Equus hemionus kulan*), goitered gazelle (*Gazella subguterosa*), wild boar (*Sus scrofa*), fox (*Vulpes vulpes*), and various birds (Chundawat and Rawat 1994, Dang 1967, Mallon 1984, Oli et al. 1993, Schaller 1977, Schaller et al. 1987, 1988a, b, 1994, Zhirjakov 1990).

Domestic livestock also are consumed; their remains were detected in 15% of leopard scats collected from Manang, Nepal (Oli et al. 1993), 15% in Ladakh, India (Chundawat and Rawat 1994), and 2.6% in Mongolia (Schaller et al. 1994). Similar observations have been reported from other study areas in China (Schaller et al. 1987, 1988a, b) and Nepal (Schaller 1977).

Prey Requirements and Predator-Prey Relationships - Schaller et al. (1994) reported that food consumption of a free-ranging adult snow leopard in Mongolia was 1.7 kg/day. This estimate was within the range estimated by Jackson and Ahlborn (1984; 1.3-2 kg/day) and those reported for large felids (1.5-1.7 kg/day) by Emmons (1987). Based on these observations, Oli (1994b) estimated that 5-7 snow leopards in Manang, Nepal consumed 3000-4500 and 4200-6300 kg of prey per year, respectively. The rate at which snow leopards harvested blue sheep, the leopard's main prey in the area, was estimated to be 9-14% of the sheep population for 5 (minimum estimated number) and 13-20% for 7 (maximum estimated number) adult snow leopards. Snow leopard:blue sheep ratio was 1:114-1:159 on a weight basis, which was considered sustainable given the importance of small mammals in leopard's diet and the lack of other competing predators (Oli 1994b).

Home Range - Home range size of snow leopards in Langu valley, Nepal varied from 12-39 km^2, but 4 of 5 radio-collared leopards maintained ranges < 23 km^2 (Jackson and Ahlborn 1989). Winter home range of 3 radio-collared leopards in Manang, Nepal ranged from 13.9-22.3 km^2 ($\bar{x}$ = 19.1; M. K. Oli unpubl. data). Late winter home range of one snow leopard in India was 19.0 km^2 (Chundawat 1990). Schaller et al. (1994) reported that a male leopard in Mongolia used 12 km^2 during 44 days of monitoring. Home range sizes may be 20-30% greater than those reported if considerable topographic relief is taken into account (Jackson and Ahlborn 1988). Although these estimates are comparable, all studies except those of Jackson and Ahlborn's (1988, 1989) were based on small number (1-3) of animals monitored over a short period, and an underestimation of seasonal ranges is likely.

On average, female snow leopards in Langu, Nepal maintained larger home ranges ($\bar{x}$ = 29.3 km^2) than males ($\bar{x}$ = 15.4 km) (Jackson and Ahlborn 1989), and a similar trend was observed in Manang, Nepal (M. K. Oli unpubl. data). Most male felids maintain substantially larger ranges than those of females, and observations on snow leopard home range are inconsistent with these observations. Also, reported home range size of snow leopards are substantially smaller than those reported for mountain lion, an extensively studied solitary North American felid similar in size to snow leopards. For example, the average mountain lion home range size in Alberta, Canada, was 97 and 204 km^2 for females and males, respectively (Ross and Jalkotzy 1992). In fact, home ranges of snow leopards are comparable to that of bobcats (*Felis rufus*), a much smaller cat; male and female bobcats in Mississippi maintain

average home ranges of 20.6 and 36.5 km^2, respectively (Conner et al. 1992). Jackson and Ahlborn (1989) argued that relatively small home ranges of snow leopards in Langu, Nepal, may a response to the sedentary prey (blue sheep) population and relatively mild climatic conditions. This, however, does not explain peculiar sex-specific land tenure system of snow leopards when compared with other felids. Difficulties in tracking snow leopards that exhibit long distance movements in rugged and largely inaccessible mountainous habitat is a plausible explanation for the observed discrepancy.

Jackson and Ahlborn (1989) reported an extensive overlap of home ranges. Similar observations were made in Manang, Nepal, where 3 radio-collared leopards shared 8.1 km^2 in a prey-rich area. Extensive overlap of home ranges but no evidence of territoriality (Jackson and Ahlborn 1988, 1989) suggests that spacing mechanism in snow leopards, apparently a solitary cat, works temporally, rather than spatially. An intensive marking behavior using scent spray, urine, and scrape (Ahlborn and Jackson 1988) may help avoid inappropriate intra-specific encounters.

Marking Behavior - Free-ranging snow leopards mark prominent locations along their travel routes using scrapes, feces, urine, tree rakes, and scent sprays (Schaller 1977, Ahlborn and Jackson 1988). In Langu, Nepal, scrapes were the most abundant marks with an average density of 72 scrapes/km and accounting for 77% of total changes in marks along the permanent transects used for quantifying leopard's marking behavior (Ahlborn and Jackson 1988). Most frequently marked features included upright boulders, rocky outcrops, cliff faces, and rock promontories especially along confluences and major ridgelines. Eighteen percent of marks were accompanied by urine or secretions from anal glands, and 4% of scrapes were associated with fecal deposits. Scrapes also were associated with 73% of scent sprayed rocks. In Langu, Nepal, scent-sprayed features consisted exclusively of rock outcrops (86%) and cliff faces (14%); in Ladakh, India, rock outcrops, cliff faces and boulders comprised 91-100% of scent-sprayed features (Fox et al. 1988). Such an elaborate marking behavior is believed to convey message to conspecific recipients regarding an individual's presence, and social and physiological status, thereby minimizing inappropriate intra-specific interactions (Leyhausen and Wolff 1959, Ahlborn and Jackson 1988).

Activity and Movement Patterns - Snow leopards are primarily crepuscular (Jackson and Ahlborn 1988, Oli 1994d, Schaller et al. 1994). Male and female leopards were active for 45.6 and 55.9% of monitored time in Langu, and 47.1 and 41.1% in Manang, Nepal, (Jackson and Ahlborn 1989, M. K. Oli unpubl. data). A male leopard was active < 50% of monitored time and showed a similar activity pattern in Mongolia (Schaller et al. 1994). In Langu, the mean linear distance between leopard locations was 1.27 and 1.01 for males and females, respectively (Jackson and Ahlborn 1989).

Habitat - Suitable snow leopard habitat may be characterized as high altitude (≥ 3000 m) sub-alpine and alpine slopes broken by cliff, gullies, boulders or rocky outcrops where they occupy grassland, scrub or barren habitats (Chundawat 1992, Jackson and Ahlborn 1988, Oli 1991, Sherpa and Oli 1988). They also occupy less steep coniferous and rhododendron forests at lower elevations (≥ 600 m; Dang 1967, Mallon 1984, Roberts 1977, Schaller et al. 1994). In Langu, Nepal, snow leopards showed a clear preference for steep (> 40°) cliffs and broken slopes with southwesterly aspects at elevations ≤ 3600 m. The leopards maintained proximity to terrain or vegetation edge and generally remained within 25 m from such features. Preferred bedding sites consisted of landslides, rockfall, river bluffs or river beds. Based on survey of snow leopard spoor, Chundawat (1992) and Fox et al. (1991) reported similar observations from Ladakh, India, but noted a seasonal use of habitat along the elevation gradient.

THREATS

Predation of livestock by snow leopards has given rise to a significant conflict between snow leopards and local human population, and the leopards are considered vermin by pastoralist. Schaller et al. (1994) quoted the headline of a Mongolian newspaper ("The money which was eaten by snow leopard"), and commented that it accurately reflected public perception of snow leopard predation on

livestock. In Manang, Nepal, the average loss of animals to snow leopards was 2.6% of total holding, which represented in monetary term almost a quarter of the per capita income (Oli et al. 1994). In a village in Qomolangma National Park, China the loss rate was as high as 9.5% of total holdings (Jackson et al. 1994), and 7.6% of sheep and goats were lost to snow leopards in the Mariang commune of the Taxkorgan Reserve, China (Schaller et al. 1987). Similar reports available from elsewhere (e.g., Mallon 1984, Fox et al. 1991, Schaller et al. 1994, Sherpa and Oli 1988) indicate that snow leopard predation of livestock is widespread.

Because most human settlements in the leopard habitat are subsistence pastoral communities, even small losses can have substantial impact on household economy. It is, therefore, no surprise that 95% of residents of Manang, Nepal had negative attitude towards snow leopards, and 87.2% considered eradication of the leopards as the preferred method of reducing predation loss (Oli et al. 1993). Strongly negative public attitudes towards snow leopards and killing of leopards in revenge for livestock predation are considered the most serious threats to the species survival in some areas (Oli 1994c, Oli et al. 1994).

The leopard hide is valued at thousands of dollars in the market place, and poaching for its luxuriant fur continues (e.g., Barnes 1989, Chopra 1988, Freeman et al. 1994, Jackson and Hillard 1986, Jackson et al. 1994, Osborne 1983). Although local hunters receive only a small fraction, it still is an attractive sum for a poacher (Jackson et al. 1994). The use of snow leopard skeleton in Chinese medicine has been another significant threat (Liao and Tan 1988, Jackson et al. 1994), and in Tibet, skeleton is valued more highly ($190) than hide ($18; Jackson et al. 1994). Yang (1994) reported that one individual killed 13 snow leopards, and a group of miners killed 28 snow leopards during 1972-1984 in Qinghai Province, China. Nineteen snow leopards were killed in 4 months in 1983, and an additional 14 leopards were reported killed between November 1990 and February 1991, in 2 different counties of Qinghai, China (Yang 1994). Unlike in Manang, Nepal, where snow leopards were reported killed in defense of livestock (Oli et al. 1994), all killings in China appear to be for fur and skeleton. Mongolia is the only country that operates snow leopard trophy hunting for a fee of $16,000 (Schaller et al. 1994).

Additionally, fragmentation of habitat and populations, local disappearance of snow leopards from some areas, and generally a declining trend in the leopard numbers over most of the range have caused concern among conservationists (Fox 1994).

Formerly, the popularity of snow leopards among zoo visitors, and little success in captive breeding had placed a high demand for wild-caught animals for zoos. For example, Xining Zoo collected 21 snow leopards during 1957-1973, and Beijing Zoo collected 73 snow leopards during 1968-1984 (Liao 1994). Liao and Tan (1988) reported that all except 3 snow leopards on display in Chinese zoos were captured in the wild. Recent success in captive breeding program seems to have eliminated the need for wild-caught leopards.

Depletion of prey populations, primarily as a result of overt hunting, has been reported from many parts of leopard's range (e.g., Jackson et al. 1994, Schaller et al. 1987, 1988a, 1988b, Schaller et al. 1994). Low density of wild ungulates and the lack of alternate prey may ensue an increased predation on livestock, escalating hatred and killing of snow leopards in retribution (Schaller et al. 1994, Oli 1994c, Oli et al. 1994). Additionally, fragmentation of habitat and populations, local disappearance of snow leopards from some areas, and generally a declining trend in the leopard numbers over most of the range have caused concern among conservationists (Fox 1994).

In Manang, Nepal, more farmlands are being abandoned than they are cleared because of low land productivity, and difficulty in farming and irrigation. The human population, as well as the number of livestock in Manang, shows a declining trend; and I suspect a similar trend may exist elsewhere in the Himalayan range of snow leopards. Thus, subsistence activities of local people, such as farming and grazing, may not be as serious a threat as generally believed (e.g., Freeman et al. 1994). I believe

that threat to snow leopard survival from subsistence activities of local people is not greater than that from the affluent many who offer $60,000 for a full-length coat made from snow leopard skins (e.g., Freeman et al. 1994) or consumers of Chinese medicine containing snow leopard skeleton.

CONSERVATION MEASURES

The snow leopard's status as an endangered species means little to a herder who has lost a significant proportion of his livestock, possibly the only source of income, to predation (e.g., Oli 1993, 1994a, 1994c, Schaller et al. 1987). The livestock predation issue must, therefore, be resolved for snow leopards and local human populations to coexist. Ranjitsingh (1994) outlined an excellent eco-development program that aims at reducing the conflict between protected areas and local human populations while assisting the affected communities in improving living conditions. These programs are applicable to most areas in leopards' range with some modifications and may provide a sustainable solution to the predation problem. Oli (1994c) proposed following conservation measures:

1. Reduction in predation loss through improved husbandry practices (e.g., closer guarding, and safer night-time coralling).
2. Compensation for specific losses. Oli (1991) has provided a detailed scheme for this option.
3. Encouraging local participation in conservation and development activities through conservation education,
4. Improving law enforcement through local cooperation,
5. Capturing and promoting Buddhist religious sentiment of 'no killing' by involving local religious establishments in the conservation process,
6. Offering complementary development projects aimed at improving local services such that gains from protecting snow leopards in retaliation exceeds perceived gains from killing them,
7. Providing alternative source of energy to protect sparse vegetation in snow leopard habitat, and
8. Controlling illegal trade of snow leopard body parts, and
9. Controlling poaching of snow leopards and wild ungulate populations.

Recently, the "Project Snow Leopard" has been launched with the aim of conserving central Asian biodiversity using snow leopard as the flagship species (Freeman et al. 1994, Hunter et al. 1994). Objectives are commendable and include local involvement, improved reserve management, multi-national conservation networks, regional cooperation, and programs for reducing poaching. The project has the potential to make a difference if implemented as planned. Also, the need for ecological studies to obtain more reliable information on species' status and distribution could not be over-emphasized.

Role of Zoos - The zoos have probably played a greater role in educating the public about endangered species, such as snow leopards, than any other conservation organization. Additionally, a remarkable progress in care and breeding of snow leopards in captivity has almost eliminated the need for capturing wild snow leopards for zoos.

Previously, care and breeding of snow leopards was considered difficult, and breeding success was low. However, the past decade has seen a remarkable success in captive management and breeding. The global population of captive leopards was 292 in 1983, 332 by the end of 1984 (Blomqvist 1988), and currently, over 500 snow leopards are managed by 150 zoos worldwide (Blomqvist 1992). The number of captive-born snow leopards continues to rise; to date, Bronx and Helsinki zoos have recorded 69 and 70 births, respectively (Wharton and Mainka 1994). About 230 snow leopards in U.S. and Canadian zoos are managed under the Species Survival Plan of the American Association of Zoological Parks and Aquariums (Wharton 1993). A studbook of snow leopard is maintained by Dr. Leif Blomqvist of Helsinki Zoo, Finland, and records indicate that the captive leopard population is genetically diverse. These animals symbolize last hope should efforts of conservation of wild populations fail (Wharton and Freeman 1988, Wharton and Mainka 1994).

WILL THEY PERSIST?

I have eluded to this question until now, primarily because the answer is not straightforward. It may be argued that the leopards will persist if they are left alone, especially when recent evidence indicates that viable snow leopard populations may exist in the wild, but unfortunately, the risks are too many. It must be realized that the mountains of central Asia are home not only to the snow leopard and a number of other animal and plant species, but also to an ethnically and culturally diverse human population. The answer to the dilemma, therefore, lies in finding a sustainable balance between the needs of snow leopards and livelihoods of the local pastoral communities, and in effectively curbing the illegal trade of snow leopard body parts. These objectives, although challenging, are not impossible. The snow leopards will persist if these challenges are taken seriously, mistakes of the past are not repeated, and the leopards are treated as the "conservation ambassadors" instead of "bio-political" subjects.

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Table 1. Two estimates of habitat area and the number of snow leopards in each country within the leopards' range.

Country	Habitat area (km^2)		Population	
	Fox (1989)	Fox (1994)	Fox (1989[2])	Fox (1994)
Afghanistan	80,000	50,000	-	100-200
Bhutan	10,000	15,000	-	100-200
China	400,000	1,100,000	1400	2000-2500
India	100,000	75,000	200-600	200-600
Mongolia	130,000	90,000	500-900[3]	500-1000
Nepal	30,000	30,000	150-300	350-500
Pakistan	80,000	80,000	100-250	100-250
Former USSR[1]	400,000	395,000	1000-2000	1160-2100

[1] Includes Kazakhstan, Kyrgyzstan, Russia, Tajikistan, and Uzbekistan.
[2] Population estimates were not available.
[3] Tseringdeleg (1994) estimated the leopard numbers in Mongolia at 1500.