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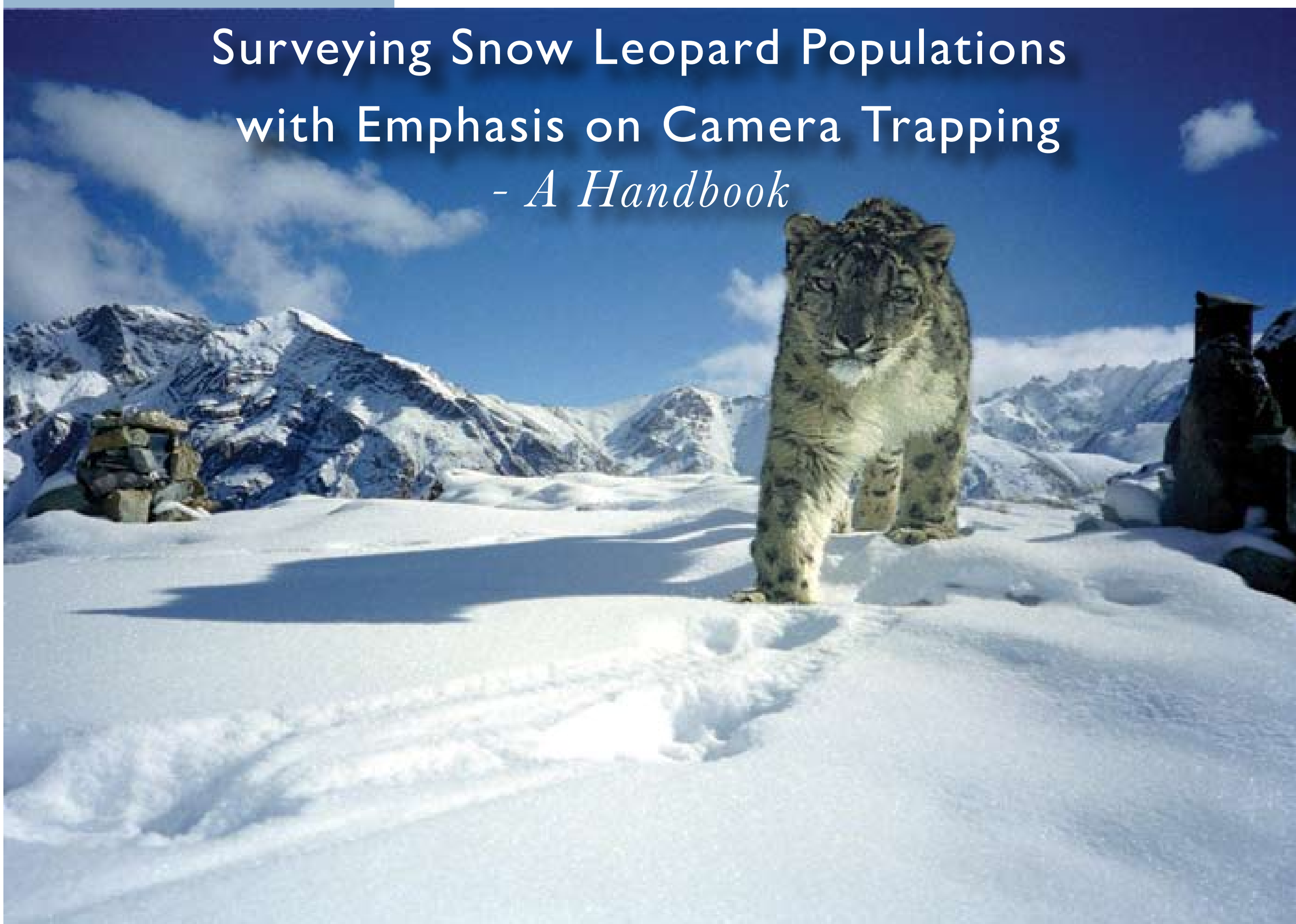
Surveying Snow Leopard Populations with Emphasis on Camera Trapping

- A Handbook



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SNOW LEOPARD CONSERVANCY

VERSION 1

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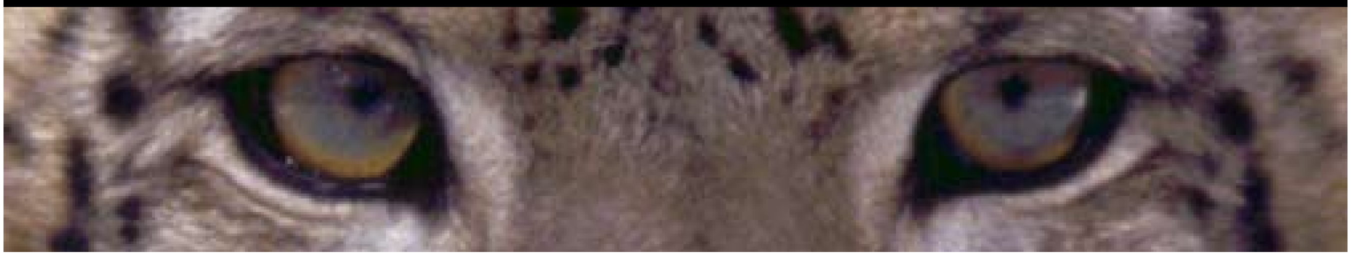

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Camera Traps are Effective Tools in Population Studies

Executive Summary

Checking a camera trap after a heavy snowfall

Solitary, elusive cats like the tiger (*Panthera tigris*) and snow leopard (*Uncia uncia*) are notoriously difficult to enumerate. Indirect techniques using pugmarks or other sign produce ambiguous information that does not directly correlate to abundance since many factors influence snow leopard travel patterns and marking behavior. Furthermore, considering the remote and rugged landscapes inhabited by snow leopards, it is hardly surprising that our knowledge of the status of this endangered species and its occupied range is very limited.

We adapted the camera trapping techniques pioneered by Dr. Ullas Karanth and his associates for counting Bengal tigers to census snow leopards in India's Hemis High Altitude National Park (HNP), located in Ladakh, India. HNP was selected because of frequent snow leopard sightings, low incidence of poaching, a relatively stable ungulate prey base and the presence of well-defined travel corridors where remotely-triggered camera traps could be placed to achieve a consistently high photo-capture success rate.

This handbook provides an introduction to snow leopard population survey techniques, followed by a detailed account of camera trapping methods. During the 2002 through 2004 winter field seasons, the Snow Leopard Conservancy experimented with infrared camera trapping techniques to define a methodology suitable for the high altitude environment. In 2001 and 2002, much of our time was spent familiarizing ourselves with various infrared camera traps, their operation and setup, and comparing the effectiveness of different models and sensor types. We placed infrared camera traps along frequently used travel corridors at or near scent-sprayed rocks (rock scents) and scrape sites within 16 km^2 sampling cells between January and March in 2003 and 2004. A total of 66 and 49 captures of snow leopards were tallied during 2003 and 2004, resulting in an overall capture success of 8.91 and 5.63 individuals per 100 trap-nights, respectively. Capture probabilities ranged from 0.33 to 0.46. Density estimates ranged from 8.49 $\pm$ 0.22 individuals per 100 km^2 in 2003 to 4.45 $\pm$ 0.16 in 2004, with the disparity between years largely attributed to different trapping densities. Snow leopard abundance estimates were calculated using the computer program CAPTURE.

Individual snow leopards were identified based on their distinct pelage patterns. The areas most useful in identification were the lower limbs, flanks, and dorsal surface of the tail. Various camera setup scenarios were explored, and the most reliable proved to be two cameras oriented at oblique angles (i.e., 45° angles) to account for asymmetrical pelage patterns, at locations where topography funneled snow leopards into narrow travel corridors. Individuals were successfully identified based on unique rosette and spotting patterns, which resulted in a minimum population census of 6 snow leopards within the survey area during both years. However, subject orientation greatly affected the reliability of identifying individuals from photographs.

Our study suggests that photographic capture-mark-recapture (CMR) sampling can be a useful tool for monitoring demographic patterns; however, a larger sample size would be necessary for generating a statistically robust estimate of population density and abundance based on CMR models. One's ability to trap over large areas is severely hampered by the rugged terrain and lack of ready access. Moving traps from one site to another can also be very time-consuming. Cumulative capture curves indicate that camera trap surveys need to be at least 35 days in duration to detect sufficient individuals, but 45-50 or more days may be necessary for ensuring adequate recaptures. We recommend a minimum trap density of approximately two trap stations per 16-30 km^2. Camera trap estimates should be supported by ungulate prey abundance surveys and calibrated data from standardized snow leopard sign transects wherever possible.

While population estimates are difficult to obtain, camera trapping can provide the minimum number of individual snow leopards present, provided traps cover a sufficiently large area and are run for at least 2-3 months, with the winter and early spring being the best time of year for such a survey. Obtaining statistically valid population estimates is expensive, time-consuming and not feasible in many situations. However, the use of inexpensive passive infrared-camera traps deployed over long time spans at frequently visited rock scents by sufficiently trained wildlife staff or local villagers could be used to monitor the number of individuals and demographic patterns. Knowing the individual snow leopards that inhabit a particular area might promote stewardship of the species among interested households in local communities.

Shy Cats Living in Remote Places

Chapter 1: The Challenge – Surveying the Status of the Elusive Snow Leopard

Large solitary and secretive felids like tiger (*Panthera tigris*) and snow leopard (*Uncia uncia*) are notoriously difficult to enumerate. Most indirect techniques (including the widely-used pugmark surveys) for estimating numbers of cryptic predators are inadequate because they neglect to address fundamental questions related to observability and spatial sampling or have not been adequately calibrated to areas of known density and land-tenure configuration (Karanth et al. 2003; Jennelle et al. 2002). These factors are strongly influenced by the extensive range and numerical scarcity of large carnivores, and their typically strong tendencies toward secretiveness as noted by Karanth and Nichols (1998) in reference to tiger populations in India. Besides sharing similar characteristics, the endangered snow leopard inhabits the world's highest and perhaps most forbidding terrain, with difficult on-the-ground access taxing even the most enterprising and persistent researcher (Jackson and Fox 1997). In addition, evaluations of all rare or elusive carnivores, especially snow leopard, are plagued by small sample size (Mills et al. 2000).

FIGURE 1
Snow Leopard Range Map (adapted from Fox, 1994)

The snow leopard is found in the high mountain regions of Central Asia, where it is thinly distributed across a vast area, in excess of 1.2 to 1.6 million square kilometers and possibly as much as 3 million square kilometers (Fox 1994; Hunter and Jackson 1997; Nowell and Jackson 1996; Sunquist and Sunquist 2002). Figure 1 indicates the snow leopard's general distribution. The total snow leopard population is judged between 4,500 and 7,500 across 12 countries: China, Bhutan, Nepal, India, Pakistan, Afghanistan, Tajikistan, Uzbekistan, Kyrgyz Republic, Kazakhstan, Russia, and Mongolia (Table 1). However, no one knows the species' actual status. Even its currently occupied range is poorly mapped because of limited funding, lack of trained biologists, and difficult logistics which severely constrain surveys across the snow leopard's high, inhospitable terrain.

Major threats to the wild snow population are retributive killing from livestock owners (especially as a result of multiple depredation incidents which occur after a leopard enters a poorly constructed night-time livestock enclosure), poaching for its exquisite fur and valuable bones or body parts (the latter used in traditional Chinese medicine), habitat encroachment, competition from livestock, and a diminshing natural prey base.

Snow leopards occur at elevations of 3,000 to 4,500 meters and occasionally venture as high as 5,500 meters in the Himalaya or as low as 600 meters in northerly latitudes (Mongolia and Russia). Population density ranges from less than 0.1 to over 10 individuals per 100 km^2 (Jackson and Ahlborn 1989; Nowell and Jackson 1996). Snow leopards favor steep terrain broken by cliffs, ridges, gullies, and rocky outcrops, although in Mongolia and on the Tibetan Plateau they occupy relatively flat or rolling terrain as long as there is sufficient cover to hide. Mountain ridges, cliff edges, and well-defined drainages serve as common travel routes and sites for social marking, including the deposition of scrapes, scats, and scent (Ahlborn & Jackson 1988). The species' distribution coincides closely with that of its principal large prey - the blue sheep (*Pseudois nayaur*) and ibex (*Capra sibirica*) - although it has been documented feeding upon a wide range of hoofed animals in addition to marmot (*Marmota spp*), pika (*Ochotona spp*), hare (*Lepus oistolus*), and a variety of small rodents and game birds. Relatively little is known about snow leopard behavior, movements, home range, social organization, and reproduction in the wild (Nowell and Jackson 1996; Sunquist and Sunquist 2002).

To date, conservationists have relied primarily upon sign to determine presence/absence and calculate indices of relative abundance for this elusive species. In the early 1990s, the International Snow Leopard Trust (ISLT) recognized the need for a standardized field survey method that field workers with basic academic qualifications could apply. Toward this goal, ISLT developed *SLIMS* – the Snow Leopard Information Management System – conceived as a comprehensive computerized database on snow leopard populations, protected areas and key habitat attributes across their entire range. *SLIMS* surveys are based on the tallying of sign found along fixed transects ranging from 0.3 to several kilometers in length, with the observer recording all observable scrapes, pugmarks, feces, rock scents and other sign left by snow leopards (Jackson and Hunter 1996). *SLIMS* surveys have been applied in different parts of the snow leopard's range, but the system is not without its shortcomings, notably sporadic and inconsistent application (due to limited buy-in by range country institutions and field biologists), a widespread lack of funding, and somewhat demanding survey protocols for persons with limited biological background (Jackson et al. 1997). A simplified methodology has been developed by ISLT and is posted on the Snow Leopard Network's website (www.snowleopardnetwork.org). Forms and the sign survey methodology can also be downloaded from the Snow Leopard Conservancy website.

It is impossible to judge the effectiveness of conservation investments without monitoring of the target species population and the quality of its occupied (or vacated) habitat. Yet it is increasingly evident that insufficient attention has been paid toward developing survey and monitoring protocols for providing protected area managers and other decision-makers with reliable baseline information upon which informed decisions can be made. Karanth and others (2003) reviewed the efficacy of the tiger 'pug-

Table 1: Habitat and population estimates for snow leopards across 12 range countries

Country	Area of Habitat (square kilometers[1])	Estimated Population[2]
Afghanistan	80,000	100 – 200
Bhutan	10,000	100[2]
China	400,000	2,000 – 2,500
India	95,000	200 – 600
Mongolia	130,000	1,000
Nepal	30,000	350 – 500
Pakistan	80,000	250 – 420
Russia	131,000	50 – 150
Kazakhstan	71,000	180 – 200
Kyrgyzstan	126,000	800- 1,400[3]
Tajikistan	78,000	120 – 300 (650)
Uzbekistan	14,000	10 – 50
(Former USSR)	(400,000)	(1,160 – 2,100)
	1,835,000[4]	Totals ± 4,500 – 7,500

[1] Fox 1992; [2] Jackson, unpublished data; [3] Recent estimates suggest a 50% or greater decline in numbers to about 650 individuals; [4] Jackson and Hunter (1996) estimated total potential habitat at 3,024,728 km^2 using GIS modeling.

mark census method' that India has been relied upon for the past 30 years. They concluded that this technique is fundamentally flawed in its underlying assumptions and that it lacks the necessary modicum of statistical rigor. Fortunately a new suite of non-invasive techniques, including remote camera trapping and genotyping of DNA contained in hair or scats, offer the prospect for counting and estimating population size with high degrees of accuracy, precision and scientific rigor – but at a higher cost. Genetic material extracted from feces and snagged hair may be used to provide information on species and individuals, including inferring genetic variation, genetically effective population size, recruitment, dispersal, home range, habitat use, kinship and paternity, even for rare and cryptic species (Piggott and Taylor 2003).

If conservationists are to ensure that populations of large predators like the tiger and snow leopard persist, they need to know far more about each species' distributional pattern and population trends over manageable time periods (Snow Leopard Survival Strategy 2003). Only through the regular monitoring of each population can range contractions or expansions be detected. Also, monitoring constitutes an important tool for studying metapopulation dynamics and patch occupancy, and for verifying that conservation actions are, in fact, having a positive impact with respect to the targeted species' numbers.

Karanth (1995) demonstrated the feasibility of using photographic capture-mark-recapture (CMR) to estimate tiger population size; later refining the sampling procedures to assess tiger numbers across representative areas contained within protected areas in India (Karanth and Nichols 1998). In 2002, we initiated a camera trapping study in the Hemis High Altitude National Park (HNP) of Ladakh, located in northwestern India, adapting techniques from the pioneering work by Karanth and his associates (Karanth 1995; Karanth and Nichols 2002), with the following objectives:

1. To develop a standardized field method and sampling strategy for applying CMR models to snow leopards using remotely triggered camera traps;
2. To estimate snow leopard density over two consecutive (winter) seasons;
3. To develop a camera trapping protocol that could be applied in other parts of snow leopard range within high and low density areas in order to estimate total numbers better; and
4. To develop a snow leopard identification protocol based on their distinct pelage patterns.

We selected HNP because of its frequent snow leopard sightings, low incidence of poaching, an apparently stable ungulate prey population, and the presence of definable travel corridors used by resident and transient snow leopards along which remotely-triggered camera traps could be expediently placed for achieving consistent capture probabilities (Jackson et al. manuscript under review). This manual draws upon the results of that research, and prior work on snow leopard sign surveys by Jackson and Hunter (1996).

Tracks of a male snow leopard at 5000 meters in Western Nepal

SNOW LEOPARD
UNCIA UNCIA

Perhaps the most beautiful of the wild cats, the snow leopard is certainly the most rarely-seen. Renowned for its smoky-grey pelage tinged with yellow and patterned with dark grey, open rosettes, and black spots which provide superb camouflage against rock and snow.

Unique adaptations allow them to tolerate extremes in climate and terrain. Their remarkable tail aids in balancing on narrow ledges and provides wrap-around warmth while resting on frigid ground. Other adaptions include long and dense woolly underfur, a well-developed chest, short fore-limbs with sizeable paws and relatively long hind limbs, making their leaping ability the stuff of local legend.

Photo: Ron Kimball

Chapter 2: About this Manual

The primary objectives of this manual are:

- Briefly review methods for determining the presence-absence (detection/non-detection), relative abundance and population size in snow leopard;
- Provide detailed guidelines for undertaking a camera trap survey, highlighting protocols appropriate to conditions prevailing in the snow leopard's mountain habitat; and
- Encourage the use of camera trapping as a means for calibrating indices of relative abundance derived from sign transects undertaken in different areas and habitats across the species' vast range.

This manual is based upon camera trapping conducted by the Snow Leopard Conservancy between 2002 and 2004 in the Hemis High Altitude National Park, India. The handbook is aimed at researchers and protected area biologists with a B.Sc. or higher degree, who have a basic understanding of population sampling theory and practice, along with the ability to detect and interpret snow leopard sign. For other persons involved in conservation and monitoring snow leopards, such as park guards and non-governmental organization (NGO) field staff, a shorter version aimed at counting snow leopards using simple passive infrared, inexpensive camera traps will be posted on the Snow Leopard Conservancy website. This will be based upon results of the trapping currently being undertaken by local villagers and range-country NGO staff in Pakistan, India and Nepal.

Topics addressed: First, we briefly describe the basic kinds of surveys and objectives each is intended to address, including presence/absence, range mapping, monitoring snow leopard relative abundance using sign deposited along their travel corridors, population census and absolute abundance estimation based on the detection and identification of individual snow leopards. The potential and limitations of using different types of sign (tracks, scats, hair and photographic images) to identify individual snow leopards is briefly discussed.

Second, we define what is meant by monitoring and the importance of systematic sampling. Finally, we present a comprehensive account of camera trapping as a means for censusing and estimating snow leopard numbers within areas of critical importance or special interest. Since range country biologists and conservationists lack easy access to the scientific literature, we provide detailed information on all aspects of camera trapping, including the assumptions underlying CMR population estimates and details of the various estimation models computed by the software program CAPTURE.

What Kind of Survey Should You Undertake?

Chapter 3: Types of Surveys for Monitoring Snow Leopard Populations

Karanth et al. (2003) listed three fundamental levels, in terms of increasing sophistication, for monitoring tigers in India. These vary with respect to the objective and geographic scale covered - from wide-ranging regional surveys for mapping predator-prey distribution to site-specific monitoring aimed at determining the annual survival, recruitment or trend of a given population. Basically, the three types of monitoring applied to snow leopards are:

1. Presence/Absence [detection/non-detection] surveys to map snow leopard distribution patterns and/or identify occupied range;
2. Sign transects to 'track' the relative abundance of snow leopards between or within particular areas over time;
3. Camera trapping and related techniques for identifying individuals and accurately estimating population size (absolute abundance).

3.1 Presence/Absence Surveys:

Seek to establish the presence of a species within a particular area, usually less than 200-500 km^2 in size, based upon indirect sign (tracks, feces, etc.) and related information obtained through careful interviewing of local people, hunters and other knowledgeable individuals. First Order Surveys under the *SLIMS* methodology target this objective (Jackson and Hunter 1996).

The surveyor must understand the fundamental difference between determining the *presence* of a species (easier) and establishing its *absence* from a particular area, the latter being much harder. The term 'detection/non-detection survey', preferable for absence *per se*, can be very difficult and even impossible to establish with a reasonable degree of certainty. Snow leopard presence can be readily validated based on reliable identification of its sign (e.g., pugmarks, feces, scent-sprayed rocks) or actual sightings (rare and often difficult to substantiate). Conversely, the absence of sign or sightings may simply indicate a failure to detect sign, and can occur even when snow leopards are actually present in the area surveyed for several reasons. First, sign longevity is subject to many environmental factors, while the intensity of social marking varies widely depending on the time of year and land-tenure status of the different individuals present (see Box A).

In fact, concluding snow leopards are potentially absent requires substantial expenditure of time and effort, which is usually not within the means of surveyors and their sponsors. Nonetheless, researchers have developed statistically-based survey methods and algorithms for estimating detection probabilities (see next section). While absence can never be verified with certainty, the presence of snow leopards in a given area becomes unlikely if no evidence is encountered during 3-5 weeks of meticulous fieldwork within a contiguous survey area of 75-200 km^2 by investigators familiar with snow leopard sign and local travel patterns.

Box A: Factors Influencing Sign Deposition and Longevity Rates in Snow Leopard (adapted from Ahlborn and Jackson 1988; Jackson and Hunter 1996).

Factor	Effect on Sign Abundance	Comments
Time of year	Marking rates vary seasonally (peak at mating), so sign accumulation is greatest in late winter and early spring.	Surveys must be conducted in comparable seasons (i.e., the same time each year to obtain trend information).
Type of marking substrate and type of sign	Scrape and rock scent longevity is dependent upon substrate and other site-specific factors.	Sign longevity not uniform with respect to substrate or type of sign (i.e., tracks are short-lived, scrapes & feces tend to be long-lived, unless damaged by weather, livestock or humans).
Weather (snow, rain & wind)	Hides and/or destroys sign over time.	Snow hides old sign, but highlights fresh pugmarks. Rain & wind destroy sign, often very rapidly.
Human or Livestock Disturbance	Sign is obliterated by the passage of people & their livestock	Livestock use varies seasonally, with most stock moving to higher elevation in late spring and summer.
Social Organization and Land Tenure	Snow leopards mark in response to conspecifics –sign density is greatest in overlapping core areas (Jackson & Ahlborn 1989).	Marking rates & sign abundance confounded by snow leopard density, home range overlap & social interaction.

3.2 Distribution or Range Mapping:

Seeks to map and/or monitor gross changes within a carnivore's spatial distribution pattern across its current or historic range. When sufficiently applied, such mapping can alert managers to population extirpation resulting from habitat fragmentation, degradation or excessive poaching of both predator and prey. Information on occurrence is essential to establishing the status of snow leopards (or any other target species for that matter) across countries or within different parts of their range, and for checking historic sites where the species is suspected to have been extirpated (MacKenzie et al. 2003). Expert knowledge was used to generate a spatial map for jaguar (*Panthera onca*) showing historic range, currently occupied range, areas of substantial predator and prey populations, and locations of sightings (Sanderson et al. 2002). Snow leopard experts are currently involved in a similar exercise under the auspices of the Snow Leopard Network (SLN), a partnership of organizations and individuals from government and the private sector working together for the effective conservation of the snow leopard, its prey, and their natural habitat to the benefit of people and biodiversity. SLN also hosts the *SLIMS* database developed by ISLT.

Detection/non-detection surveys provide a means to evaluate snow leopard spatial distribution patterns, and to estimate the proportion of a given area it occupies (i.e., 'patch occupancy') - provided such surveys are undertaken systematically rather than in an *ad hoc* manner (Thompson 1998, MacKenzie et al. 2002; 2003). The survey area of interest is typically demarcated into search cells (also called grids or sample blocks) ranging in size from 10 – 100 square kilometers; within each cell, representative sites are visited and the presence (or apparent absence) of the target species is determined from sign (pugmarks, scrapes, etc), direct sightings (obviously rarely realized) or through focused interviews with knowledgeable local residents. Good survey practice includes an estimation of the overall survey effort (e.g., hours or days spent searching for sign, along with the areal extent covered) and latitude/longitude records of all sightings of animals or sign. Obviously, the proportion of range that can be covered is determined by the available budget, staffing, logistics, and access or security issues. Indeed, large portions of the snow leopard's range are located along international borders in areas closed to foreign scientists and even nationals of the country. As shown in Figure 1, as much as 25% of the snow leopard's range falls within 50 km of an international boundary.

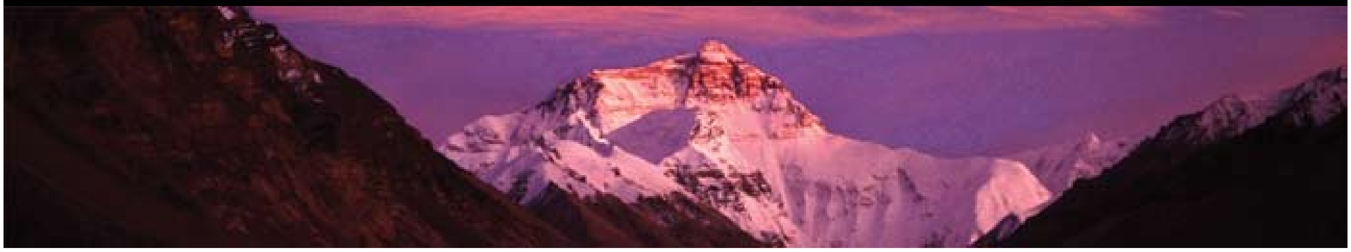
However, in order to generate reliable data for generating spatial projections, investigators must pay special attention to sampling design to ensure surveys are undertaken appropriately and systematically. The first step is to divide the larger area of interest in equal-sized cells of a manageable size, which should not exceed the minimum home range area of snow leopards typical of the habitat and terrain type under consideration. In high quality, prey rich habitat (Jackson 1996) this might be cells of 16 - 30 km^2 (e.g., rugged terrain in Nepal's western Himalaya where there are few people and good numbers of blue sheep); in the prey-sparse and relatively open terrain of Mongolia's Gobi Desert (McCarthy 2000), cell sizes of 100 - 200 or even 400 km^2 might suffice. Cell size will, however, influence the coarseness of the resulting data, and any decision thus involves a balance between the desired resolution of the survey and the level of effort and cost required to cover smaller search sites. According to the manual for forest leopard (*Panthera pardus*) by Henschel and Ray (2003), there is no rule regarding cell shape. Square or hexagonal cells are examples of spatial sampling units that have the smoothest fit against one another, leaving no gaps in between. In reality, topography and accessibility usually determine what cell size or shape works best.

Once a suitable cell size has been determined, the survey area can be divided into sampling units. The next (and more difficult step) is to select a series of contiguous sampling cells to visit and inspect for snow leopard presence or absence, either by searching for sign, or by using detection devices like remotely-triggered cameras. With a sufficiently large but representative sampling effort, snow leopard spatial distribution can be mapped over a reasonably large area. However, it is generally impossible to sample all cells within the desired survey area, so that a random or preferably a stratified sampling of units must be selected for visitation.

It is beyond the scope of this manual to discuss the various sampling strategies and designs available. Rather, the reader is referred to standard texts like Lancia et al. (1994), Thompson et al. (1998) or Williams et al. (2002). A few important pointers are:

- Ensure continuity between the sampled cells. In other words, there should be no gap large enough to support a snow leopard (see Section 4.3);
- Select areas representative of the full range of habitats found within the area of interest (i.e., not just areas with high habitat suitability) and sample these in general proportion to their occurrence;
- Use a standardized and consistent search technique and be sure to record your sampling effort (e.g., time per unit area spent searching for sign or animals; conduct surveys during comparable times of day or year using trained surveyors).

Clearly, a good knowledge of the survey area is warranted, and in this regard topographic maps (scale 1:250,000 or better) along with accompanying satellite imagery are almost indispensable.



Unfortunately, maps are difficult and often nearly impossible to obtain for many snow leopard range countries; however, satellite images and 1:100,000 scale maps developed by the former Soviet Union for some regions are available on the internet (see Appendix 4 for selected map resources).

In their manual on tiger monitoring, Karanth and Nichols (2002) recommended the use of adaptive cluster sampling: this builds on a simple or stratified random sampling design by sampling all the cells bordering those where the target species' presence has been recently recorded and/or verified, and continuing sampling 'outward' until the cluster is surrounded by cells that fail to detect leopard presence. The fact that snow leopards usually inhabit mountainous terrain will help determine in which direction cells should be consistently added. While snow leopards are known to cross montane basins or level plains 50 km and wider, such habitats are not permanently occupied; rather they are used by individuals moving from one mountain massif to another (McCarthy 2000).

Another important consideration is how much effort one should put into the search to verify 'presence,' as noted above. There are no hard and fast rules for search effort, since this will vary greatly with respect to observer knowledge and skills, accessibility and logistics, and type of terrain. For example, it is easier to detect snow leopard scrapes or related sign in areas where snow leopard travel is strongly constrained and 'funneled' by the terrain, in places with minimal livestock disturbance, and during the months immediately following the mating season (Ahlborn and Jackson 1988; Box A). While snow leopard presence can be definitively established through (reliable) observations of fresh sign (especially scrapes and pugmarks), the absence of sign does not necessarily equate to the absence of snow leopards from the area as noted above. Rather, non-detection may indicate either the absence of the cat or its presence has simply gone undetected (see Karanth & Nichols 2002). Marking behavior in snow leopards appears to be socially-driven (Ahlborn and Jackson 1988). Simply assuming that the failure to detect the cat indicates its absence from the area could, therefore, lead to a biased estimate of site occupancy (MacKenzie et al. 2003; Wintle et al. 2004).

This highlights the importance of using a survey method that attempts to estimate the ***detection probability*** of the targeted species. Detection probabilities can be assessed either by having multiple observers independently visit the same cell where no sign was detected, or having the same observer visit that cell on two or more different occasions. Such statistics can then be used to adjust the estimate for the number of cells where leopards have been detected, yielding more reliable information on the proportion of area occupied. This technique is described by Karanth & Nichols (2002) for tiger. It has been further developed using models to estimate site occupancy rates when the probability of detection is less than one. For details, see MacKenzie et al. (2002; 2003), along with their computer program (PRESENCE) which generates estimates of patch occupancy rates and related parameters (U.S. Geological Survey Patuxent Wildlife Research Center website; www.mbr-pwrc.usgs.gov/software.html). Wintle et al. (2004) also offer a spreadsheet for computing detection probabilities.

3.3 Monitoring Relative Abundance based on Sign:

A quantitative index of abundance which has a ***direct or at least consistent*** correlative relationship to absolute density can be used as a measure of relative abundance for a target species. Sign transects, in which the number of pugmarks, scrapes, feces and rock scents, tallied according to a standardized protocol, are a widely promoted method for monitoring snow leopard relative abundance - especially within relatively confined areas like national parks and other protected areas (Jackson and Hunter 1996). Under *SLIMS*, relative abundance is expressed as an encounter rate (i.e., the number of pugmarks, scrapes or feces per kilometer walked). However, there has only been one study that attempted to correlate sign density and cat density (Ahlborn and Jackson 1988), which indicated that sign predicted about 60% of known visitations with sign density being highest within overlapping 'core-use areas.' For forms and information, see the *SLIMS* Users Group Website at: www.snowleopard.org/whatwedo/science/slims or SLC's website.

Another example of an abundance index could include the number of leopard photographs per unit effort (Carbone et al. 2001), or the ratio of new versus old scrapes encountered (with the frequency of rescraping thought to be greater in sites with a higher snow leopard density). However, sampling effort can be relatively demanding depending upon the amount of variability within data sets. While comparisons can be made between different areas, indices are better applied to tracking year to year annual population trends within the same area since sign deposition rates and sign longevity are affected by a host of environmental and behavioral factors (Ahlborn and Jackson 1988) (Box A).

This variability affects all indices of abundance implicit in the number of pugmarks, scrapes, feces, or rock scents tallied, in that these usually do not calibrate accurately with animal abundance, and typically require substantial sample size to account for dataset variability. Ahlborn and Jackson (1988) found scrapes were a better predictor of snow leopard visitation than shorter-lived pugmarks, but these investigators noted that substantial effort would be required to reliably detect a difference between survey areas or sign density from one year to the next. They estimated that 36, 158 and 121 transects would be required to detect sign with a ± 30% confidence of obtaining the mean number of scrapes, feces and tracks observed in a high density (10-12 individuals per 100 km^2) snow leopard area in Nepal. Thus, significant levels of effort are required to estimate animal density from sign abundance.

Reliability in sign identification is another important factor to consider. Snow leopard and lynx tracks are very similar in shape, appearance and even size, and the same can be said of common leopard. Special care must be taken in identifying feces, for snow leopard scats are also similar in size to those left by common leopard, wolf, and even fox (since 'token scats' left by snow leopard are unusually small in shape, length and diameter). This problem is greatly compounded in areas with sympatric snow leopard and common leopard distribution, as occurs along the southern flanks of the Himalaya, or in the eastern portions of the Tibetan Plateau. Even canid and felid tracks can be confused by inexperienced field personnel. Tracking substrates in mountains are mostly coarse-grained and thus ill-suited to preserving detailed pugmark impressions (except in snow, but such detail is lost rapidly through sun and wind ablation). Artificial tracking pads (Sharma 2003) can be employed but are labor intensive and must be carefully or strategically located. Unless they blend into the local background, some individuals may avoid stepping on them, leading to biased abundance estimates.

Variation in sign abundance may be related to differences in land-tenure pattern or shifts in prey availability and abundance due to seasonal, habitat-related or year-to-year productivity. The presence of humans may influence snow leopard visitation patterns to a particular area. Therefore, be alert to such factors and seek relevant environmental, ecological and behavioral information on the survey area, especially the threats underlying the particular predator and prey population. A useful exercise may involve the construction of a '*Threats Matrix*' along lines of that described by Salafsky and Margolius (1999).

Finally, in the interests of survey reliability, replicability and consistency, a standardized non-subjective methodology must be aggressively pursued and applied by all survey participants. A wise concomitant strategy would be to survey the relative abundance of key prey species like blue sheep or ibex, as a secondary means for assessing probable predator population size.

Readers are referred to Wilson and Delahay (2001) for a review of methods to estimate carnivore abundance using field signs and observations. For information on snow leopard sign identification and surveys, see the *Snow Leopard Survey and Conservation Handbook* published by the International Snow Leopard Trust (Jackson and Hunter, 1996[1]), along with 'lessons learned' from applying this technique in Mongolia (McCarthy and Munkhtsog 1997).

3.4 Estimating Absolute Abundance:

Estimates of absolute abundance depend upon an ability to ***detect and distinguish*** individuals from one another, using an unbiased field sampling and analytical technique. Basically, there are three options for precise population estimation: first, capture and instrumentation (i.e. marking) of individuals with radio-collars, the most expensive, labor-intensive and time-consuming alternative.

Secondly, the identification of individuals through DNA genotyping (Foran et al. 1998a and 1998b). The third method entails the use of remotely triggered cameras and date-stamped photographs: spot or striping patterns have been used to estimate the number of cheetah (*Acinoyx jubatus*) in the Serengeti (Kelly, 2001), tigers in India and across South Asia (Karanth 1995, O'Brien et al. 2003), jaguars in Central America (Maffei et al. 2004; Silver et al. 2004),

[1]Available in three PDF files at: www.snowleopardconservancy.org/handbook.htm

bobcats (*Lynx rufus)* in the US (Heilbrun et al. 2003) and wild dogs (*Lycaon pictus*) in South Africa based on non-invasive photographs obtained by researchers or the general public (Maddock and Mills 1994). While Miththapala et al. (1989) distinguished leopards in Sri Lanka from their whisker spot patterns, body spotting is easier to use (Henschel and Ray 2003).

DNA genotyping employing non-invasively sampled techniques like hair traps or snares and the collection of feces has been used to estimate population size in mountain lion (*Puma concolor)* (Ernest et al. 2000), brown bears (*Ursus arctos)* (Mowat and Strobeck 2000), coyote (*Canis latrans)* (Kohn et al. 2001), and swift fox (*Vulpes velox)* (Harrison et al. 2002), for example. This technique has yet to be applied to snow leopard, with the current effort being aimed at assessing genetic variability of the population and determining the best markers and protocols for genotyping. The initial excitement over non-invasive genotyping has been somewhat tempered as more sources of error are identified, including violation of population closure assumptions, and false alleles (e.g., Taberlet et al. 1999, Boulanger and McLellan 2001, Mills et al. 2000, Lorenzini et al. 2004). Consequently, some investigators recommend combining different methods, including remotely-triggered cameras, radio-telemetry and DNA genotyping (Boulanger et al. 2002), but this significantly elevates cost and the required skill level.

Smallwood and Fitzhugh (1993) developed a technique for 'identifying' individual mountain lions (*Puma concolor*) from their tracks, which was tested and further refined by Grigione et al. (1999) and Lewison et al. (2001). Drawing upon the considerable tracking skills of the Kalahari Bushmen, Stander (1997) was able to estimate common leopard numbers with a high degree of confidence based on track appearance (size and shape). This investigator examined the relationship between spoor (track) frequency and true density using radio-telemetry, and concluded that indirect sampling through counting spoor could provide repeatable and inexpensive measures for some population parameters when individuals could be reliably distinguishable on the basis of their pugmark characteristics (Stander 1998). However, most studies of track counts have only provided coarse-scale output (e.g., Smallwood and Fitzhugh 1995; Van Sickle et al. 1992).

Riordan (1998) reported on the recognition of individual tigers and snow leopards in a zoo collection using statistical techniques (Principal Components Analysis, self-organizing map or SOM and other unsupervised Bayesian classifications) to discriminate between different individuals. Sharma et al. (2002 and in review) used Discriminant Function Analysis (DFA) involving 9 pugmark length and width variables to separate individual tigers and their gender in the wild. We are cooperating with this investigator on a feasibility study to assess if fresh pugmarks in snow could be used for individual identification, gender discrimination and age-class estimation in snow leopard; results of this work are expected by late 2005 or early 2006.

However, the method currently used most widely for individual recognition involves the use of remote cameras. An important consideration is their relatively high purchase and deployment cost, even for popular models like CamTrakker ™ and TrailMaster ™. Several investigators have developed their own low cost or homemade models (e.g., Joslin 1988, Jones and Raphael 1993, York et al. 2001), but reliability often becomes a factor of concern (this study). Yet despite the cost, remote cameras are being increasingly used to monitor carnivore populations (Henschel and Ray 2003, Harrison et al. 2002, Moruzzi et al. 2002, Trolle and Kery 2003, Silver et al. 2004).

The best snow leopard habitat is found in places rarely visited by people or their livestock (Langu Valley, Nepal).

There are many factors to consider beside the equipment or tools required for a rigorous count. As noted by Karanth et al. (2003), deriving absolute densities of predator and prey populations requires substantial effort that can only be achieved at a few priority sites, where sufficient resources and technical 'know-how' exists for systematically estimating population size and density under a rigorous and statistically sound sampling regime. This manual suggests procedures for estimating snow leopard population size at medium or high density sites using camera traps, based on surveys in the Hemis National Park of northern India conducted between 2002 and 2004. But we cannot understate the need for more research to refine the methods as well as establish valid sampling strategies.

3.5 What Kind of Survey is Most Appropriate?

This really depends upon the question or questions you are seeking answers to, the survey's specific objectives, and the availability of funds, equipment and trained persons for undertaking the survey. Table 2 summarizes different survey objectives and their level of effort, while Table 3 lists the major advantages and disadvantages of each kind of survey.

Table 2: Examples of Snow Leopard Surveys and Associated Methods (adapted from Henschel and Ray, 2003)

Primary Survey Method & Objective	*Level of Survey*: *Simple* →			*Complex*
	Presence-Absence (informal) *Ad hoc* site search for sign	**Presence-Absence (formal or systematic)** Systematic site-based search for sign	**Relative Abundance** Standardized sign transect (e.g., *SLIMS*)	**Estimate of Absolute Density (rigorous survey)** Camera trapping / DNA genotyping / radio-telemetry
Detect presence or absence of snow leopards within a defined area.	X	X	X	X
Map snow leopard distribution & 'hotspots' at regional scale (e.g., county, province, country).		X	X	
Evaluate what proportion of an area is occupied by snow leopard.		X	X	X
Determine abundance of snow leopards in different areas or within a given area over time.			X	X (density given sufficient individuals & captures)
Monitor changes in spatial distribution at a regional scale (e.g., country or county).		X	X	X
Evaluate the impacts of prey or habitat change on snow leopard presence, relative abundance, or density.			X	X
Generate habitat relationships or spatially-explicit population model.			X	X
Estimate absolute snow leopard density within a relatively small defined area.				X

Table 3: Advantages and Disadvantages of the Different Survey Levels

Characteristic	**Informal Presence/ Absence Survey**	**Systematic Presence/ Absence Survey**	**Relative Abundance Survey**	**Absolute Density Estimate**
Surveyor skill level	Relatively low (least skilled)	Moderate	Moderate	High or very high (requires highly trained biologist)
Specialized equipment	None (maps optional)	Some (GPS / maps)	Some (GPS / maps / compass / tally counters)	Extensive (remote cameras, GPS, radio-collars, etc.
Survey duration	Short (days)	Moderate (weeks)	Moderate (weeks)	Long (months or years)
Logistical complexity	Low	Moderate	Moderate	High
Survey cost	Lowest	Moderate	Moderate	High
Output precision level	Low	Low – moderate	Moderately high	High

3.6 Sampling Considerations:

Snow leopard biologists may use systematic presence/absence, relative abundance and absolute density surveys for monitoring the cat's status over space and time, although from a cost and effort viewpoint camera trapping should only be attempted in national parks, high-value conservation sites or for the calibration of sign abundance indices. But whichever survey objective is contemplated, it is imperative that you approach each task systematically, based upon a sound understanding of underlying concepts and the 'do's and don'ts' of sampling. By monitoring absolute or relative numbers, managers can be better assured of detecting a change in spatial occurrence and abundance of snow leopards, and in so doing, should gain a better appreciation of the relationship between population size, habitat condition and selected land use parameters.

Animals are rarely, if ever, distributed randomly across the landscape. Rather, they space themselves in complex ways related to habitat type or condition, resource abundance and availability, and through intricate social interactions between conspecifics (Williams et al. 2002; Morrison et al. 1992). Spatial distribution of individuals can be defined as the occurrence and spacing of individually recognizable snow leopards within a defined area over a specified period of time, and requires an understanding of home range size, which varies with respect to each animal's gender and residency status (males typically occupy larger ranges than females, and permanent residents occupy more stable ranges than transient individuals) (Sunquist & Sunquist 2002).

Monitoring, in its most general sense, implies the repeated assessment of some quantity or attribute within a defined area over a specified time period (Thompson et al.1998), using a consistent, largely unbiased and ***comparable method*** of gathering data (our emphasis). Such monitoring can be labeled as 'Same Place - Same Method - Same Season' surveys, and are distinguished from those surveys that are not repeatable with respect to methodology or sampling regime. Evaluating the null hypothesis [i.e., that no change in relative abundance between time *a* and time *b* likely occurred] begs the more important question: if a significant population decline has occurred, what is the probability that the survey has enough power to be able to detect it (Kendall et al. 1992, Beier and Cunningham 1996; Zielinski & Stauffer 1996). Correctly rejecting the null hypothesis (and accepting the alternative) is known as statistical power, which must be considered *a priori* when designing and planning quantitatively-based monitoring schemes.

Sample size and variance are the most important factors determining one's ability to detect real change in population size over time or between two comparable areas. If the number of sampling units is too small, and/or the variance too extreme, the monitoring program will be 'insufficient to detect even catastrophic declines in populations over short periods' (Zielinksi & Kucera 1995:8). In developing a sampling scheme for monitoring such change, it is vital therefore to determine *a priori* the probability of detecting a significant change at varying sample sizes. This allows the investigator to choose an adequate sample size for ensuring that any greater change in occurrence or abundance can in fact be detectable with an acceptable degree of probability and confidence. The software program MONITOR by James Gibb can be used to determine the most appropriate (or achievable) sample size, and to explore interactions among the quantitative components of a monitoring program (downloadable at: nhsbig.inhs.uiuc.edu/wes/populations.html).

Relative abundance can be assessed with remote cameras using an index such as the number of leopard photos obtained per 100 trap nights of effort (Carbone et al. 2001, O'Brien et al. 2003). But this implies constant capture probabilities across time and location, an assumption that may easily be violated according to Jennelle et al. (2002). Other issues include the number and cost of camera traps or the availability of trained personnel, and related factors that assume decisional importance for the effort to derive rate-based indices should not differ markedly from that needed to obtain estimates of capture probabilities, abundance, and thus densities. As emphasized by Henschel and Ray (2003), there is little reason ***not*** to utilize a population estimation framework, unless special circumstances exist where rate-based abundance indices would be useful or are mandated by the available resources (e.g., in a new survey area where investigators need to experiment with camera placement, or where the number of cameras are insufficient to obtain sufficient captures and recaptures or to permit individual identification for all or most captures).

The development of a sound sampling regime is, in part, an art as much as a science. We recommend that you contact local people who may have some (albeit limited) knowledge of local snow leopard and prey distribution and abundance patterns, so that you can more efficiently prioritize survey areas by selecting representative sites (i.e., avoid placing traps only within the best habitat). Local herders and hunters are often quite knowledgeable informants, although all questioning needs to be conducted carefully, with the questioner remaining neutral, and seeking to cross validate facts from different sources. Again, as Henschel and Ray (2003) and virtually all social scientists observe, 'it is easy to bias answers if the informant feels he or she may gain some advantage by providing information they perceive as being highly desirable.' In other words, ***how you ask each question*** matters very much!

Camera Trapping Methodology and Snow Leopard Identification

Chapter 4: Using Camera Traps to Estimate Snow Leopard Population Size

Karanth (1995) was the first field researcher to adopt remotely triggered cameras for capture-mark-recapture (CMR) estimates drawing on the statistical inferential technique detailed by Otis et al. (1978) and Pollock et al. (1990) for CMR animal studies. Like other biologists, we have benefited greatly from the pioneering tiger work of Ullas Karanth and his associates (Karanth 1995, Karanth & Nichols 1998; 2002; Karanth et al. 2004). Camera trapping, whether to inventory shy nocturnal species, or to conduct counts of thinly distributed carnivores like tiger, jaguar, cheetah or ocelot, is fast becoming a routine tool for conservation biologists working in hot humid forests (O'Brien et al. 2003; Silver et al. 2004; Wegge et al. 2004) or temperate habitats (e.g., Swann et al. 2004 and York et al. 2001). Henschel and Ray (2003) authored a handbook for surveying and monitoring leopards in African rainforests, Silver (2004) a handbook on jaguar, while Karanth and Nichols (2002) produced a definitive guide for researchers, managers and conservationists interested in monitoring tiger populations. Other papers have focused on comparing different makes of cameras (e.g., Moruzzi et al. 2002), developing identification procedures for specific species (e.g., bobcat, Heilbrun et al. 2003; cheetah, Kelly 2001), or the development of inexpensive camera systems (e.g., Jones and Raphael 1993, York et al. 2001).

Although this manual describes camera trapping for snow leopards in detail, readers are urged to consult the literature since every camera trapping study is, to varying degrees, an unique undertaking influenced by factors such as the type of camera used and species targeted, sampling protocol, environmental conditions, and human activities.

At the time of this writing, applying camera trapping to the subzero, high altitude Himalayan environment is still a novelty, although Joslin (1988) described a simple camera for use in cold climes over a decade ago. Our experience with camera trapping in Ladakh suggests camera trapping holds great promise for censusing a population within a defined area, estimating snow leopard population size using a sampling scheme, and calibrating data generated from sign transects in differing habitats or conditions (Jackson et al. in review). Besides high ambient levels of infrared light associated with high altitudes, remote cameras must be able to operate at temperatures well below zero degrees Celsius with daily temperature fluctuations often exceeding 70 degrees Celsius.

4.1 Factors to Consider before Mounting a Camera Trap Survey:

There are many factors to consider before undertaking a camera trap survey. For example, over how large an area should you set camera traps? Can the travel paths of the targeted snow leopard population be located, and will you be able to achieve sufficient captures/recaptures to make a population estimate within the allowable time constraints? How should the cameras be oriented with respect to the leopard's travel path, and more importantly, how many will be needed to complete a survey? Do you have the other necessary resources (trained field personnel, logistical support, funding, etc.) to conduct the survey and analyze the data?

Clearly, the more prepared you are, the greater the chances for a successful outcome. We concur fully with Scott Silver, who noted in his introductory manual on jaguar camera trapping (Silver 2004), that "the value of a pilot study for camera trapping ***cannot be overstated***" (emphasis ours). Among other objectives, a pilot study enables you to:

- Locate the best snow leopard travel routes and design a suitable sampling strategy;
- Determine how to frame the photographs (what camera angle works best?);
- Assess the probable capture success rate, which varies between areas and time of year (the ability to make a population estimate depends upon accurately estimating the capture rate);
- Test equipment for its sensitivity and reliability, and gain proficiency in its use;
- Verify that the selected film type, speed and camera setup will provide images of sufficient detail to identify individual snow leopards;
- Establish logistical protocols for ensuring sufficient habitat can be sampled and all camera trap stations serviced before they run out of film or batteries (all camera traps must be functioning throughout the survey to meet all assumptions of the study design, so that one's ability to monitor all stations may be a limiting factor - this can only be determined through a trial run);
- Ensure field staff are adequately trained in advance of the survey; and
- Seek support from the local community in order to minimize the potential for theft or damage to equipment.

4.2 Underlying Assumptions for Camera Trap Population Census and Estimation:

The use of closed population capture-mark-recapture estimators requires that the four basic assumptions shown in Box B are satisfied during the survey (Otis et al. 1978).

Box B: Capture-Mark-Recapture Assumptions

Assumption	Explanation	Implication
1) Demographic & geographic population closure during the survey period.	Population size "N" should be constant (no births, deaths, immigration or emigration during the sampling period).	Camera trapping must be conducted over a relatively short time frame to meet this assumption. We recommend a sample period of ≤ 40-60 days during winter months (e.g., the non-birthing period). Transients should be identified, if possible, and closure should be tested.
2) Equal 'catchability' for all individuals within each sampling interval or occasion.	All individuals should have the same, preferably constant probability of being captured in each sample.	Trap density & effort should be comparable across each resident's home range.
3) Each individual is uniquely & permanently marked.	Sampled individuals have to be reliably distinguishable from one another.	Each captured individual must be unambiguously distinguished from all other individuals in the survey area.
4) All previously captured (i.e., marked) individuals must be distinguished from unrecorded or non-captured (i.e., unmarked) individuals.	All individuals must have distinctive rosettes, spots or other features on their body from which individual identification can be made.	Coat pattern asymmetry requires images of both sides of the body (i.e., each camera trap should consist of two cameras set to photograph both sides of the snow leopard for definitive identification at first capture).

Assumption # 1 (population closure) means that sampling intervals must be kept relatively short, although capture results can be examined to determine if the closure assumption has likely been violated.

Assumption # 2 (equal likelihood of capture) is harder to satisfy. In reality, some individuals are more likely to be caught than others, leading to capture heterogeneity in which capture rates may vary with regard to age, sex, social dominance, trap placement and/or capture method. For example, dispersing juveniles may move more widely than resident adults or exhibit less aversion to visiting camera traps. Males tend to be easier to trap than females, who are usually more wary. Once caught, some animals may become reluctant to be captured a second time, thereby affecting subsequent sampling, while traps placed well within an individual's home range may be more likely to be visited than those located along its periphery. In addition to sexual and age-specific responses, baits vary temporally in their efficiency to attract target animals based on their novelty and the availability of preferred natural foods.

Assumptions #3 (unique markings) and **#4** (accurate identification of individuals) are best addressed by placing two cameras facing in opposing directions at each trap station to photograph both sides of the target animal, and using rigorous identification criteria. The best identifying marks are natural ones rather than artificial or impermanent marks that are usually lost over time. Section 4.7 provides guidelines for identifying snow leopards.

For more information on these assumptions, we refer the reader to the handbook edited by Karanth and Nichols (2002), Nichols' excellent summary in *BioScience* (1992), or the more technical monographs authored by Otis et al. (1978) and White et al. (1982).

4.3 Recommended Sampling Design and Effort:

An understanding of local snow leopard movement and marking behavior is fundamental to achieving an efficient camera trapping design. Individuals of both sex mark intensively, leaving sign such as scrapes, feces, urine and scent-sprayed rocks (rock scents) at prominent locations where the chance of a conspecific encountering them is highest (Ahlborn and Jackson 1988). Jackson (1996) reported that snow leopards show strong preferences for traveling along topographic edges, particularly along the base or crest of a cliff, narrow valley floors or distinctly defined ridgelines (especially knife-edged ridges). Sign visibility and the extent to which marking is concentrated appears to depend upon the type of landscape and number of leopards present. For example, scrapes are hard to find in open areas where snow leopard travel is not funneled along a common pathway or corridor and easiest to locate where the travel lane is obvious or narrow (i.e., along the crest of a sharp ridge or edge of a narrow valley bottom). Sign type varies greatly in visibility as well as longevity, but in general scrapes and feces are far more resilient to weathering than pugmarks: thus scrapes are considered better indicators of visitation than pugmarks, provided reliable information is available on scrape age.

CAMERA SETUP

SLC PARTNERSHIP

Villagers from the Khunjerab Village Organization (KVO) setting a passive infrared camera as part of a community-based partnership with SLC to document and monitor snow leopards within the buffer zone of the Khunjerab National Park. This protected area embraces important snow leopard habitat, harbors Pakistan's only population of the endangered Marco Polo sheep and abuts China's Taxkorgan Nature Reserve in Xinjiang. The project trains V-SLC's (Village Snow Leopard Conservators) in snow leopard and ungulate survey and monitoring techniques.

Photo: Andrew Chinn

Marking is thought to facilitate temporal and spatial spacing among resident and transient cats and may allow for a high degree of overlap between individuals, especially in food-rich sites (Jackson and Ahlborn 1989). These investigators showed that core-use areas contained more sign than non-core or less intensively utilized parts of the leopards' home area. Although little is known about the factors influencing snow leopard home range size and shape or land tenure pattern (Jackson 1996), it appears that different individuals visit, share, and leave social marks in common places year-round - but increase their marking frequency during the short time female snow leopards are in estrus (January through March or early April). We believe such marking helps maintain land tenure patterns between among individuals, while also allowing for optimal spacing with respect to prey and other resources (Sunquist and Sunquist 2002).

Although snow leopards use well-defined travel lanes, the species' typically rugged habitat and the lack of any road network greatly constrains access. Thus, it may not be possible to:

- Deploy cameras at high elevations or in sites located far from a human footpath, although these areas usually represent less disturbed habitat or places where cameras are least vulnerable to theft;
- Sample large areas essential to obtaining a statistically valid sample (unless one has numerous cameras or the ability to relocate them efficiently between sampling occasions or sessions); and
- Regularly move traps from one location to another without interrupting the continuity of trapping.

These constraints make it harder to address underlying assumptions of population closure and equal capture probability. While it is not necessary to photograph every snow leopard in the survey area unless employing a census strategy, every individual present must have ***some chance of being captured in a photograph*** (i.e., there are no 'holes' where a snow leopard could roam undetected during the survey) (Karanth and Nichols 2002). This is best and most conservatively addressed by ensuring you have at least one camera trap within each area of habitat equivalent to the smallest adult female home range. The home range size of snow leopards varies widely, from less than 12-35 km^2 in prime habitat (Jackson and Ahlborn 1989) to as much as 400 km^2 in marginal, prey sparse habitat (McCarthy 2000). Thus in good quality habitat, we believe that appropriate camera spacing is about 2 trap stations per 16-30 km^2, the estimated minimum home range of an adult female (note each trap station should consist of at least one infrared monitor and two cameras setup to photograph both sides of the snow leopard).

A flowchart outlining the differences between a Sample Census (in which you attempt to count all individuals present within your survey area) and a Population Estimate (in which the population size within the survey area is sampled and statistically derived using the program CAPTURE) is shown in Figure 2. See Box C (next page) for a detailed explanation of each step. We use the term sample census based on the assumption that not every animal within a given survey area will be captured, especially along the perimeter of the survey area where only a small portion of a home range may occur within the survey area. For the purpose of this handbook a camera trap consists of an infrared monitor (i.e., the trigger mechanism) and two cameras, whether it be a TrailMaster 1550 Active Infrared Monitor™ connected to two cameras or two individual CamTrakker™ (or DeerCam™) units set up at one site. A trap station refers to the location in which a camera trap is set up. Each sampling cell should contain a minimum of two trap stations. We define "survey area" as a contiguous block of habitat whose boundaries are delineated by natural topographic features such as a watershed, large river or mountain range.

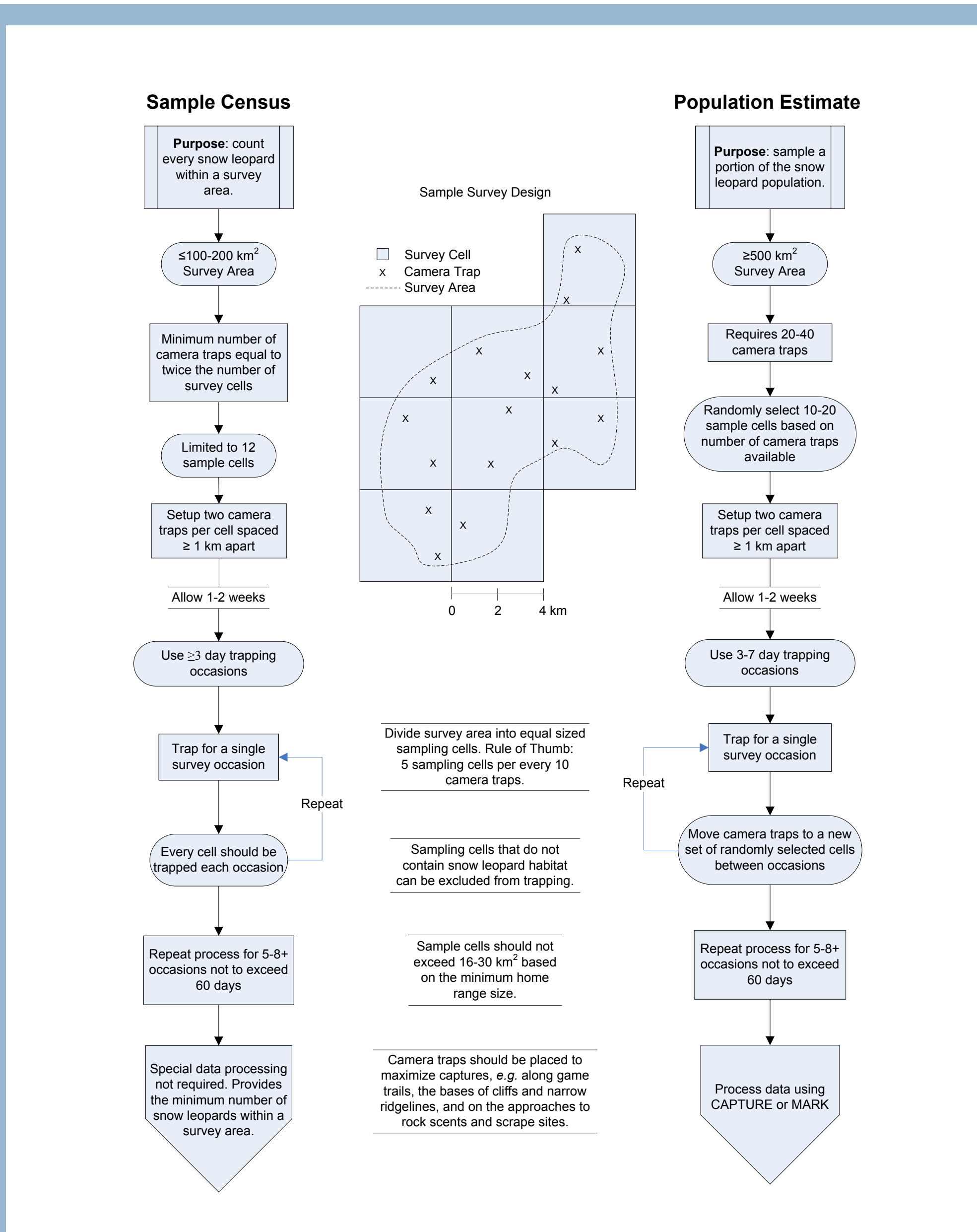


FIGURE 2
Flowchart depicting the step-by-step procedures for conducting a sample population estimate, and a theoretical survey design layout. See Box C for a detailed explanation of each step.

Box C: Survey Design Considerations and Recommendations

Factor	Design Recommendations
All individuals within the survey area should have an equal and at least 'non-negligible' probability of being captured, e.g. photographed at one or more trap station during the survey	Study design should ensure there are ***no holes within the survey area*** such that an individual could travel within its home range and not have some probability of being photographed. Within each survey cell, camera traps should be strategically placed to maximize the probability of capture success, e.g. near scrape sites and rock scents, along game trails, narrow ridgelines, and at valley confluences and mountain passes, etc.
Timing and Duration of Survey	Camera trap surveys are best undertaken during the snow leopard's mating season (January through March or early April) when social marking peaks and the sexes are actively searching for one another (and possibly traveling more intensively or widely). Camera trapping should be undertaken for a total of 40-60 consecutive days. A survey period in excess of 60 consecutive days may result in a violation of closure assumptions. The setup and removal time should not be counted in the sampling period. Each sampling occasion should begin after all camera traps are operational.
Setup Effort	In the Himalaya, it usually requires 10-15 days for setup and 4-6 days for removal. Initial setup is typically limited to 2-3 camera traps per day, and as little as 1 per day in areas far from base camp. Plan for an average of 2 hours to setup each camera trap.
Capture Probability and Sampling Occasion Adjustment	Capture probabilities must be ≥ 0.10. Values of 0.20 for ≥ 5 occasions are preferable (Otis et al 1978). We recommend > 0.30 if possible. Maximize the number of sampling occasions (i.e., aim for 5 or more occasions during the 40-60 day survey period). Each sampling occasion should be 3-5 days in length for ***abundance estimation*** or 4-7 days for a ***sample census*** in order to maximize capture probabilities. Ensure survey cells are comparable with respect to trapping effort throughout the survey period.
Size of Area Sampled	The program CAPTURE works best with populations $\geq$ 15-20 individuals, which is unlikely to be met in most situations due to logistical constraints and resource limitations associated with remote, high altitude environments and low carnivore densities.. High density areas require a minimum survey area of 100-200 km^2. Low density areas require a minimum survey area of 500-750 km^2.
Study Design	The size of the survey area should be determined based on logistical constraints, monetary and equipment resources, staff availability, snow leopard density, etc. Determine whether a sample census or abundance estimate will be conducted. Delineate the survey area into suitable and non-suitable snow leopard habitat. Good habitat is defined by broken, rocky terrain and marginal habitat is defined by gently rolling, smooth-surfaced terrain lacking cover. Non-suitable habitat should not be surveyed if it is highly unlikely to be utilized by snow leopards. Divide the survey area into equal sized sampling cells no larger than the minimum home range of an adult female (16-30 km^2).
Distribution of Camera Traps **Note – snow leopard distribution is unlikely to be homogenous across the entire survey*	Each survey cell should have two trap stations spaced at least 1 km apart. In some situations in which the majority of a survey cell contains non-suitable snow leopard habitat, and two trap stations cannot be placed a minimum of 1 km apart, one trap station can be utilized.
Number of Cameras	You can never have enough! Even with 20 camera traps, only an area of 250 km^2 can effectively be sampled simultaneously. Otherwise cameras must be moved periodically or the sampling period must be extended which runs the risk of closure violation. Rule of thumb: six camera traps per every 100 km^2 area surveyed. Minimum number of camera traps needed is six. Each camera trap consists of an infrared sensor and two cameras to simultaneously photograph each side of the snow leopard. Example: one TrailMaster 1550 Active Infrared Monitor attached to two cameras using a Multi Camera Trigger II, or two independent CamTrakker Rangers or DeerCams. Note that CamTrakker and DeerCams are stand alone units and would require two complete units at each trap station. One TrailMaster can be connected to an unlimited number of cameras using the Multi Camera Trigger II.

Figure 3 shows the layout used in the HNP study. The reality is that some parts were better sampled than others because of more favorable topography and access. But the important point is that we took the time to identify core overlapping areas, and ensured that these zones were well covered under the assumption that all individuals (at least the adult cohort) would visit such sites at one time or another over the course of the survey - in this case conducted during the mating season. Our data indicated greatest visitation by the dominant resident male and resident females, with varying degrees of range overlap among each individual - a finding consistent from radio-telemetry (Jackson and Ahlborn 1989; Jackson 1996).

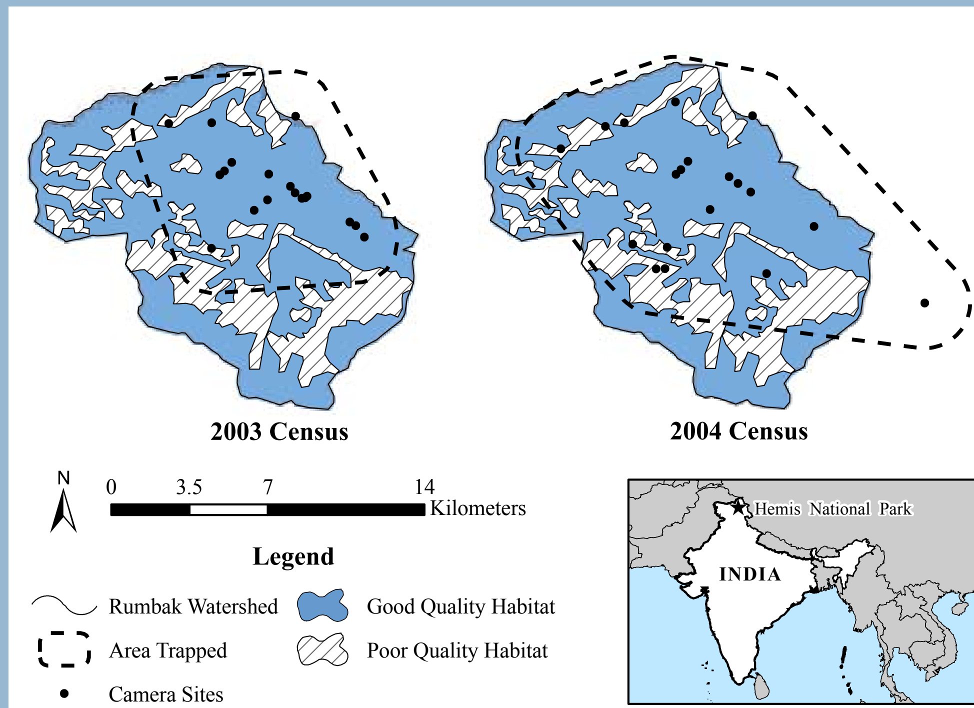


FIGURE 3
Survey area in Hemis National Park showing camera trap layout for the 2003 and 2004 census studies.

4.4 Timing of Camera Trap Surveys:

In our experience, camera trap surveys are best undertaken in late winter or early spring following peak snowfall but during mating which occurs from late January through March or early April. At this time (1) snow leopards are usually at lower elevation; (2) disturbance from livestock and attendant herders is minimized; and (3) there is increased marking activity and snow cover to facilitate locating travel paths and/or core-use areas. But, we again emphasize that a pre-survey reconnaissance will significantly improve success in identifying the most suitable trap sites, help clarify site access and establish logistical needs, and determine, in advance, the number of cameras needed to sample an area large enough for generating a population estimate.

4.5 Sensor and Camera Selection:

A snow leopard camera trap survey requires equipment capable of functioning reliably at low ambient temperatures and under high levels of infrared light associated with the high altitudes (elevations ranging from 2,000 to as high as 5,500 meters) and northerly latitudes (28° to > 50°N). Cold temperatures result in significantly reduced battery life, although moisture and humidity are rarely a problem compared with the tropics. Remote cameras can be activated using pressure pads (triggered by the body weight of a passing animal) or infrared sensors. Active infrared camera traps take a picture when an animal or object interrupts an infrared beam, which is invisible to the human eye. Passive infrared systems are triggered when a moving animal (or object) with a different temperature than ambient temperature crosses the camera's detection zone.

We experimented with passive and active infrared sensors, including a low-cost homemade model and an expensive digital video camera. The commercially available 35 mm system that we deployed most widely comprised TrailMaster™ 1500 and 1550 Active Infrared Trail Monitors (Goodson and Associates, Inc., 10614 Widmer, Lenexa, Kansas 66215, USA), followed by two passively triggered units, the CamTrakker™ Original and Digital (CamTrak South, Inc., 1050 Industrial Drive, Watkinsville, Georgia 30677, USA) and the DeerCam 200™ (Non-Typical, Inc., 860 Park Lane, Park Falls, Wisconsin 54552, USA). See Table 14 (Chapter 6) for a comparison of cameras used during this study.

We found the TrailMaster 1550 to be the most reliable system given the harsh conditions of the Himalayan winters in spite of the relatively high cost. Batteries lasted in excess of four months, even in winter when nighttime temperatures regularly dropped below

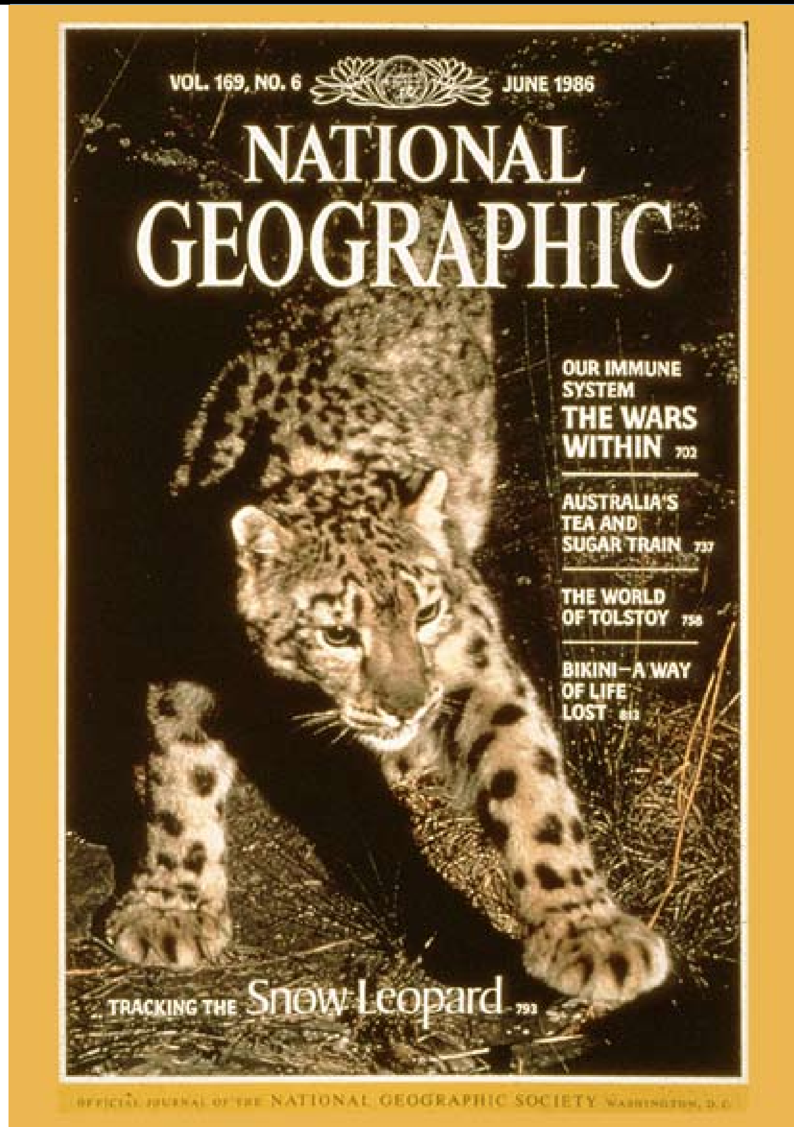
-12° C. By comparison, the same batteries (Duracell™ Coppertop alkaline C 1.5 volts) lasted 14 days or less in the CamTrakker Original. We observed at least six instances during side-by-side comparisons in which a snow leopard had walked through a camera trap and failed to trigger the passive infrared sensor, while photographed by the active infrared sensor. We attributed this to either a battery or sensor failure. Cold weather tests have not yet been conducted on the DeerCam™; however, this unit's flash is notably weaker than the other two remote camera models used, and relies on a similar sensor mechanism to the CamTrakker.

In our experience, detection performance was similar to that reported by Swann et al. (2004). The snow leopard's long, thick fur provides excellent insulation during the cold winter months and may have been partially to blame for occasional failure of the heat and motion detectors, especially when leopards passed through a camera trap traveling at a quick pace. Otherwise the cameras we deployed reliably detected snow leopards during both day and night.

We found a tendency in CamTrakkers to falsely trigger if background rocks heated or cooled during daily temperature fluctuations or with concurrent wind-blown vegetation movement. The active infrared system of TrailMaster units appeared to be quite sensitive to early morning or late afternoon light if it reflected off snow, even when receivers were oriented to the north. Active infrared sensors are more prone than passive sensors to being triggered during heavy snow or rainfall, if water droplets or snowflakes interrupt the transmitted pulses or accumulate in front of the transmitter or receiver.

Pressure pads represent an alternative to infrared sensors. The senior author used a pressure pad (Tapeswitch™ ControlMat presence sensing switching pad, Tapeswitch Corp., 100 Schmitt Boulevard Farmingdale, NY 11735, USA) during an intensive radio-tracking study of snow leopards to obtain the first remote pictures of wild snow leopards for *National Geographic* (Jackson and Hillard 1986). He found them unreliable during periods of subzero temperatures and heavy snowfall: snow would melt during the daytime and then freeze solid at night, capable of bearing the weight of a passing cat without allowing the internal circuits to make contact and trigger the camera.

Joslin (1988) and Jones and Raphael (1993) described low-cost homemade units which depend upon bait to attract animals who then trigger the camera manually by pulling a string attached to the bait. York et al. (2001) detailed a low-cost electronic camera operated by a pressure pad, similar to that used to obtain the first remote pictures of snow leopard in the 1980s. Using the same camera, we constructed and tested an active infrared trigger but this proved to be unreliable in field tests (see Appendix 4). However, if upgraded with better quality components, it might prove a viable alternative, but is unlikely to be cost-effective due to the construction time and effort required.



The first image of a snow leopard ever taken by a remotely triggered camera trap was selected for the June 1986 cover of *National Geographic*

SNOW LEOPARD FACTS

ENDANGERED THROUGHOUT IT'S RANGE

Adult snow leopards stand less than 60 cm at the shoulder, measure 100-130 cm from nose to base of tail, and sport a long, thick tail almost as long. Wild snow leopards typically weigh between 25-45 kg.

They live solitary lives, except during the brief mating season - January through March or April - or when females are accompanied by their dependent offspring. Their loud almost human-like yowls pierce the still mountain air during the mating season.

Snow leopards are found in the mountain ranges of Central Asia, the "Roof of the World." The cat's historical and current range and population are poorly documented, with status surveys considered high priority in nearly all 12 countries supporting this elusive cat.

Photo: Steve Flaherty, ©2003 Leopards, Etc..

We tried two digital remote cameras (CamTrakker Digital ™, manufactured in 2001, and the Stealth Cam DIGRC-XTR ™, Stealth Cam, LLC, P.O. Box 211662, Bedford, TX 76095, USA), but these units were too slow for capturing wild snow leopards besides requiring frequent battery replacement. Nevertheless, we anticipate that reasonably priced, rapidly activated and long-lived remote digital camera models will be available to wildlife biologists within a few years.

4.6 Guidelines on Setting Remote Camera Traps:

4.6.1 Trap Site Selection:

After delineating the survey area and survey cells (see section 4.5), the next step is to visit cells selected for surveying in order to locate the best spot to place camera traps. As noted earlier, camera traps are best located along ridgelines or valley bottoms, along the approach to scrape sites or frequently used rock scents, and in places where the leopard's movement is physically constrained by boulders, cliffs, vegetation and other natural features

Find a place where the ground is relatively flat, to avoid blind areas within the sensor's zone of detection. We have found the most productive sites to be along a narrow ridgeline or drainage beside the base of a cliff or large rock face, and close to a stream or valley junction, or intersecting trails - especially if these happen to be located within a commonly-used core-use area (Jackson and Ahlborn 1989). Clear the site of vegetation or any other feature that may interfere or falsely trigger the camera trap.

We obtained the most consistent photos in relation to body position when camera traps were set up along the approach (3-5 meters) to regularly used rock scents and scrape sites. Snow leopards typically spend a fair amount of time marking and investigating scent marks left from other leopards. Photos of leopards obtained by camera trap station setups at rock scents or scrapes, although resulting in multiple photographs of one individual, often provided images of snow leopards in variable body postures, which made individual identification difficult. In reality, sites are often too small or narrow, steep or otherwise encumbered by obstacles to permit placing cameras on either side of the pathway - one reason that we employed several configurations for deploying cameras (next section).

Once the best spots are located, record the position on a map or with a GPS unit so that the site can be given a geographic (latitudinal and longitudinal) location and identifying name for future reference.

4.6.2 Sensor and Camera Alignment:

The importance of devoting sufficient time and attention to optimizing sensor and camera alignment cannot be over-emphasized.

Passive infrared traps, such as the CamTrakker and DeerCam, have the camera and sensor housed within a single physical unit so that orientation is dictated as much by sun direction as trail configuration and the desired photographic angle. By contrast, the TrailMaster consists of independent sensors and camera(s) that allow for greater flexibility in setup. It has the ability to link multiple cameras to the same trigger via wires which should be concealed or buried in the ground. With either system, however, it is critical to orient sensors to prevent false triggering due to solar interference. This can be achieved by facing the sensor toward the north or south rather than to the east or west. Seek a place where nearby rocks will "shadow" and thus protect the sensor during early morning and evening hours when solar radiation is most likely to interfere with the infrared sensor. Also make sure that passive infrared sensors are not directed toward a large rock or cliff face which may absorb heat and falsely trigger the camera. Use a flat rock to shade the sensor, of course taking care not to block the beam. This also prevents snow from falling on the camera lens or sensor.

Trees are scarce or entirely lacking in most snow leopard areas. Consequently we constructed natural-looking cairns from locally collected, flat rocks to both protect and conceal cameras and their sensors (Figure 4). We recommend mounting cameras and transmitters or receivers on small tripods (UltraPod™, Pedco Products, Redmond, Washington 98073 USA which are provided with TrailMaster Canon cameras); besides providing stability, it is easier to adjust their angle or direction for more precise picture framing and infrared beam aiming. Make sure that the sensors cannot be moved by wind or other factors, since such motion can falsely trigger the system and waste your film. To stabilize the TrailMaster receiver, we mounted the receiver on a 4 x 6 inch galvanized steel flange bracket or joist hanger (Model HUC46-R, Simpson Strong-Tie™, Dublin, CA), which accommodated camera cabling so that the unit would sit firmly on a flat surface. Twine or small elastic "bungee" cords can be used to secure each unit within the structure. Carefully placed rocks or other well positioned obstacles prevent snow build-up in front of sensors and can help determine the path taken by a snow leopard as it walks past the camera. Finally, the rock structure helps to protect the camera, sensor and film from overheating due to direct sun exposure. The active infrared sensor should be set at 35-45 cm above ground level (i.e. the average chest height of a snow leopard), measured at the location of the snow leopard's anticipated path of travel where it intersects the infrared beam. The sensors should also be concealed reasonably well within natural-looking stone structures (Figures 4 & 5).

FIGURE 4
Typical Camera Trap Station (The TrailMaster sensor is concealed in a rock cairn on the left as indicated by the red circle). A snow leopard approaches the rock scent along a well defined travel corridor

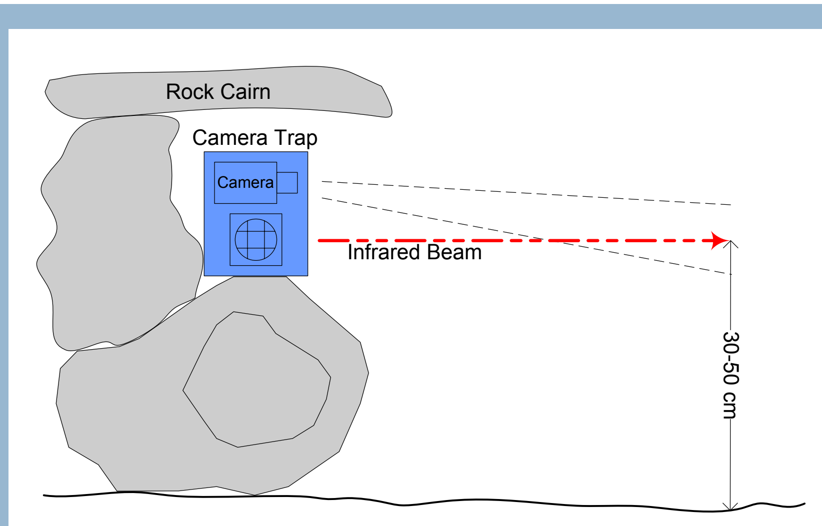


FIGURE 5
Example of a rock cairn to properly elevate, align and shelter a camera trap, e.g. a TrailMaster, CamTrakker or DeerCam. A flat rock or other structure should be placed over the sensor or camera to protect the unit from sun, rain and snow. The infrared beam should be set to intersect the travel path at a height of 30-50 cm, i.e. the chest height of a snow leopard.

Figures 6a and 6b illustrate alternative camera and sensor orientations with respect to the path of travel, in this case using TrailMaster camera traps. The cameras should be placed no closer than 2 m from the suspected travel path: a distance of three meters worked very well for us, although snow leopard trails along ridges or cliff-lines are often narrower than this, in which case the cameras may have to be aligned on the same side (Figure 6b).

In our consecutive 2-year population census we deployed 11-18 TrailMaster 1550 monitors, each with two 35mm Canon™ SureShot A-1 cameras, positioned 2-3 meters from the infrared beam and synchronized by the TrailMaster Multi-Camera Trigger II. Since this switch activates each camera a split second or so apart, cameras can face one another without interference from their flashes. In 2003, we faced the cameras in line with the anticipated travel paths in an effort to obtain close-up photographs of the face for quick identification (Blomqvist and Nystrom 1980). In 2004, we oriented cameras at either 45º or 90º angles along the anticipated travel path to capture simultaneous photographs from either side of the snow leopard's body. We found that camera placement was usually dictated by site-specific conditions and obstacles including uneven ground, rocks, boulders or bushes.

FIGURE 6A

Primary camera trap setup for a TrailMaster 1550 with two attached 35mm cameras setup at oblique angles to capture both sides of a snow leopard to account for asymmetry in pelage patterns. The camera trap should be located approximately 2-3 meters from a rock scent, scrape site, etc., along a travel path to ensure consistant subject orientation. The transmitter and receiver should be placed well off the trail and concealed with rocks, vegetation, etc. Cameras should be setup at 45 degree angles from the anticipated line of travel at a distance of 2-3 meters from the confluence of the path and infrared beam to properly frame the image and capture the entire snow leopard. *Note: figure is not to scale.*

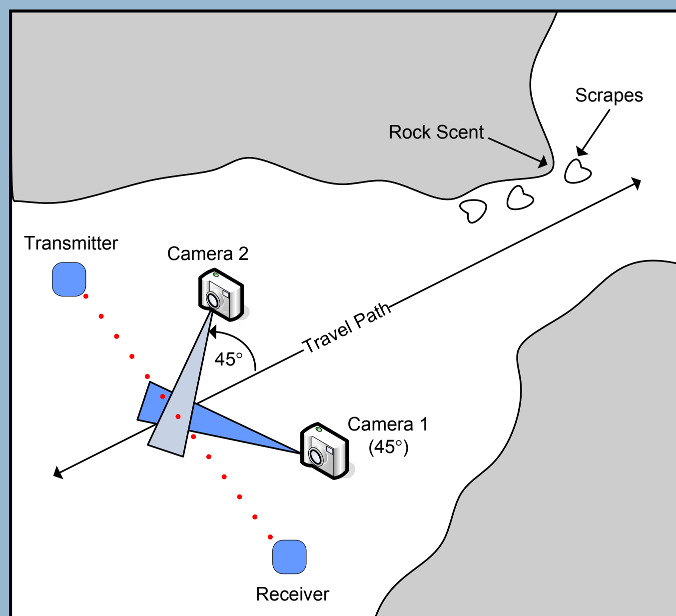
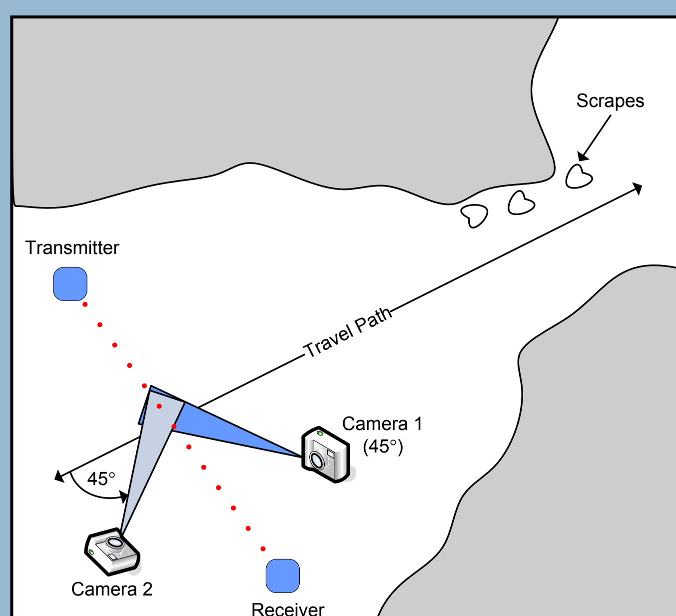


FIGURE 6B

Secondary camera trap setup for a TrailMaster 1550 with two attached 35mm cameras, which should be used when site conditions do not allow for the primary setup configuration. This setup does not account for pelage pattern asymmetry, but will result in simultaneous photographs of the forelimb, flank and dorsal surface of the tail. Camera trap placement should maintain the minimum distances outlined in Figure 6a. *Note: figure is not to scale.*



Once the cameras are in place, conduct a test by walking through the camera trap to trigger the sensor. First, have the person move slowly to determine where the sensor first detects this person (as shown by the flashing LED indicator light) so you can determine the starting and ending points for each camera's "detection zone." Then, standing still (with your body outside this cone-shaped area) and only moving your hands, determine the upper and lower detection heights above the ground. Adjust the sensor height and angle until its beam is centered along the pathway at chest height of a snow leopard (35-45 cm). We used a *p*-value of 5, requiring that the beam is broken for a ¼ of a second to record an event and trigger the camera. However, a higher *p*-value of 8-15 may be warranted in areas subject to false triggering. The *p*-value is the sensitivity of the TrailMaster sensor and ranges in value from 1 to 30 (1 = 0.05 seconds and 30 = 1.5 seconds).

Next, set the camera delay between pictures. This will depend if non-target species like domestic sheep or goats are present, since their passage through a sensor can quickly expend film, including rolls with 36 exposures. If herd-forming livestock are present, we set the camera delay for 3-5 or more minutes. If you are using a TrailMaster or other unit that allows fixing the time period when a photograph can be taken, then set the camera to operate from mid- or late afternoon through the early morning (or for an equivalent time period that you would not expect livestock to be foraging near the camera trap station). If possible, set all cameras to operate during the same time interval, otherwise you will have to prescreen all data and remove any visits not matching the common time all cameras are in active mode. Whenever possible, we encourage the use of a 20 second camera delay time, which allows the flash to recharge while maximizing chances of capturing more than one image during each visitation: the more pictures available, usually the easier it is to identify the visiting snow leopard. We turned the camera's "red-eye" flash feature off to minimize disturbance and to avoid alerting the animal in advance of its photograph being taken.

See Appendix 1 for detailed Trail-Master and Camtrakker setup procedures.

4.6.3 Clearing of Vegetation:

After cameras and sensors have been properly aligned, remove or cut all vegetation or features that may interfere with the "zone of detection." Make sure that the images will be properly framed and clear of all obstacles. When framing the image, take care to include the entire cat not just its head or shoulders. People often frame photos centered on a subject's head and not the whole body. Vegetation trimming and/or removal is vital for minimizing the likelihood of false triggering.

4.6.4 Film and Other Camera Settings:

We recommend using ASA 400 speed film, based on our experience of blurred pictures from snow leopards traveling through a camera trap quickly. Color slide or print film such as Fujicolor™, provided the greatest amount of information compared to black and white film. During the 2003 field season we compared Fuji vs. Kodak and color vs. black and white films, as well as 100, 200, 400 and 800 film speeds. We found Fujicolor Superia X-TRA 400 to be the most reliable with respect to clarity and color definition for low light, action shots. We exclusively used Fujicolor 400 film in all 35mm cameras during the 2004 field season.

If possible, have the film developed early in the survey to correct issues like poor framing or absence of date/time stamp. Label each roll of film with a unique number and the date of deployment. Record this information on a camera trap datasheet (see Form # 2, Appendix 2). It is critical that careful records are taken to prevent confusion during data analysis.

Make sure that each camera is set to imprint an accurate date and time stamp for each photographic capture, using a consistent format if different makes of camera are being deployed in the same survey. Avoid confusion related to different day-month order between the British and American systems for formatting the date; most cameras allow one to set either the day and time, or the day/month/year sequence, but not both.

Once setup is complete, make a sketch of the site and record relevant information on the type of trail, terrain and snow leopard sign present (see Form # 1, Appendix 2). Form # 2 can be used to record pertinent information during monitoring visits to a site. Implement procedures for ensuring that each monitoring form, roll of film and resulting photographs are allocated to the correct site, date and observer. We recommend taking an initial photograph for use as a frame of reference.

Detailed instructions for adjusting sensors and setting cameras for TrailMaster and CamTrakker systems are provided in Appendix 1.

4.6.5 Use of Baits and Lures:

Baits are routinely used to attract brown or black bears to camera traps and hair snares. McDaniel et al. (2000) tested the efficacy of different lures to detect lynx (*Lynx canadensis*), concluding such attractants induced the cat to face rub on hair snares, thereby improving the probability of detection and allowing for a lower trap density. Snow leopards will investigate rock scents sprayed with novel odors such as cologne or perfume, e.g. Calvin Klein *Obsession*™ or *Lady Stetson*™. However, these scents may not ensure or increase visitation. Observations on captive snow leopards indicated the novelty of such odors wears off relatively quickly, possibly within 7-10 days (Barbara Palmer, personal communication) so the cat may be less likely to respond as strongly to the same scent during follow-up visits.

Playback calls have been used to estimate population size in the spotted hyena (*Crocuta crocuta*) and lion (*Panthera leo*) (e.g., Mills et al. 2001), but these carnivores are readily sighted. The use of playback vocalizations of reproductively active, captive snow leopards enabled us to attract and maintain contact with a consorting pair in 2003. Hunters routinely use prey distress calls in an attempt to bring carnivores closer, but the use of any lure also greatly increases the likelihood of individuals responding differentially, thereby leading to violation of one of the more important assumptions underlying capture-mark-recapture population estimation.

Due diligence in camera placement has a far greater influence toward increasing capture success, and avoids the problem of differential responses or alerting cats to the presence of a nearby camera trap. Because of the robust tendency of snow leopards to use the same, usually well-defined travel paths and common scent marking sites, we feel the use of lures is neither necessary nor desirable.

4.6.6 Camera Monitoring and Data Recording:

Cameras should be checked every 3-10 days and immediately following periods of snowfall, so that any accumulated snow can be removed from blocking sensors and otherwise disabling cameras.

When checking camera traps, first deactivate the sensor and then gather the following information using a standardized data form (see Appendix 2 for an example):

- Current film frame number and event (TrailMaster and DeerCam), along with the film roll number if changing film;
- Note the presence or absence and type of snow leopard sign along with its relative age;
- Replace film if there are less than 5 pictures left, being sure to label each roll with the associated camera number and date of deployment;
- Remove snow or any other debris that may have formed in front of sensors or cameras;

Herdsmen with yaks used for transport

Shepherd and flock

Poachers selling a snow leopard pelt

- Clean lens of any dust or watermarks that could degrade picture quality;
- Check that the sensors and cameras are still properly aligned and functioning (all stations must be functioning throughout each sampling period to meet the primary assumptions of capture-recapture);
- Replace any camera or sensor batteries near the end of their projected duty cycle;
- Collect hairs from nearby hair snares if DNA is being collected, so that the visitations can be photographically matched with known snow leopards;

Store the film in a cool, dry place until it is developed. When sending it for processing, make sure that you keep a record of the laboratory processing number for matching with the film's original number, date and location where it was initially deployed. If cameras are moved between trap stations, record these clearly on the data form and in your field notebook. After receiving the prints, be sure to label each print with the date of deployment and each location, and record the date and time each photograph was taken. After the individual has been identified, record its number on the print as well. We cannot over-emphasize the importance of carefully keeping track of where each photograph came from and the dates the film was in the field.

REMOTE CAMERA TRAPS

CATS IDENTIFIED BY UNIQUE MARKINGS

Surpised by the flash, but inadvertently providing valuable identification data, a snow leopard trips a camera trap.

The Snow Leopard Conservancy deployed up to 20 different remotely-triggered camera traps in the Hemis National Park for the census studies of 2003 and 2004. In that time, they collected almost 200 photographs of snow leopards.

Individual snow leopards could be differentiated and identified based on their distinct pelage patterns, as described in Section 4.7

4.7 Identifying Individual Snow Leopards from Photographs:

Snow leopard pelage patterns vary between individuals with respect to the size, shape, orientation and coloration of individual spots and rosettes. Pelage patterns are asymmetrical, often varying significantly between the sides, lower limbs and tail. Blomqvist and Nystrom (1980) used the leopard's highly distinctive spotting pattern on the forehead to distinguish individual snow leopards in captivity (Figure 7). However, based on the difficulty in reliably obtaining clear, focused images of the forehead in the field, we examined other body parts for their potential use as diagnostic identification areas. We were able to successfully capture the face, but photographs were often too blurry to see sufficient detail in the forehead even when using fast film (ASA 400) or the head was turned to the side when the picture was taken (for details see Chapter 5).

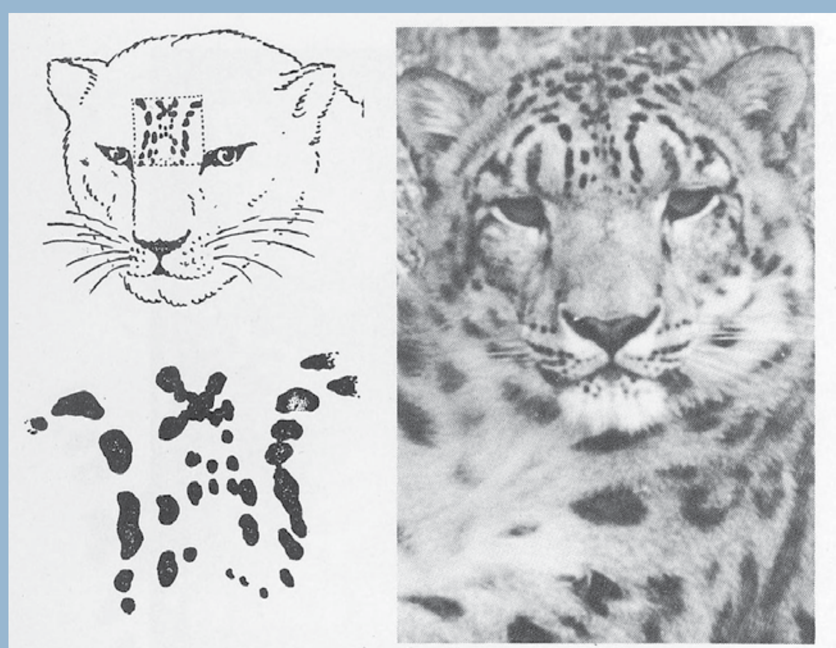


FIGURE 7
Facial Features used by Blomqvist and Nystrom (1980) to Distinguish Individual Snow Leopards in Captivity.

We successfully identified individual snow leopards based on their distinct pelage patterns as illustrated in Figures 8 and 9.

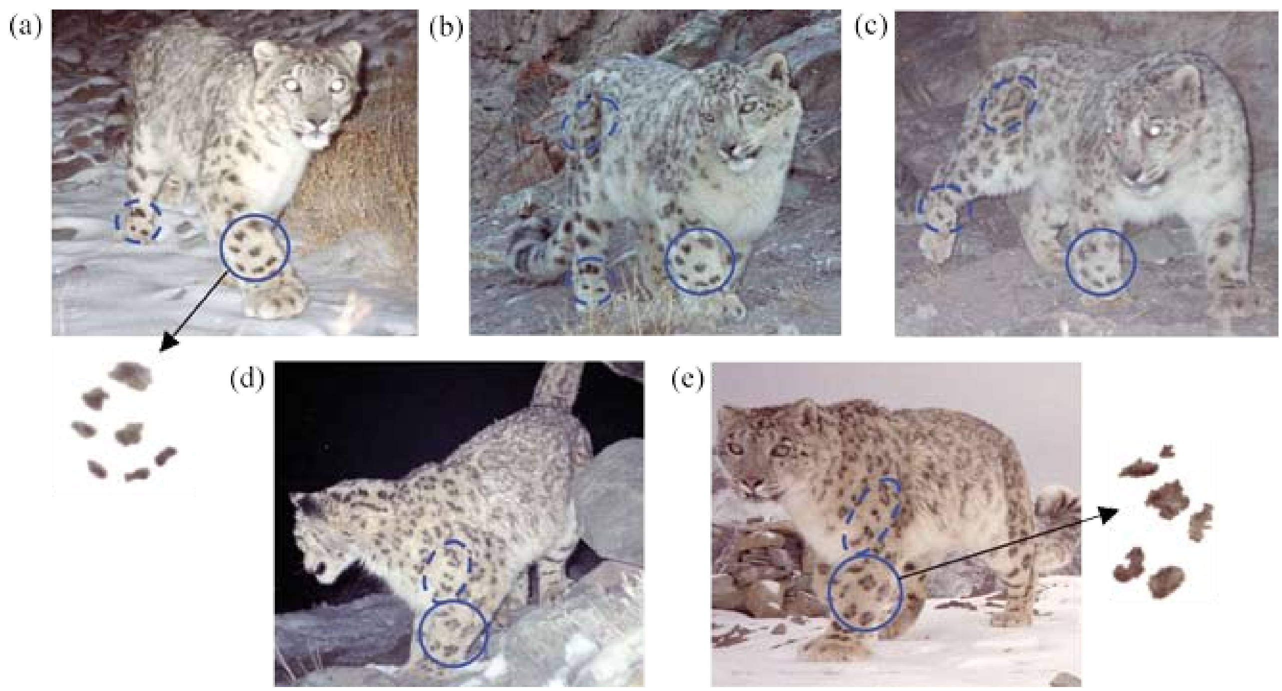


FIGURE 8
Example of identification of two separate individuals based on pelage patterns; snow leopard HNP-1 (a, b, c) and HNP-3 (d, e). All photographs were taken at different trap stations on different days. Solid blue lines indicate "primary" features and the dashed lines indicate "secondary" features. A slight change in body posture or camera angle can affect the availability of features as indicated by the uppermost secondary feature in photos a, b and c. To assist in individual identification, spotting patterns or individual spots can be lifted off the photograph using Adobe Photoshop™ (Adobe Systems, Inc.).

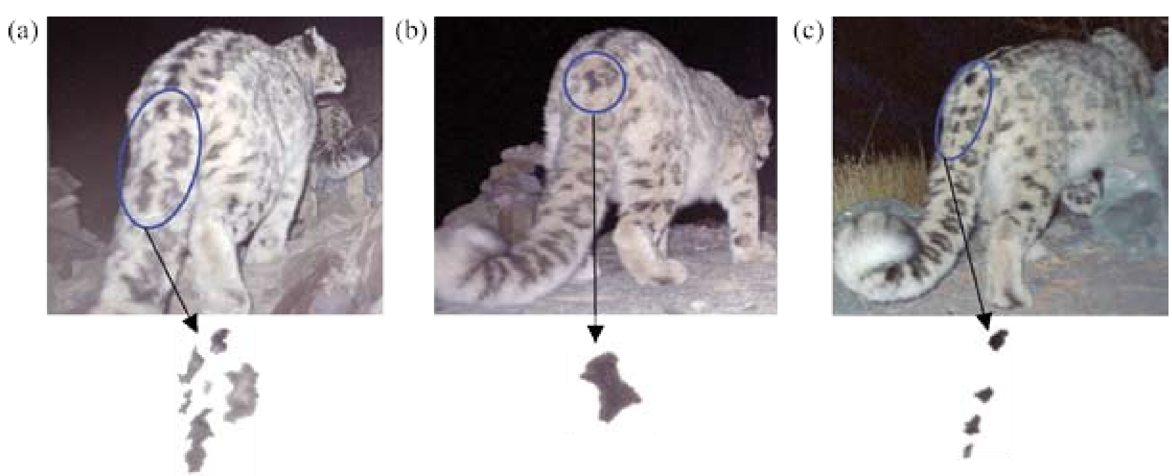


FIGURE 9
Example of distinct pelage pattern(s) on the dorsal surface of the tail of three different snow leopards, HNP-1 (a), HNP-5 (b) and HNP-7 (c). Useful markings may consist of an individual spot (b) or localized groupings of spots (c) and/or rosettes (a). It should be noted that some individuals exhibit a complete lack of distinct markings within this area, which can also be useful in identification.

CANDID CAMERA

RARE GLIMPSES INTO THE DAILY ROUTINE OF A SNOW LEOPARD

Snow leopard HNP-7, identified in several SLC photographs, poses in the barren mountain landscape at 13,500 ft in the Hemis National Park.

Each photograph was examined for clarity, subject orientation and framing to locate unique markings useful for identification, using the following protocol adapted from Heilbrun (2003) for identifying individual bobcats using pelage patterns:

1. A photograph was considered an "initial capture" only if it could not be positively matched with a previously photographed individual;
2. A "recapture" need not have been a photograph of the entire animal, but one that could be positively matched to a previously identified individual;
3. A poor photograph or one that could not be classified as an initial capture or recapture was classified as a "non-capture;"
4. Areas used for identification included uniquely shaped or arranged rosettes, spots or groupings thereof, located on the lower limbs, forequarters, flanks and dorsal surface of the tail;
5. Distinct areas used for identification were classified as either primary or secondary features. A single primary feature was designated for each photograph and was defined as the most distinct, clearly visible and easily recognizable marking or group of markings that readily identified an individual. All other distinct markings were classified as secondary features;
6. A positive identification was made by comparing the primary feature and at least one secondary feature to determine if the animal was an initial capture, recapture or non-capture; and
7. Identification of one different feature was considered sufficient to determine that two photographs depicted different animals.

Images that were not identified using the above criteria could often be linked to a known individual using a paired photo, date-time stamp and event-related information obtained from the TrailMaster or DeerCam. It was only when neither paired photo was identified that it was marked as an initial capture or non-capture (insufficient information to make a determination). Areas such as the lower limbs proved the most useful in identification due to the short fur and clearly defined spot shapes; however, even slight rotation in body orientation can influence the ease with which patterns can be identified. To optimize identification, care must be taken to select sites and position cameras to minimize variation in body orientation between successive captures.

See Chapter 5 (Section 5.2 and 5.3) for a discussion of factors influencing the ease of identification and Chapter 6 (Section 6.1) for recommendations resulting from this study.

4.8 Data Analysis and Statistical Methodology:

The software program CAPTURE (White et al. 1982, updated by Rexstad and Burnham 1991) is used to generate population estimates based on capture-mark-recapture models under the assumption of a closed-population. Capture data is first analyzed to test the assumption of population closure and to generate a summary of the capture history. Second, a series of tests are performed to determine which model fits the data the best, i.e. the data is run through each model and assigned a ranking of 0 - 1.0; higher values indicating a better fit. Finally, CAPTURE generates population estimators and confidence intervals for each model outputting the results to an ASCII-formatted file. The program and user instructions can be downloaded from the Colorado State University site maintained by Dr. G.C. White: www.cnr.colostate.edu/~gwhite/software.html.

Once photo identification is complete, the first step is to develop a capture history for each individual, using an "X matrix" for each sampling occasion (e.g., a spreadsheet that can be generated in Microsoft Excel™, Microsoft Corporation). The matrix is filled out for each individual by entering a "1" if it was captured during the occasion (irrespective of the number of times) or a "0" if it was not captured at all during that particular sampling occasion (a day or group of days). The columns are then totaled to determine the total number of captures during each occasion that are (a) 'first-time' captures, and (b) 're-captured' individuals who were identified or 'tagged' during a previous occasion of the survey. Table 4 shows a hypothetical example of a capture history, while Table 5 shows the summary capture statistics needed for CAPTURE to compute capture probabilities and a population estimate from the same data set. Look on the above website and Appendix 2-E for instructions on formatting input files and running the CAPTURE program.

The test for closure within CAPTURE is not statistically robust, and Stanley and Burnham (1999) present closure test for time-specific data that, in principle, tests the null hypothesis of closed-population model M_t against the open-population Jolly-Seber model as a specific alternative. The test is said to be the most sensitive to permanent emigration and least sensitive to temporary emigration and of intermediate sensitivity to permanent or

Table 4: Example of a Capture History Table

Cat ID No.	Age Class & Sex (if known)	Capture History by Sampling Occasion[1] (n=9) (0 = no visit; 1 = visit detected)								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	Adult/Male	1	1	1	0	1	1	0	1	1
2	Adult/Female	0	1	1	1	0	0	0	1	1
3	Subadult	0	1	1	0	1	0	0	1	0
4	Subadult/Male	0	0	0	1	0	0	0	0	1
5	Adult/Female (with 2 cubs)	1	0	0	0	1	0	0	0	0
6	Adult	0	0	0	0	0	0	0	0	1

[1] Each sampling occasion may vary in length from 3-7 or more days

Table 5: Hypothetical Summary Capture-Mark-Recapture Statistics (derived from Table 4)

Parameter	Sampling Occasion								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Total number of animals caught (photographed) during each occasion.	2	3	3	2	3	1	0	3	4
Total number of unique individuals caught previously to this trapping interval.	0	2	4	4	5	5	5	5	5
Number of newly caught individuals (i.e. previously unmarked and first observed in this occasion).	2	2	0	1	0	0	0	0	1

temporary immigration. The program CLOSURE is available for download at the following web address: www.mesc.usgs.gov/products/software/clostest/clostest.asp.

Table 6: Summary of Closed Population Models Evaluated by CAPTURE

Model		Sources of variations in capture probabilities	Appropriate Estimator	Comments
Model M_o	Equal or Constant Capture Probability Model	None (i.e., capture probabilities are constant with respect to all factors). Incorporates only 2 parameters (population size & capture probability).	Null (model against which all others can be compared).	Too simplistic for most free-living populations.
Model M_h	Heterogeneity Model	Heterogeneity (each individual has its own capture probability which remains constant over sampling period).	Jackknife	Jackknife estimator increases robustness.
Model M_t	Schnabel Model or Variation by time	Time (allows capture probabilities to vary by time only).	Darroch	Very sensitive to behavioral response or innately varying capture probabilities.
Model M_b	Trap Response Model (equivalent to a “removal” model)	Behavior (assumes that on any given trapping occasion, all unmarked individuals have one probability of capture, and all marked individuals another probability of capture).	Zippin	Allows capture probabilities to vary by behavioral response (trap-happy or trap-shy individuals) after first capture.
Model M_{tb}	Time variation in captures or recaptures	Time & behavior (allows capture & recapture probabilities to vary with time).	None available	Needed for testing relationships between models.
Model M_{th}	Both time & heterogeneity affect capture probabilities	Time & heterogeneity	None available	Needed for testing relationships between models.
Model M_{bh}	Behavior & Individual Response Model	Behavior & heterogeneity	Generalized removal	Under this model, each individual has its own probability of first capture.
Model M_{tbh}	All Effects Model	Time, behavior & heterogeneity	None available	Needed for testing relationships between models.

The CAPTURE program offers 7 different models to estimate population size (Table 6). The simplest or Null Model (M_0) assumes no difference in capture probability between individuals or sampling occasions. The Heterogeneity Model (M_h) tests for differences in capture probabilities between individuals that may result from accessibility to traps, social dominance, or differences in age and sex (White et al. 1982). The Schnabel Model (M_t) assumes difference in capture probabilities between different sampling occasions or sessions (i.e., over time). The Trap Response Model (M_b) allows for differences in capture probabilities between newly caught individuals and subsequent capture probabilities due to favorable (trap-happy) or unfavorable (trap-shy) first-capture experiences. For example, some individuals might avoid camera traps having a negative reaction to the camera flash upon initial capture and may, therefore, decrease the likelihood of the individual being recaptured (i.e. becoming trap-shy). Conversely, the use of baits may increase capture probabilities by attracting some individuals more over others, in this case leading to trap-happy animals. The program also combines these models to examine the interaction of these effects, using the estimators, M_{bh} (heterogeneity and trap response model), M_{th} (heterogeneity and time response model), M_{tb} (time and trap response model) and M_{tbh} (heterogeneity, time and trap response model), all of which require relatively large sample sizes.

CAPTURE gives a value of 1.00 to the best model, but the selection values are relative so there is some room for interpretation. However, Otis et al. (1978) recommend selecting one with a value ≥ 0.90 and which has acceptable goodness of fit.

Table 7 summarizes the tests CAPTURE uses for determining which model best fits the dataset. Tests 1-3 compare the relative fit of the null model with the time, heterogeneity and behavior models respectively. Tests 4 -7 judge the Goodness-of-Fit of these models and compares the relative fit of the heterogeneity and behavior-heterogeneity models. While this table offers guidance to determining whether to accept or reject the respective null hypotheses, we suggest becoming familiar with the underlying theory by reading the monographs by Otis or White et al. (1978, 1982) or consulting a statistician.

Karanth & Nichols (2002) recommend using the heterogeneity model (M_h), since this most likely reflects the behavior of large solitary cats like

Table 7: Specific Tests of Assumptions used in Model Selection Procedure (from Otis et al. 1978):

Test #	Source Variation	Null hypothesis	Alternative hypothesis	Comments
1	Heterogeneity	Model M_o fits data	Model M_h fits data	Examines capture frequencies for evidence of variability among individual capture probabilities.
2	Trap response after 1st capture	Model M_o fits data	Model M_b fits data	Examines gross behavior effects on capture probabilities.
3	Time variation in capture probability	Model M_o fits data	Model M_t fits data	Tests for variation in average daily capture probabilities.
4	Trap response and/or time variation given heterogeneity	Model M_h fits data	Model M_h fails to fit data	If M_h is true model, we expect this test not to reject. Test 1 should favor M_h.
4a	As above	As above	As above	Tests for trap response or time variation or both with large individual recaptures.
5	Heterogeneity and/or time variation given trap response	Model M_b fits data	Model M_b fails to fits data	If M_b represents the best model, we expect this test not to reject. Test 2 should show similar favor.
5a	Heterogeneity and/or time variation using first capture only	First capture probabilities are constant	First capture probabilities vary by time and/or individual	Test identical to goodness of fit test for simple removal model.
5b	Heterogeneity and/or time variation using only recaptures	Recapture probabilities are constant	Recapture probabilities vary by time and/or individual	If M_b is true, then this null hypothesis should not be rejected.
6	Trap response and/or heterogeneity given time variation	Model M_t fits data	Mode M_t fails to fit the data	If M_t is the model, then we would expect this test not to reject; also we expect Model M_o to be rejected in favor or M_t.
7	Trap response given heterogeneity	Model M_h fits data	Model M_{bh} fits the data	This test is useful because if we reject M_h in favor of M_{bh}, the estimator to use is the generalized removal method.

BREEDING FACTS

TWO CUBS IN TYPICAL LITTER

Unusual among Felidae in having well-defined breeding and birthing seasons. Litter size usually 2-4, exceptionally as many as seven. Cubs are usually borne between the months of May and August, with a distinct peak in June. They become independent of their mother at 18-22 months of age. Sibling groups may remain together briefly, explaining occasional sightings in the wild of as many as 5 animals in a group.

Photo: Ron Kimball.

tiger. As Henschel and Ray (2003) commented, this makes biological sense because most large cats exhibit some degree of territoriality with home range size and trap access varying depending on the individual's social position and spatial location in the landscape. Wegge et al. (2004) reported a significant behavioral response with tigers indicating evidence of trap shyness, which they attributed to photo flash and the possible detection of camera traps from track impression pads placed within 50 m of each trap. They concluded that density estimates were also greatly influenced by distance between traps and the trapping duration. Periods of heavy snow fall, which may restrict snow leopard access (and hence capture probability) to traps at higher elevations could introduce a time bias depending upon the availability of alternative capture sites which are accessible to the affected individuals.

Capture models can also be computed with the substantially more versatile (and complex) computer program MARK, which offers significantly more robust modeling, but obtaining sufficiently large sample sizes for model parametization is most unlikely (see www.cnr.colostate.edu/~gwhite/mark/mark.htm).

4.9 Calculating Population Density:

In order to obtain an accurate population density estimate, it is necessary to establish the size of the survey area as precisely as possible. In trapping-grid studies it has long been realized that the area from which animals are captured is not necessarily limited to the area enclosed by the outer traps (Otis et al. 1978). Rather, one has to add a boundary strip to the polygon area defined by the outermost traps, since animals are captured from this zone as well.

In their tiger study, Karanth and Nichols (1998) computed the width of this added boundary strip using the "mean maximum (linear) distance moved" by the tigers that they captured on more than one occasion. Boundary strip width was then defined as being half the mean maximum distance moved according to the following equation:

$$W = (\Sigma\, d \,/\, m) \,/\, 2$$

where W is the resulting boundary strip width, d is the maximum distance moved, and m is the number of maximum distances compared. Then the boundary strip of width W must be added around the perimeter of the area covered by camera traps, to obtain the sampled area. One can then estimate snow leopard population density as:

$$D = N \,/\, A(W),$$

where D is the resulting snow leopard density, N is the population size computed by CAPTURE, and $A(W)$ is the resulting area sampled, including the boundary strip.

Silver (2004) offers an alternative means for deriving the effective sample area; he employed GIS (Geographic Information Systems) software to generate circular buffers using a radius equivalent to half the mean maximum linear distance moved among multiple captures of individuals during the survey period. The merged area of all of the circular buffers provided an estimate of the entire area sampled. These areas are then divided by the population or abundance value generated using CAPTURE to provide an estimate of snow leopard density in the surveyed area. This number refers to the sampled area only, for extrapolation to a broader area may not be valid, especially if terrain, habitat, prey abundance or human density and activity differ.

Findings from Hemis National Park Study

Chapter 5: Results

This chapter presents results of the snow leopard census and population estimates undertaken by the Snow Leopard Conservancy in Hemis National Park, Jammu and Kashmir State, India, from January 2003 to March 2004 (Jackson et al. *in review*). The two years prior to these surveys (2001-2002), we experimented with various types of active and passive infrared camera traps to determine which model(s) performed best under high altitude, cold winter conditions, and which trap configuration maximized capture success. Although our methodologies varied from 2003 to 2004, we maintained the minimum number of camera traps necessary within the core survey area to conduct a formal population census. During 2004 we used an additional 11 camera traps placed within marginal habitat and along the perimeter of the survey area to assess sampling methods for use in estimating snow leopard abundance, which did not detract from our census efforts within this important protected area.

Table 8: Summary of Trap Effort and Success for the Period 2001 - 2004

Parameter	2001-2002	2003	2004
Sampling Period	2 Nov 2001 – 15 Nov 2002	21 Jan 2003 – 25 Mar 2003	15 Jan 2004 – 24 Mar 2004
Trap-nights	1,652	741	871
Total number of photos	223	465	1,014
Number of individual snow leopards identi-	3	6	6
Total number of snow leopard photos	30	112	87
Number of snow leopard captures	28	66	49
Number of photos with false/no images	72 (32.3%)	278 (59.8%)	758 (74.5%)
Number of photos of non-target species	121 (54.3%)	86 (18.5%)	174 (17.2%)
Blue sheep (primary prey species)	14 (6.3%)	13 (2.8%)	6 (0.6%)
Domestic livestock	65 (29.1%)	48 (10.3%)	139 (13.7%)
Canid (fox & wolf)	7 (3.1%)	19 (4.1%)	15 (1.5%)
Bird (snowcock & chukor)	35 (15.7%)	6 (1.3%)	10 (1.0%)
Number of trap stations	20	18	19
Number of cameras traps:			
TrailMaster	3	11	27
CamTrakker	7	4, 1 digital	0
Snow Leopard Capture Success:			
Number captures/100 trap-nights	1.69	8.91	5.63
Capture Frequency (avg.number)	(59.0)	(11.2)	(17.8)

Note: Data from 2001-2002 spans the whole year, with camera traps being regularly shifted from one site to another. These data are not directly comparable to the 3-month census periods during 2003 and 2004.

5.1 Capture Success and Population Census:

We obtained a total of 66 and 49 captures, comprising 112 and 87 individual pictures of snow leopards. This represents a capture success of 8.91 and 5.63 individuals per 100 trap-nights in 2003 and 2004, respectively (Table 8). The lower snow leopard capture success and estimated density in 2004 resulted from placing additional camera traps within marginal habitat while at the same time increasing the area sampled surrounding core or optimal habitat (see Figure 3). It took 58 days to detect all individuals captured in 2003, compared to 11 days in 2004. However, we detected 67% of all animals tallied in 2003 within the first 14 days of trapping. Falsely triggered images comprised 60% and 75% of all images in 2003 and 2004, respectively, which were largely attributable to periods of heavy snowfall that covered the infrared sensors and quickly depleted the cameras of film. Furthermore, 2004 was a significantly wetter winter than 2003 and resulted in an order of magnitude difference in the number of false images between the two years. Domestic livestock (primarily sheep and goats) represented 10.3% and 13.7% of non-target species captured over the two census periods, while canids (mostly red fox and wolves)

FAMILY PHOTO

HNP-2 with her two cubs, eight months or younger photographed in early March 2004. Such photographs are rare. Usually the cubs trail behind, and are alerted to the camera trap when their mother triggers the device. They circle around it.

and birds were responsible for most of the remaining non-target captures (5.4% and 2.5%, respectively).

We identified a total of ten snow leopards during the two census years. Of these, only two individuals were captured during both census periods, an adult female (designated HNP-2) and a subadult male (HNP-3). The female HNP-2 was photographed with the dominant male (HNP-1) during February 2003 and was later photographed with two cubs in February and March 2004. During 2003, the dominant male (HNP-1), as determined by the frequency of captures, was captured on 33 occasions, whereas the other five individuals were captured a total of 14 (HNP-2), 8 (HNP-3), 4 (HNP-4), 3 (HNP-5) and 3 (HNP-6) occasions. Only one capture (two photographs) was unidentified in 2003 because the individual passed too close to the camera resulting in blurry images. In 2004, HNP-2 and HNP-3 were captured a total of eight times each. HNP-1 was last observed on December 23, 2003 and is thought to have lost his land tenure, been injured or died since he has not been photo-captured after this date despite extensive trapping. As a result, four new individuals were photo-documented within the 2004 census period resulting in 6 (HNP-7), 12 (HNP-8), 2 (HNP-9) and 5 (HNP-10) captures. An additional four captures were unidentified due to blurry images or poor framing (e.g., only the tip of the tail was photographed). Four captures consisted of cubs from HNP-2 and HNP-9.

5.2 Identification of Snow Leopards:

Comparatively speaking, individual identification of snow leopards is more difficult than tiger, cheetah (*Acinonyx jubatus*), common leopard (*Panthera pardus*) or jaguar (*Panthera onca*) due to their long fur, diffuse coloration and patterning, and highly variable rosette shapes (e.g., the rosettes/spots have a tendency to change their shape in areas with long fur). Combined with variation in body positioning and coat movement, the body parts exhibiting the most distinctive spotting patterns are those with shorter hair, which are less prone to distortion. We analyzed spotting patterns from different parts of the body for their efficacy in identifying individual animals, as described in Chapter 4. Individual identification from photographs was compared with remote video footage from the documentary film (*Silent Roar*) covering snow leopards filmed in the same area between 2001 and 2004. The film crew obtained extensive remote footage of resident snow leopards at rock scents, where leopards spent several minutes investigating scent or scrapes before remarking such sign. The video provided us with the opportunity to view resident leopards within the study area from several angles and to link asymmetrical patterns identified in the still images and validate individual identification.

Individual identification of snow leopards was accomplished using the distinct pelage patterns on the forelimbs, flanks (predominantly the posterior portion of the side) and dorsal surface of the tail (Figures 8 and 9, Chapter 4). All areas of the body including the face, shoulders, flanks and hind limbs were assessed for their utility in individual identification based on rosette/spot pattern definition, variability and ease at which each area could be readily recognized and reliably photographed in the field. The forelimbs, flanks and tail were most easily photographed in the field and exhibited distinctive patterns that could be linked to individual leopards.

SAMLING SHEY

BUDDHISM & CONSERVATION

"We Tibetans are basically Buddhists and . . . we preach love and compassion towards all other living beings on earth. And therefore it is the responsibility of all of us to realize the importance of wildlife conservation."

H.H. 14th Dalai Lama

Thashung Gompa, in the remote Dolpa region of Nepal, was built by a buddhist abbot 900 years ago to conserve wildlife. Likewise, the Lama of Phu village in the adjacent Manang region tried to convince the villagers that all life is interconnected. With the snow leopards becoming increasingly rare, Lama Karma announced that he would leave Phu for good. Reluctant to part with their guru, the villagers promised not to kill again. They have kept that promise to this day, and both the blue sheep and the snow leopards are back. Similarly, wildlife around Samling Gompa is protected by its lamas.

The dorsal surface of the tail exhibited a moderate degree of variability and often provided distinctive markings. However, patterning along the sides of the tail tended to be very similar between individuals, and in some cases, lacked distinguishing marks altogether (which can also be useful in identification if this is limited to a few individuals within a given survey area). The flanks were moderately variable, but were not always readily visible due to the long fur. The short hair and distinct markings on the forelimbs exhibited the highest degree of variability and subsequently provided the most repeatedly photographed and least distorted area useful in identification. The fur on the forelimbs is short, and the more sharply defined solid spots vary little in relation to body orientation or coat movement.

The small spots on the snow leopard's forehead, which are widely used by zoo keepers for identification, were not reliable in our field studies because they were too faint or excessively grainy when enlarged to permit reliable identification in the majority of our images. Furthermore, the head was usually turned away from the camera, often only slightly, thereby preventing clear photographs of the forehead. Although forehead patterns are useful in a controlled setting, it is unlikely that these images can be repeatedly obtained in the field. Other facial parts exhibit more generalized patterns, especially around the eyes, and are thereby less useful for identification. Although patterning on the flanks is generally large, easily photographed and exhibits distinctive patterns, these tend to be more diffuse and less defined than other sites. The long fur and periods of shedding often obscure flank patterns such that individual rosettes/spots cannot be readily distinguished. The shoulders exhibit a gradation between the patterns on the flank and those of the forelimb and neck. The rosettes/spots are smaller and more numerous in this area, but quickly become diffuse in the long fur and thus unusable for identification. The hind limb typically exhibits large nondescript spots, which are not very useful in identification, but do provide valuable secondary information.

We identified 96.4 and 97.6% of all photographs tallied in 2003 and 2004 respectively, to one of 10 individuals. In 2003 we trapped six snow leopards (HNP-1 through HNP-6) judged to be 2 adult males, 2 adult females, 1 subadult male and a juvenile of unknown gender. In 2004 we recaptured two individuals (1 adult female, HNP-2 and 1 subadult male, HNP-3), along with 4 new animals (HNP-7 through to HNP-10, classified as 2 males, 1 adult female, and 1 juvenile of unknown gender). We documented 2 females with cubs, both litters judged at about 6 months of age the time of first capture. Determination of sex from photographs of snow leopards is difficult at best, unless evident from the animal's size or presence of genitals as in adult males. Female snow leopards typically have smaller and rounder heads with less robust chests, but gender classification via photographs is marred by uncertainty unless they are matched with DNA samples collected concurrently. We have developed and field tested a procedure for non-invasively snagging hair from wild snow leopards, which is available upon request; but genotyping of snow leopard DNA is still in the early stages.

5.3 Effect of Camera Layout on Capture Success and Identification:

In 2003, cameras were set to photograph snow leopards directly approaching or departing trap sites in an effort to obtain photographs of the face and dorsal surface of the tail. Consequently, most animals were photographed either looking toward (36.9%) or away from the camera (34.2%), as shown in Table 9. This resulted in 26.1% of all images with three-quarters of the animal's torso showing, but only 9.9% showing the full torso. In 43.6% of photographs three legs were evident, while the dorsal surface of the trail was fully visible in 37.8% of the images. In 2004, cameras were set to obtain an oblique view (45° angle) and a side view (90°). Consequently, a greater proportion of images (22.6%) captured lateral views of the face, full or three-quarter torsos (60.3%), but with lowered success at photographing the leopard's relatively distinctive tail (3.8%). Factors contributing to the high variability in subject orientation include the narrow travel paths favored by leopards (< 2-5 meters in width), their tendency to walk close to the rock or cliff base, and individual differences in approach behavior to rock scents and scrape sites.

We therefore recommend placing both cameras at 45 degree angles on opposite sides of the subject or if site constraints dictate, on the same side set at opposing 45 degree angles (Figures 6A & 6B). Such alignment is most likely to produce good images of the forelimbs, flanks and dorsal surface of the tail, with a higher probability of individual identification. Simultaneously photographing both sides of the snow leopard is preferable, since the pelage pattern is asymmetrical.

Table 9: Proportion of Body Parts visible in Photographs of Snow Leopards during the 2003-2004 Census Periods

Body Position	Percent of sample	
	2003 (n = 112)	2004 (n = 87)
Facial angle		
Not visible of pose not known	19.8	35.8
Side-ways to camera (approx. 90°)	9.0	22.6
Looking away from camera (90°)	34.2	17.0
Looking toward camera (45°)	36.9	24.5
Extent of torso visible		
Not visible	24.3	11.3
Fully visible	9.9	35.8
Approx. ¾ (75%)	26.1	24.5
Approx ½ (50%)	21.6	9.4
Less than ¼ (25%)	18.0	18.9
Number of limbs (fore or hind) visible		
None	8.2	18.9
One	9.1	15.1
Two	29.1	26.4
Three	43.6	30.2
All four limbs	10.0	9.4
Extent of tail visible		
Not visible	20.7	15.1
Completely visible (dorsal surface)	37.8	3.8
Mostly visible	12.6	39.6
About half	10.8	26.4
Only slightly visible	18.0	15.1

5.4 Closure Tests and Model Selection:

The statistical test for closure in CAPTURE supported the assumption of population closure (i.e., no immigration, emigration, births or deaths) during the census in 2003 (7-day sampling occasion, z = 0.843, P = 0.800; 5-day sampling occasion z = -0.075, P = 0.470) and 2004 (7-day occasion, z = 0.423, P = 0.664; 5-day occasion, z = 0.539, P = 0.705). The more robust closure test of Stanley and Burnham (1999) also supported population closure in both years (2003: 7-day occasion, χ^2 = 1.584, df 6, P = 0.954; 5-day occasion, χ^2 = 2.496; df 9, P = 0.981; 2004: 7-day occasion, χ^2 = 4.601, df 8, P = 0.799; 5-day occasion, χ^2 = 8.659, df 8, P = 0.372).

Table 10 indicates the goodness of fit test results. The sample was too small to assess the relative fit of the null model (M_0) versus the heterogeneity model (M_h), the heterogeneity model versus the behavior and heterogeneity model (M_{bh}), or to compute chi-square values for assessing the goodness of fit of the time-based model (M_t). There was no evidence of gross behavior responses (M_0 versus M_b), except for the 7-day occasion sampling

Table 10: Capture-Recapture Model Statistics for Snow Leopards Camera Trapped in Hemis National Park.

Year, survey duration & sampling occasion[a]	Number of occasions	M_o vs. M_b			M_o vs. M_t			M_h Goodness-of-Fit			M_b Goodness-of-Fit		
		χ^2	df	*P*	χ^2	df	*P*	χ^2	df	*P*	χ^2	df	*P*
2003 [b]													
63 days (7-day occasion)	9	0.470	1	0.493	5.428	8	0.711	9.600	8	0.294	9.215	7	0.238
65 days (5-day occasion)	13	1.798	1	0.179	11.806	12	0.461	21.286	12	0.046	17.552	12	0.129
2004 [b]													
70 days (7-day occasion)	10	3.817	1	0.051	9.229	9	0.416	6.733	9	0.665	8.250	7	0.311
60 days (5-day occasion)	12	1.046	1	0.306	15.574	11	0.157	17.407	11	0.096	12.896	9	0.167

[a] Closure supported in all examples (see text).
[b] Samples too small for comparison M_t versus not M_t and comparison M_h versus M_{bh}.

in 2004. The 7-day sampling occasion indicated no evidence of time variation in capture probabilities (M_0 versus M_t) and a reasonable fit of the heterogeneity model (M_h). There was some evidence of different behavioral responses between newly caught and previously captured individuals under the 5-day sampling occasions, being most pronounced in the 2004 population survey.

CAPTURE selected the null model for the 7-day sampling occasions in 2003 and the all effects model (M_{tbh}) or behavior and individual response Model (M_{bh}) in 2004, but we elected to use the null model for population estimation due to the small sample size (Table 11). Under the 5-day occasion dataset, CAPTURE marginally selected the heterogeneous model (M_h) in 2003 and the null model (M_0) in 2004. Small sample size was undoubtedly the primary reason for our inability to derive a more sophisticated model than the over-generalized null model, M_0, which assumes constant capture probabilities with respect to all factors (i.e., variation between individuals or variation due to time or behavior).

Table 11: Models Selected by CAPTURE (see Chapter 4, section 4.8).

Year / sampling interval	M_o	M_h	M_b	M_{bh}	M_t [a]	M_{th} [b]	M_{tb} [b]	M_{tbh} [b]
2003:								
7-day occasion (N = 9)	1.00	0.89	0.39	0.65	0.00	0.39	0.40	0.69
5-day occasion (N = 13)	0.99	1.00	0.58	0.76	0.00	0.41	0.62	0.74
2004:								
7-day occasion (N = 10)	0.91	0.75	0.62	0.99	0.00	0.67	0.45	1.00
5-day occasion (N = 12)	1.00	0.90	0.34	0.67	0.00	0.51	0.41	0.78

Shaded areas indicate models selected by CAPTURE. For description of models, see Otis et al. 1978 and White et al. 1982.
[a] Sample too small for estimation.
[b] No population estimates available for this model.

5.5 Capture Probabilities and Population Estimates:

Table 12 indicates capture probability and population estimates for four CAPTURE models. High capture probabilities (0.333–0.667) were recorded during both years, while population estimates varied according to year and model, but the difference is negligible, both within and between the two years. Thus, for 2003 under the null model CAPTURE estimated the sampled snow leopard population at 6 individuals with a standard error (SE) of 0.16-0.28. In 2004, the population was estimated at 6 ± 0.22 (SE) for both the 7- and 5-day occasion datasets using this model. The heterogeneity model (M_h) produced an ill-conditioned population estimate for the 7-day occasion dataset in 2003 (7 ± 1.35 snow leopards with a 95% confidence interval of 4-10 individuals), but a very comparable estimate to that offered by the null model in the following year (i.e., 6 ± 0.19-0.20 snow leopards). Population estimates for the trap response model (M_b) and a combined heterogeneity and trap response model were comparable between the two years.

The 95% confidence intervals provided in Table 12 were computed by hand, since CAPTURE converts all values to integers when printing. Taking the 2004 population estimate as an example, if the estimate is 6, and the standard error (SE) is 0.22, one would expect the upper confidence limit to be 6+.22*1.96, or about 6.44. This would be converted to 6 by CAPTURE. Similarly, the lower limit would be 6-.22*1.96, but again CAPTURE does not print a lower limit less than the total number captured, in this case 6 animals. Thus, this CAPTURE may generate outputs with counter-intuitive confidence intervals, which in our example would be 6-6.

Given the small sample size, we elected to use the null model as the 'best' model for our dataset. We can be 100% confident that the number of snow leopards is ***at least equal to the total number captured and identified with reasonable certainty***. Population estimates from both years and nearly all models closely matched our census of six individuals.

All individuals were captured within the first two weeks in 2004, but it took nearly two months to detect all snow leopards in 2003, with individual HNP-6 being trapped for the first time during the second-to-last sampling occasion. There is some evidence of 'trap happy' behavior in 2003, when snow leopard HNP-1's tenure as a dominant male appeared to be well established. Following this male's recent absence from the area during the 2004 census, the snow leopards we tallied showed a tendency toward trap shyness. It is not known to what extent these changes might be related to a shift in marking patterns or the land-tenure flux, but a new cohort of four individual snow leopards were detected during the 2004 survey with three cats from 2003 (HNP # 4,5 and 6) not being detected by camera trapping. Given the high probability of captures (> 0.30), we may assume that they could have left the area as well. Radio-tracking represents the best means of determining the movements and fate of such animals, although these four individuals possibly have turned up had we camera-trapped additional areas contiguous to the Rumbak watershed.

Table 12: Estimated Abundance and Capture Probabilities of Snow Leopards Sampled in Hemis National Park

Year	Based on M_o (Null)		Based on M_h (Heterogeneity)		Based on M_b (Trap Response)		M_{bh} (Heterogeneity & Trap Response)	
	Capture probability / occasion	Estimated abundance (± standard error of mean)[a]	Capture probability	Estimated abundance ± SE	Capture probability	Estimated abundance ± SE	Capture probability	Estimated abundance ± SE
2003								
7-day occasion	0.389	6 ± 0.28 C.I. = 5.45 - 6.55	0.333	7 ± 1.36 interpolated C.I. = 4.35 - 9.65	Capture = 0.316 Recapture = 0.428	6 ± 0.59 C.I. = 4.84 – 7.16	Not computed	6 ± 0.59 C.I. = 4.84 - 7.16
5-day occasion	0.346	6 ± 0.16 C.I. = 5.69 - 6.31	0.346	6 ± 5.51 interpolated C.I. = 0 - 16.80	Capture = 0.231 Recapture = 0.404	6 ± 0.59 C.I. = 4.84 – 7.16	Not computed	6 ± 0.59 C.I. = 4.84-7.16
2004								
7-day occasion	0.383	6 ± 0.22 C.I. = 5.57 - 6.43	0.383	6 ± 0.19 C.I. = 5.63 - 6.37	Capture = 0.667 Recapture = 0.333	6 ± 0.01 C.I. 5.98 - 6.01	Not computed	6 ± 0.01 C.I. = 5.98 – 6.01
5-day occasion	0.333	6 ± 0.22 C.I. = 5.57 - 6.43	0.333	6 ± 0.20 C.I. =5.61 - 6.39	Capture = 0.461 Recapture = 0.305	6 ± 0.06 C.I. = 5.88 – 6.12	Not computed	Not computed

[a] C.I. = lower and upper 95% confidence limits around mean computed by hand (see text);

HARMONY VALLEY

LIVESTOCK AND WILDLIFE

SLC promotes environmental awareness using local language posters, children's books and teacher training to convey the basic principles of the high mountain food web and the snow leopard's place in it, all within the local cultural context.

This poster, in the style of a traditional Buddhist Thangka, shows two mountain settlements. "Harmony Valley" practices good environmental stewardship, while "Conflict Valley" could benefit from improvements. The image is meant to stimulate discussion, and to encourage herders to make the connection between good livestock husbandry and elements of wildlife protection that are within their control.

Poster created by Leslie Nguyen

5.6 Effective Area Sampled and Population Density Estimates:

We calculated the mean maximum linear distance moved by individual snow leopards between successive captures to be 3.15 and 4.03 km in 2003 and 2004, respectively (Table 13). Thus, we added an outer boundary strip of 1.58 and 2.02 km during 2003 and 2004, respectively to the polygon enclosed the outermost camera trap stations, effectively censusing 71 km^2 in 2003 and 135 km^2 in 2004. We judged 60-70% of the Rumbak watershed as providing good snow leopard habitat consisting of steep, irregular slopes, richly endowed with rock outcrops, cliffs, gullies and other cover, and the remaining 30-40 % classified as poor habitat (consisting largely of open rolling slopes with little or no physical or vegetative cover) (Figure 3). The 2003 survey yielded an estimated snow leopard density of 8.49 ± 0.22 (SE) individuals per 100 km^2 (excluding cubs), compared to 4.45 ± 0.16 in 2004. Given similar mean distances moved and the same minimum number of individuals (6) captured during each survey, these different estimates most likely reflect differences in camera spacing, coverage and type of habitat surveyed. In 2003, our traps were concentrated within core snow leopard habitat; in 2004 we placed more traps within marginal habitat and sampled a larger area but mostly within the same watershed, leading to a lower density estimate. We concluded that a density of approximately 5 snow leopards per 100 km^2 was consistent with Chundawat and Rawat's (1994) estimate of 4 snow leopards based on the availability of blue sheep in the Rumbak drainage.

Table 13: Mean Distance Moved, Effective Area Sampled and Estimated Snow Leopard Density in Hemis National

Year	No of trap sites	Area (km^2) with camera traps	Mean maximum distance moved (km)	Std error	Buffer strip width (km)	Effective area sampled (km^2)	Estimated snow leopard density[1] under null model (M_o) (number per 100km^2 with SE)
2003	18	28.46	3.15	0.38	1.58	70.70	8.49 ± 0.22
2004	19	60.71	4.03	0.42	2.02	134.87	4.45 ± 0.16

[1]See text for explanation of density estimates

A Role for Camera Trapping in Snow Leopard Research and Conservation

Chapter 6: Conclusions and Recommendations

6.1 Applicability of camera trap surveys of snow leopards

If aptly applied, we believe that photographic capture-mark-recapture (CMR) is a useful tool for estimating population size and monitoring population trends of wild snow leopards. The sensors and cameras deployed over two annual census periods performed well under the harsh conditions prevailing at high elevations (3,400 – 4,600 meters) in the Himalaya - notably low nighttime winter temperature often below 0° Celsius, daytime temperatures as high as 35° C, and high ambient solar radiation.

Snow leopards are harder to identify than tigers which exhibit clear lateral striping patterns and a tendency to travel on roads, or common leopards that have much shorter fur and more sharply-defined and contrasting spot patterns. Camera-subject orientation proved to be a key factor in the ability to identify individuals, and we found that two cameras oriented at 45° angles to the path of travel worked best in obtaining photographs of the forelimbs, flanks and dorsal surface of the tail. This resulted in more consistent subject orientation and reproducible images of the key identification areas, and significantly increased ease of identifying individual snow leopards.

Camera traps are best placed along the approach/departure to rock scents and scrape sites. Camera traps set immediately at rock scents or scrape sites often resulted in images of snow leopards in variable poses based on their tendency to investigate and mark the area. Camera traps were most effective at locations where topography or related environmental features restricted travel to a well-defined pathway. But care must be taken to prevent the subject from walking too close to the camera, which may result in blurry, unusable images and lost capture data. Obtaining good quality side profile photographs of snow leopards proved surprisingly difficult because most travel paths are narrow (less than 2-3 meters in width), in addition to the snow leopard's preference for walking close to a boulder or cliff base. This makes it harder to simultaneously capture images of both sides for positive identification at first capture, which has proven so effective in tiger, leopard or jaguar camera-trapping studies (for example, Karanth and Nichols 1998; Henschel and Ray 2003; Maffei et al. 2004, Silver et al. 2004). In addition, the snow leopard's sides (mainly the shoulders and flanks) and to a lesser extent, the hind limbs, appear to be less reliable for identification than the forelimbs, flanks and tail due to the long fur that moves, altering the pelage patterns. Also, outlines of the open rosettes and spots do not stand out as sharply as they do in common leopards or jaguars, especially if the coat is covered with a light dusting of snow. Photographs taken along travel lanes, where animals are walking quickly, tend to produce blurred or cropped images which may be unidentifiable. We found little or no evidence that our study population was affected by either the camera flash or noise, with most individuals being repeatedly recaptured, except possibly in 2004.

Besides following the rules for camera placement discussed in Chapter 4 to maximize snow leopard captures and minimize false triggering (Section 4.6), unnecessary images of livestock can be avoided by setting the infrared sensors to operate during the time(s) of day when herders and their flocks are likely to be absent. To this extent, TrailMasters offer the greatest flexibility and can be set to operate during one or two daily time periods. CamTrakkers, however, can be set to operate 24 hours a day or only during daytime or nighttime hours. It is very important to remember that all camera traps should be set to operate within the same daily sampling window to meet the assumption of equal effort (the alternative is to only include data from common periods of time in population estimation dataset).

Our capture histories best fit the closed CMR null model M_0 or possibly the alternative model M_h, which incorporates individual heterogeneity into capture probabilities and represents the model of choice for tigers (Karanth and Nichols 1998, O'Brien et al. 2003). It is important to emphasize that the ability to select the most appropriate model is a function of sample size. Due to our small sample size, we had no choice but to accept the over-generalized null model, an inevitable consequence of working with a shy species that occurs at low density over extensive mountainous terrain. On the other hand, our capture probabilities were double those reported from tiger surveys in good habitat (Karanth and Nichols 1998), and many times greater from less productive habitat as is the case with the rare Sumatran tiger (Karanth et al. 2004; O'Brien et al. 2003). Presumably, this reflects the snow leopards' strong predilection for using common travel lanes, revisiting the same site to mark frequently (particularly during the winter mating season) and its limited apparent trap-shyness (Ahlborn and Jackson 1988, Jackson 1996).

As noted, capture probability can be maximized by placing traps near communal rock scents and scrape sites and along narrow "choke" points where topography constrains and funnels movement (e.g., stream or valley confluences and intersecting travel routes on ridgelines), particularly if these happen to be located within core use areas (Jackson 1996). Besides ensuring there are no gaps in trap coverage, we recommend camouflaging the infrared sensors and cameras in fairly natural-looking rock cairns. We ensured all camera traps were concealed within structures built from rocks readily available at each site. We also recommend avoiding the use of tracking pads, a suspected problem in one tiger study (Wegge 2004). These investigators felt that the tracking pad

TWO BY TWO

THE NEXT GENERATION

Two cubs are captured on film by a camera trap. Monitoring reproductive success is a vital component of good management of an endangered species like the snow leopard. The SLC believes that the future of the snow leopard depends on successful conservation efforts that grow from within the communities living with the cats.

Non-invasive baseline research such as the use of camera trapping and DNA sampling technologies in population studies will help monitor the success of conservation efforts and play a part in ensuring a future for the cats.

acted as a cue to the nearby presence of a photo flash, which some individual tigers appeared to regard as "unpleasant." (op cit., page 256). Like tigers, snow leopard cubs and juveniles are not as readily detected as resident adults for they tend to avoid capture by trailing behind their mother (who generally triggers the camera). However, this cohort is best estimated during winter snowfall when cub pugmarks are readily detectable.

Cumulative capture curves indicated that camera trap surveys need to be at least 35 days in duration to detect sufficient individuals, but 45-60 days are preferable for ensuring adequate recaptures without violating closure assumptions. We found sampling occasions of 5 days in duration worked well, offering some latitude for periodically moving traps. Karanth and Nichols (2002) recommend moving traps every few days or so in order to sample larger areas. Obviously this is difficult to accomplish given the snow leopard's mountainous habitat, where travel is mostly by foot. Moving traps from one site to another can be very time-consuming, so that even having a full compliment of traps active every night of trapping may not be achievable. The preferable alternative is to conduct a census in which the entire survey area is saturated with camera traps such that no individual within the area surveyed could move throughout its home range without the potential of being captured in a camera trap. The census is essentially a count of all individuals within a given area and can be conducted at a much smaller scale requiring less staffing, fewer cameras and lower costs. The disadvantages are such that only a relatively small area can be sampled due to logistical constraints and the census cannot be extrapolated beyond the survey area. By contrast, a population estimate can be conducted on a much larger scale provided a proper sampling scheme is used. A true appreciation of snow leopard numbers throughout their range will likely require a meta-analysis of several years of surveying and census data, which is not currently available.

Virtually all researchers are constrained by the number of camera traps available to them. Another alternative to purchasing and simultaneously deploying numerous cameras involves dividing the survey area into a number of contiguous blocks (3-5 or more) and then moving cameras from one location to another within the same block every 5-7 days. Assuming the survey has 20 units available for use, that the minimum density is about 1.5 cameras per 16-30 km^2 and that each camera must be deployed at the same site for not less than 5-nights to ensure good capture probabilities, it will be difficult to sample areas much larger than 500-750 km^2 during a single survey (see Box C, Chapter 4). Furthermore, assuming that only two trap stations can be relocated within a single day, a minimum of 10 days would elapse between moving all camera traps to new sites. Therefore, the only alternative is to synchronize movement of traps on a block-by-block basis so that each has a similar trapping effort during each sampling occasion (see Karanth and Nichols 2002). One likely consequence is that some trap sites would be covered for longer periods than others, possibly introducing a trapping bias in favor of those individuals spending more time in such areas.

6.2 On Camera and Sensor Selection and Performance

Table 14 (next page) summarizes the basic features of remote sensors and cameras used in this study. Although they are more expensive and demanding to set and operate, we found that active infrared sensors like the TrailMaster 1550 provide greater control and reliability if properly deployed and monitored. Passively triggered infrared monitors have a tendency to miss the target animal if their heat signature does not differ significantly from ambient temperature, as we experienced on several occasions. However, passive infrared sensors which rely on a dual trigger, i.e. motion and heat, would not result in as many false images

Table 14: Comparison of Infrared Sensors and Cameras used in this Study

Characteristics	Analog				Digital
	TrailMaster *TM 1550*	**TrailMaster** *TM 550*	**CamTrakker** *Original/Ranger*	**DeerCam** *Scouting Camera*	**CamTrakker** *Digital*
Specifications					
Components	Two weatherproof units: receiver & transmitter. Multiple 35mm cameras can be attached to a single trigger using the TM Multi-Camera Trigger	One weatherproof unit. Multiple 35mm cameras can be attached to a single trigger using the TM Multi-Camera Trigger	One weatherproof unit. Includes a 35mm camera housed within the unit	One weatherproof unit. Includes a 35mm camera housed within the unit	One weatherproof unit. Includes a 35mm Sony digital 4.1 Megapixel camera which can be housed inside or separate from the unit
Setup *Note: Field setup can be simplified by programming the settings prior to field placement*	Moderately difficult. Requires familiarity with system. Approximate setup time: 30-60 minutes	Easy. Approximate setup time: 10-30 minutes depending on the number of cameras attached	Easy. Approximate setup time: 10-20 minutes	Moderately difficult. Approximate setup time: 20-40 minutes	Easy. Approximate setup time: 10-20 minutes
Trigger	Active. A conical pulsed infrared beam detects target species when the beam is broken for a specified duration	Passive. Dual heat and infrared motion detectors. Requires both detectors to be triggered simultaneously to register an event	Passive. Dual heat and infrared motion detectors. Requires both detectors to be triggered simultaneously to register an event	Passive. Dual heat and infrared motion detectors. Requires both detectors to be triggered simultaneously to register an event	Same as analog CamTrakker
Range *Note: Effective distance of passive infrared monitors vary depending on environmental conditions*	150 feet distance; narrow 3/8 inch beam; direct line of sight	65 feet distance; wide detection zone 150° arc 4° depth	60 feet distance; moderately wide but consistent detection cone of 8 feet diameter	60 feet distance; narrow or very narrow detection cone[1]. Hot weather detection 20 feet.	Same as analog CamTrakker
Instant Camera Triggering *(Note: low light or night-time pictures subject to recycling of flash)*	Yes	Yes	Yes	Yes	No, requires time to power up the camera; can take up to 30 seconds; power ready mode can drain battery within 24 hours[2].
Sensitivity[1]	Highly variable. Allows for accurate target specificity	Variable. Allows for moderate target specificity	Fixed setting	Two settings: high and low via a jumper switch	Same as analog CamTrakker
Time Zone Settings	Yes, two definable time periods per 24 hour interval	Same as TM 1550	Yes, day, night or both (controlled by CdS cell)	One time zone per 24 hour period (set with Xpander)	Same as analog CamTrakker
Data Log	Yes, records date, time, number of events and indicates if a picture was taken. Stores >1,000 events	Yes, records date, time, number of events and indicates if a picture was taken. Stores >1,000 events	No	Yes, records date, time, number of events and indicates if a picture was taken. Stores up to 65,353 counts, 99 photos, 999 running days	No

Table 14 continues on the next page

Table 14 (continued): Comparison of Infrared Sensors and Cameras used in this Study

Characteristics	Analog				Digital
	TrailMaster ***TM 1550***	**TrailMaster** ***TM 550***	**CamTrakker** ***Original/Ranger***	**DeerCam** ***Scouting Camera***	**CamTrakker** ***Digital***
Power Requirements					
Power	Low power consumption; lasts >2 months in extremely cold temperatures. Designed to last a year Requires 8 C-cell batteries and a Lithium-ion camera battery	Low power consumption; lasts >2 months in extremely cold temperatures. Designed to operate 6-12 months Requires 4 C-cell batteries and a Lithium-ion camera battery	C cell system sensor life ± 2 weeks at subzero temperature (see below) Requires 4 C-cell and 2 AA 1.5V Lithium batteries Ranger is available with 6v rechargeable sealed lead acid battery (manufacturer battery life rated at 2-3 months at subzero temp)	Sensor life ≤ 2-3 weeks; camera battery life may be less in cold temperatures 2 9-volt and 2 AA-batteries designed to operate for >2 months	High power consumption. Requires ability to recharge in the field Sold with 2 nickel metal hydride batteries both of which need to be used together. Use of camera outside of the unit requires an additional 2 AA batteries
Solar-Rechargeable	Possible	Possible	Possible	Possible	Possible
Low Battery Indicator	Yes	Yes	No	Yes (LED and with Xpander option)	No
Camera					
Camera	Modified 35mm camera; models may vary from year to year Features: weatherproof, date/time stamp	Modified 35mm camera; models may vary from year to year Features: weatherproof, date/time stamp	Modified 35 mm camera; models may vary from year to year (Ranger uses Olympus Trip 505) Features: date/time stamp	Modified 35 mm camera; Olympus Trip 505 Features: date/time stamp	Sony DSC-P41 Cyber-Shot 4.1 Megapixel digital 35mm camera; models may vary from year to year Features: memory stick, USB connection
Camera Delay	Highly variable; ranges from 6 seconds to 99 minutes	Highly variable; ranges from 6 seconds to 99 minutes	Highly variable; ranges from 20 seconds to 45 minutes	Highly variable; ranges from 15 seconds to 60 minutes	Highly variable; ranges from 20 seconds to 45 minutes
Cost					
Single Unit/One Camera *Note: Does not include accessories*	TM 1550: $260.00 TM Camera:$290.00	TM 550: $180.00 TM Camera:$290.00	Ranger: 229.95 Original: $429.95	DeerCam DC-200 $150 – 200; Expander $50	Digital: $750.00
Single Unit/Two Cameras *Note: Does not include accessories.*	Total: $890.00	Total: $810.00	Would require two complete units. Total: $460 to $860	Would require two complete units. Total: $300 to $450	Would require two complete units. Total: $1,500

Notes: [1]All models are less sensitive at higher ambient temperatures (Swann et al. 2004).
[2]We also tested a Stealth Cam DIGRC-XRT digital camera with 3 megapixel resolution, built-in LCD display and a diagonal passive infrared lens with a 48 diagonal field of view at approx 30 feet. Performance is similar to digital CamTrakker. Operates on 6 AA batteries, but battery life is significantly extended using the optional accessory solar panel (use NiMH 2100 mAH rechargeable batteries). No time zone setting, but camera delay can be set from 1-60 minutes.

SAFE CORRALS

PARTNERSHIPS WITH LOCAL COMMUNITIES

Traditional stone livestock pens prevented livestock from escaping but were less effective at keeping opportunistic snow leopards out. Herders usually react to multiple losses by trapping or poisoning snow leopards.

Here, farmers predator-proof their livestock corral with the aid of materials, methods and training provided by the Snow Leopard Conservancy. Each party contributes materials, labor, expertise or funds within their means, toward a solution that grows from a highly participatory and holistic planning process known as APPA or Appreciative Participatory Planning and Action.

Improved corral under construction in Skyu-Kaya, Hemis National Park.

Photo: Rinchen Wangchuk

due to snowfall. We feel that the high degree of false triggers associated with active infrared sensors is far better than missing snow leopards that pass through camera traps. Note that pressure sensors will almost inevitably fail during periods of snowfall and subzero temperatures, after snow and ice forms a solid frozen surface preventing the pad from moving and closing the electrical circuit. Snow leopards were recorded during all hours of the day, although there is preponderance for captures from dusk to early dawn.

Advantages of the TrailMaster 1550 include its long-lasting battery life (at least 2-3 months even during the low or very low temperatures of winter which dropped to -12°C each night), non-volatile memory for storing event information, waterproof cameras that are not housed with the sensor for maximum setup options, and portable tripods that make framing each scene simple and quick (although the tripod can be accidentally knocked over unless it has been properly secured with small rocks). On the downside, we had to paint each camera a flat black or gray (38 in all) since they were bright white and red from the factory. Although TrailMasters are designed to be mounted on trees or stakes, working above treeline in remote habitat where wood is scare, meant that we had to mount the receiver to a metal flange available at most hardware stores in the U.S. for a minimal added expense.

The latest CamTrakker remote camera addresses the need for longer battery life and has three camera models available in the digital camera units. These offer an alternative to the more complicated TrailMasters in that CamTrakkers are easier to use, especially for local villagers with little experience working with technical equipment, and are packaged as a single unit. The digital CamTrakkers provide a means of evaluating capture data in the field, which could provide close to real-time data analysis and minimize problems due to improper framing, etc. However, most digital units still use significantly more battery power than analog cameras and more importantly, do not trigger as fast – factors that should be considered prior to deciding which remote camera to purchase. Thus, one should consider the user's experience with camera traps, the cost per unit and reliability in detecting snow leopards prior to deciding which camera system to purchase.

6.3 Camera Trapping Population Survey Costs

Table 15 (next page) summarizes the cost of conducting a snow leopard population abundance estimate under the supervision of one or more skilled biologists and requiring the establishment and operation of a base camp for the duration of the 60 day survey. Clearly, camera trap population estimation surveys are expensive, especially when undertaken in remote areas requiring onsite presence for 6-8 weeks or more. Besides covering salaries and challenging logistical costs, acquiring sufficient numbers of camera traps is very costly, especially if these are TrailMasters or equivalent high-end sensors. Many sites can only be accessed by 4-wheel drive vehicle and/or by foot or pack-animal, a journey that might take a few days to a week or longer.

However, survey costs can be reduced substantially by (1) training and employing in-country biologists; (2) conducting a sample census rather than a population estimate; (3) deploying inexpensive passive infrared cameras; or (4) employing suitably trained villagers to

Table 15: Estimated Costs of an Intensive 6-8 Week Population Estimation Camera Trap Survey

Option (see below)	Description	No units	Item Cost	Total Cost US Dollars	Subtotal
	Equipment Purchase				
A	TM sensors & 2 cameras	20	950	19,000	$19,000
B	DeerCam (wholesale price)	40	160	6,400	
B	DeerCam Xpander	2	35	70	
B	Rechargeable NiMH AA's	80	3	240	
B	Rechargeable NiMH 9 v batteries	80	8.5	680	
B	AC/DC Battery Charger	2	25	50	$7,440
A & B	Garmin™ GPS	2	325	650	
A & B	Brunton™ Sherpa Altimeter	2	135	270	
A & B	Tape measures, notebooks etc	Fixed		150	$1,070
A & B Camping Gear	Tents	2	250	500	
	Sleeping Bags	3	175	525	
	Other items	Fixed		300	$1,325
	Expendable Supplies				
A & B	Rolls of Film (Fuji 24 exp, ASA 400 Print)	80	2	160	
A & B	Film processing / prints	80	8	640	
A	Lithium cells for Canon / TrailMaster	40	5	200	
A	Duracell C cells (for TrailMaster)	160	0.9	144	
B	Duracell AA's (DeerCam)	120	0.4	48	$1,192
	Field Costs				
A & B	Vehicle rental (2 vehicles for 6 days @ $50)	2	300	600	
A & B	Horses (5 horses for 12 days @ $10 day)	60	10	600	
A & B	Food & per diem (team @ $40 per day)	60	40	2,400	
A & B	Hotel (enroute)	16	50	800	$4,400
	Salaries (months)				
A & B	Foreign Scientist	2	5,000	10,000	
A & B	Local Scientist	3	500	1,500	
A & B	Field Assistant (2)	4.5	100	450	$11,950
	Report Preparation and Dissemination				
A & B	Report Preparation	fixed		300	
A & B	Copying	fixed		100	
A & B	Phone & communications cost	fixed		250	$650
	Cost Per Survey			**Option A**	**Option B**
Survey Item	Equipment Purchase (one time cost)			$21,395	$9,835
	Staff (see below for cost savings)			$11,950	$11,950
	Field Costs (transport, food & supplies)			$6,194	$5,898
	Contingency 2.5 % (field & staff only)			$453.6	$446.2
	Totals			**$39,993**	**$28,129**
Notes	Option A = Active infrared sensors (TrailMaster) Option B = Passive infrared sensors (DeerCam). Add $60-100 per unit for CamTrakker Ranger units with rechargeable sealed lead acid batteries reported to last up to 6 months. Costs assume a 60-80 day survey and maintenance of a 4-person base camp. If local people are trained to deploy and monitor cameras, staff costs could be reduced by 60% or more. If equipment is amortized over 5 surveys the total per survey cost is estimated at $20,262 - $22,877.				

LANGU VALLEY

LEOPARD LANDSCAPES

Snow leopard habitat appears to be highly insular and fragmented. Rugged terrain like this, little impacted by humans, represents an island of "core habitat" for snow leopards and their prey.

Presumably, such areas provide a vital source of emigrating individuals for repopulating adjacent areas under the metapopulation concept of "source - sink" population dynamics.

maintain and monitor cameras, as the Snow Leopard Conservancy has been doing in the buffer zone of the Khunjerab National Park in Northern Pakistan. For example, by employing a local biologist to organize and supervise the population survey, costs can be reduced 25% from about $ 40,000 to $ 30,000, a figure which includes purchasing 20 TrailMaster 1550 sensors and 40 good-quality 35 mm cameras (Table 15).

6.4 Implications of Camera Trapping for Snow Leopard Ecology and Conservation

The Snow Leopard Survival Strategy or SLSS (McCarthy and Chapron 2003) emphasized the need for systematic surveys to determine baseline snow leopard population size in different parts of the species' range, noting that "past estimates of snow leopard numbers represent little more than a 'best guess' and are based on very limited surveys." The SLSS recommended photo-trap camera surveys to census snow leopards in multiple areas, the collection of hair samples for deriving genotypic population estimates, and the correlation of *SLIMS* data with known population sizes in order to validate the technique as a predictive tool.

As noted in this handbook, the primary constraints to using camera traps for estimating wild snow leopard populations are the small sample size, initial cost of purchasing the camera traps, training of personnel, and high costs of working in areas with few or no roads. Nonetheless, we believe that camera trapping is a viable tool for censusing and estimating snow leopard population size, especially in areas where densities exceed 2-3 individuals per 100 km^2. Our study yielded statistically 'tight estimates' of the number of snow leopards within an area of approximately 100 km^2 in size within Hemis National Park. With the low confidence intervals under the Null Model, we can be confident that the number of snow leopards is at least 6 individuals, a number equal to the total number of individuals trapped during each season. The high detection probabilities (0.33 – 0.34), combined with the large number of occasions, indicates that all animals in the population using the sampled area were probably captured. For example, the probability of ***not capturing*** an animal during the 12 occasions of the 2004 survey is very low, as derived using the following formula:

$(1-p)^n$ (probability of non-detection raised to the n^{th} power, were n is the number of occasions)

$(1-0.33)^{12} = 0.0082$, the probability of not capturing an animal during 12 occasions

Data from successive occasions can be pooled if detection probabilities are below 0.20 in order to achieve our recommended minimum capture probability of 0.30 or greater. If population estimates are not feasible, census surveys using camera traps provide the minimum number of snow leopards present along with the trapping effort, expressed as the number of animal photographs per trap night, which can be viewed as an index of relative abundance - provided capture probabilities remain constant across traps or over time between different sites and years, which may not always be the case (Carbone et al. 2001, Jennelle et al. 2002).

Given the significant cost and effort involving camera trapping, it is imperative that survey areas be carefully and strategically located. Since population data is largely lacking, we deem the highest priorities are camera-trap and genetic surveys within known snow leopard "hotspots," including protected areas and adjacent areas of sufficient size to harbor or potentially support a minimum viable population size of 50 – 250+ breeding females (Jackson and Ahlborn 1991). In addition to maps of protected areas produced by WCMC, the World Conservation Monitoring Centre located in Cambridge, England, or species- and ecoregion maps compiled by WWF, there is the new and very exciting internet-based 3-D mapping tool *Google Earth*™ which Google recently launched (see Appendix 4.4). This free software offers remarkably high-quality images of the terrain found across the snow leopard's Central Asian range, which should aid greatly in locating areas with suitable snow leopard habitat, in establishing the best access routes, and for better estimation of the number of camera traps and time required for a census or population estimate.

CAT TRACKS

PUGMARKS

Although very rarely sighted, sign of the near-mythical snow leopard is not hard to detect if you know where to look - and if populations have not been depleted to the near vanishing point as appears to be the case in too many places across the mountain ranges of Central Asia.

This fresh pugmark was found on a high pass late one afternoon.

Timing of surveys is another critical factor to consider, as discussed in Chapter 4. Snow leopards tend to be more concentrated in winter and early spring, and most dispersed during summer when both predator and prey typically move to higher elevations or areas less disturbed by humans. Winter surveys are thus more efficient in terms of camera trap requirements and the amount of land area which can be covered than surveys conducted during summer months. In winter, traps can be placed at lower elevation along the valley edges, whereas in summer camera traps must be placed along high ridgelines which typically require a grueling hike to reach. Servicing such sites is, of course, equally time-consum-ing. In any event, we cannot over-stress the importance of conducting a pilot study to determine how, when, and where best to place photo-traps for maximum effect. The bottom-line to population estimates are (1) setting sufficient numbers of camera traps to achieve high capture probabilities (≥ 0.20-0.30), and (2) covering large contiguous land areas in order to capture an adequate number of individual snow leopards (preferably 15-20) to process through CMR population estimation programs.

Our study suggested the snow leopard population within Hemis National Park might be somewhat larger than previously thought. Assuming a density of approximately 6 snow leopards per 100 km^2 in areas of good habitat and no more than 2-4 per 100 km^2 in marginal habitat, HNP may contain approximately 175 snow leopards. This is substantially more than the estimate of 50-75 individuals (Fox and Norbu's 1990), but closer to Mallon and Bacha's (1989) estimate of 75-120 cats within a 1,200 km^2 section of the park. We suspect the difference between these figures may partially reflect recent conservation initiatives aimed at protecting the snow leopard and its prey through reducing livestock loss, along with poaching and retributive killing of snow leopards (Jackson and Wangchuk 2001).

The current method of determining population status of snow leopards, known as *SLIMS*, uses sign as an index of abundance, but is subject to many confounding factors (see Box A, Chapter 3). This highlights the need for deriving more robust estimates of detection probabilities and population size, if necessary using jackknife techniques. Regardless, we recommend that camera trap estimates be supported by ungulate prey abundance surveys and calibrated data from standardized snow leopard sign transects. There should be enough prey (wild ungulates and domestic livestock) to support the projected number of cats. Based on the movement patterns of radio-collared snow leopards in Nepal, Jackson and Ahlborn (1984) estimated that they killed a blue sheep-sized prey about once every 10-15 days, or 20-30 annually. They concluded that a population of 150-230 blue sheep would be required to sustain one adult snow leopard in the Langu Valley, given its blue sheep sex and age structure, and assuming an overall harvesting rate of about 13% of the standing crop. This number would be less in areas with supplementary prey, such as marmot and livestock, both of which were absent in the Nepal study site.

We detected a change in population composition between 2003 and 2004. The dominant male snow leopard, HNP-1, which was photographed more than any other snow leopard within the survey area since 2001 (when it was caught on remote video), was last detected by camera traps on December 23, 2003. We believe that the resulting home range vacancy played a major role in the addition of four new individuals detected during the following camera trap survey in 2004. Several video cameras deployed since February 2001 indicated the presence of HNP-1 and female HNP-2 with two cubs, the latter filmed without their mother at age 14 months or older (although they may not have yet been fully independent of her). Snow leopard HNP-1 was captured at least a dozen times on video between early 2001 and his last capture. Between 2001 and 2004, we detected two litters (one in Feb 2001 and the second in Feb 2004; each comprised of 2 cubs) born to female HNP-2. She was filmed and photo trapped consorting with HNP-1 in mid-February 2003. A second breeding female (HNP-9) was photographed with her single cub during the 2004 survey at the far edge of the survey area. These observations may suggest the survey area harbors a healthy cohort of breeding females and possibly also a stable population. The deployment of remote cameras offers a helpful means of obtaining baseline population demographic information, data vital to assessing the long-term effectiveness of conservation measures. However, we emphasize that identifying the gender and age of captured leopards is problematic and subject to error. Similarly there is no ready method to identify residents from transients, although a female with cubs or a frequently recaptured large snow leopard (male) would almost certainly be residents to the area. We defined residents as adult or subadult snow leopards detected within the same general area over successive seasons and years, or for a period of at least 6 months (Hemker et al. 1984). As Karanth and Nichols (2002) have noted, monitoring resident females is the most reliable means for assessing the trend of a particular population, and determining whether it is producing surplus individuals for dispersing into adjacent areas or not.

There is a definite need for more research to establish camera trap sampling parameters under varying habitat conditions. Obtaining statistically sound population estimates across different sites and habitats will be expensive, time-consuming and not feasible in all situations. An alternative involves the use of inexpensive passive infrared-sensing cameras deployed over longer time spans at frequently visited rock scents by suitably trained wildlife guards or local villagers for population demographic monitoring. With ongoing identification of individuals from the accumulating images would at least indicate the minimum number of individuals present and the duration of their "residency" within trapped sites. Simple capture histories could be used to identify known or probable residents versus transients and dispersing or dying individuals, if sample size permitted and camera coverage were large sufficiently extensive. By knowing each snow leopard that inhabits a particular area, local villagers might become more committed to protecting this rarely seen carnivore. For community-based conservation to be a sustainable strategy for protecting snow leopards, we have to find ways whereby local people - in partnership with government and local NGOs - can monitor the snow leopard and prey populations in their area. It is simply not realistic to always have to depend upon outside researchers for such services. Rather, their efforts should be directed toward refining camera trapping methodologies and finding new techniques for non-invasively monitoring populations of cryptic predators like the endangered snow leopard.

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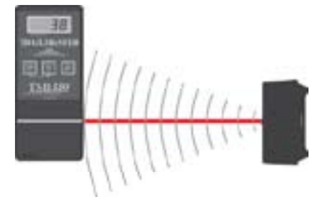
TrailMaster Camera Trap Instructions

Appendix 1-A: TrailMaster Field Setup



Before going out into the field

- Make sure the TrailMaster and camera(s) have fresh batteries.
- Make sure camera cables and connecters are intact and functioning.
- Make sure camera lenses are clean.
- Make sure you have ALL necessary equipment (e.g., cables, batteries, tripods, etc.).
- It is preferred that the date, time and all TrailMaster settings are set prior to heading into the field.

Verify battery condition

- Receiver will display [Lo b] if batteries are low.
- Transmitter led on bottom should immediately flash red when transmitter is turned on. When transmitter is turned off the red led should flash briefly after several seconds. Either of these indicates good batteries.
- When installing new batteries, be sure to label each battery with the date (ddmmmyy; *e.g.* 14AUG03) and record on the datasheet. Verify that the voltage is at least 1.5v.

Setting Time, Date, Sensitivity & Camera Delay

Turn receiver on by the toggle switch on the bottom.

Press TIME SET, press R/O ADV to set the correct hour	(**00**:00)
Press TIME SET, press R/O ADV to set the correct minute	(00:**00**)
Press TIME SET, press R/O ADV to set the correct year	(20**0**2)
Press TIME SET, press R/O ADV to set the correct year	(200**2**)
Press TIME SET, press R/O ADV to set the correct month	(**0**:00)
Press TIME SET, press R/O ADV to set the correct day	(0:**00**)
Press TIME SET, press R/O ADV to set the correct *P*-value[1]	(-P **5**)
Press TIME SET, press R/O ADV to set the correct Cd-value[2]	(Cd **.3**)

[1] *P*-value is the sensitivity of the system and values range from 1 to 30 (1 = 0.05 seconds and 30 = 1.5 seconds). The default p-value is 5 or 1/4th of a second and is what we used during the 2003-2004 study. We recommend using a higher *p*-value of 8-15 to reduce false triggering if it becomes problematic.

[2] **Cd** or Camera Delay function prevents the camera from being triggered for a predefined time period ranging between 0.1 and 98 minutes. This feature helps prevent the unit from shooting an entire roll of film on one animal, which may stand in front of the camera for an extended period of time. We are using a Cd = .3, thus the camera will not take a picture for 18 seconds after a picture is taken.

Setting Time Zones (for 24 hour use)

Press and hold the TIME SET button then press the SET UP button

Press R/O ADV to set the hour Time Zone 1 will start	(**00**:1n)
Press R/O ADV to set the minute Time Zone 1 will start	(1n:**01**)
Press R/O ADV to set the hour Time Zone 1 will end	(**00**:1F)
Press R/O ADV to set the minute Time Zone 1 will end	(1F:**00**)
Press R/O ADV to set the hour Time Zone 2 will start	(**00**:2n)
Press R/O ADV to set the minute Time Zone 2 will start	(2n:**00**)
Press R/O ADV to set the hour Time Zone 2 will end	(**00**:2F)
Press R/O ADV to set the minute Time Zone 2 will end	(2F:**00**)

TrailMaster 1500/1550 has the ability to operate continuously or during one or two time zones within a 24 hour period. For example, to track snow leopards during the early morning and early evening hours, set Time Zone 1 to turn on at 4:00am and turn off at 7:00am and set Time Zone 2 to turn on at 7:00pm and turn off at 10:00pm. In most cases we operate the TrailMaster in continuous data collection mode. This can be done by turning on Time Zone 1 at 12:01am and not setting an off time (i.e., all zeros). For this to work Time Zone 2 has to be set to all zeros.

Set the Camera to Imprint the Date and Time

- Make sure lens is clean.
- Make sure batteries are in good condition.
- Set the correct date and time and program the camera to imprint the Month/Day/Year.
- Some cameras have a panoramic option. Make sure the panoramic function is not selected.
- Some cameras incorporate a redeye reduction feature with automatic flash modes, which increase the camera's response time. Select the operating mode that does NOT use this feature; for our purposes we will use the flash mode.
- Connect the camera cable and ensure it does not interfere with the lens.

Field Setup and Alignment

1. Verify the event reads zero. Clear the event data by pressing SET UP, then pressing R/O ADV. The window will read "clr". Press TIME SET to clear event data.
2. *Note*: the infrared sensor is sensitive to direct sunlight; therefore the receiver and transmitter should not be pointed in the direction of early morning or late afternoon sun.
3. The TrailMaster should be setup along the approach to active rock scents or scrape sites, and along game trails and ridgelines. Look for a narrowing in the trail or ridge line where a cat would have little choice but to pass through the camera trap.
4. The cameras should be placed approximately 2-3 meters away from the rock scent or scrape site. This will ensure that cats are photographed more consistently in the same pose instead of varying positions as is the case when they are investigating rock scents. Make sure that the cameras are framed to photograph the entire snow leopard not just the head, which means each camera has to be placed about 3 meters from the snow leopard's travel pathway. Make sure the cameras are turned off during set up. Connect the cables to the receiver, multicamera trigger and cameras. Refer to figures 4-6 in Chapter 4.
5. Setting up the receiver and transmitter:
   - These units should be placed perpendicular across the game trail or ridgeline approximately 2-3 meters from the rock scent or scrape site.
   - The units should be placed approximately 3 to 5 meters apart.
   - Set the units at the approximate chest height of an adult snow leopard, e.g. 40 cm above the game trail or above the ground where a snow leopard will pass.
6. Aligning the receiver and transmitter:
   - Make sure both receiver and transmitters are turned on (toggle switches on the bottom).
   - Press SET UP; the red alignment light should flash when the transmitter is aimed at the receiving window.
   - Move the transmitter up/down and left/right until the unit is centered on the receiving window.
   - Once the units are aligned, the receiver will automatically go into data capture mode after four minutes. It can also be placed in data capture mode manually by pressing TIME SET, while the red light is flashing.
7. Remove any vegetation that may interfere with the infrared beam or camera view. Make sure all units are secure and cannot be easily moved.
8. Once the TrailMaster is set up, walk through the area quickly to verify the system is functioning. The display window should now read 1.
9. If TrailMaster is functioning properly, turn the cameras on and leave the area.

Fill out a Datasheet for each Camera Station!!

Checking Event Data

Press R/O ADV; the date, time and event number will be sequentially displayed every time R/O ADV is pressed. When viewing the time of an event, the presence of a period between the first and second digit indicates that a picture was taken at that event. Record all data then clear the events as described in step 1 above.

Protocol For Labeling Film

Label all film with the date (day/month/year, for example 20 JAN 2003) as well as the camera number in which it is loaded and TrailMaster unit number (*e.g.,* P-3; TM 10), using a permanent marker pen. Record the number of exposures on the data sheet, along with the make and film speed. Once the unit has been set-up, tested and BEFORE leaving the site, remember to note the current frame number of each camera. When film is collected, remember to mark the date of collection (day/month/year, for example on the film canister itself, and record the number of exposed frames on the relevant datasheet.

Protocol For Labeling Batteries

Write the date (day-month-year) on each battery when first installed. Since much of the world uses "day-month-year" while Americans use "month-day-year," we need to spell out the month in words (*e.g.* 14AUG02), and record on the datasheet. Do not use low quality batteries in the TrailMasters; rather only install the Duracell's provided from the U.S. Verify the voltage is at least 1.5v.

The date will enable us to determine how long batteries last under different conditions (*e.g.,* winter versus summer). TrailMaster may last up to 8 months on high quality batteries. Thus, please check battery voltages periodically (after 2 months of use) during winter and 4 months during summer.

Summary of TrailMaster 1550 Settings & Camera Layout

<u>Receiver</u>:

On	=	3 pm – 11 am
Delay	=	0.1 (6 seconds)
Pulse rate	=	5
Password	=	1234 (for example)
Height of beam	=	40 cm (16 inches)

<u>Cameras</u>:
Setup according to Figure 6 (Chapter 4).
Each camera loaded with film and the date imprint is selected.

<u>Field Supplies</u>:
TM (receiver, transmitter, 2 cameras with 2 cables, 1 multi-trigger unit with cable, camera tripods, batteries & film)

Tape measure
Black permanent making pen
Screwdriver
Duct-tape
Data forms (set-up and activity record)
Spare camera batteries
C cells

Film (ASA 400 or 200 for daytime use only)
Lens paper, brush & cleaning fluid
GPS (for locations)
Compass (to record aspects)
Altimeter (for altitudes)
Pens and pencils

Important Notes

- Ensure that Receiver and Transmitter do not face directly into the early morning or late afternoon sun (since it generates infrared signals that will trigger the TM). The receiver is best placed facing toward the north, with the transmitter southward (rather than directly east or west). If necessary, shield the detectors behind a rock, ridge or cliff face. Ideally, place the transmitter and receiver at about 40 cm or 18 inches above the ground to better cope with accumulating snowfall. Avoid placing them in areas where snow might drift or collect. The alternative is to visit each site immediately after snowfall to clear the snow. In placing detectors next to a large rock, try to ensure that snow will not melt, then freeze and form icicles in front of the sensor windows (or a camera lens) – these will trigger events!
- Avoid placing cameras so that they point skyward, which is more likely to collect snow and cause them to become obstructed. In addition, make sure that they are shielded from falling snow or rain with a rock cover or "hood", and that there is no ledge upon which snow could collect or obstruct the lens (see picture). Make sure the hood does not obstruct the flash.
- Data forms must be filled out VERY CAREFULLY: review information to make sure that you have recorded your name, date, camera numbers, film frames, any films changes with new film number, presence of tracks, anything which was not working and had to be fixed, addition of any batteries, etc.
- If camera(s) are moved to another site, make sure both the old and new datasheets indicate the relocation!
- Same for film. Make sure it is labeled and the number entered against the correct camera trap station.

CamTrakker Camera Trap Instructions

Appendix 1-B: CamTrakker Field Setup

Initial Camera Setup

1. Make sure batteries are fresh (requires 4 C-cell batteries)
   a Make sure batteries are inserted correctly (negative should touch the spring).
2. Set the red dip-switches for "*Continuous, 20 second camera delay*" as follows:
   a. Switch #1 – "On" (or up)
   b. Switch #2 – "Off" (or down)
   c. Switch #3 – "Off" (or down)
   d. Switch #4 – "Off" (or down)
   e. Switch #5 – "Off" (or down)
   f. Switch #6 – "On" (or up)
   g. Switch #7 – "Off" (or down)
   h. Switch #8 – "On" (or up)
3. Set the correct date and time on the camera
   a. Hold the DATE button down for 2 seconds
   b. Day/Month/Year will flash in sequence
   c. Enter the correct date by using the "Tele" button to increase the number or the "Wide" button to decrease the number.
   d. Select Day/Month/Year to imprint on each picture
4. Load film in the camera
   a. Write the film number on the roll of film and record on datasheet
5. Make sure the camera is ON and place back in unit with the foam and lid
6. Make sure the CamTrakker is OFF (external black push-button on side of unit)
   a. Verify this by removing Velcro tab from front of housing; it should flash red (off) and not green (on) when you pass your hand in front of the infrared sensor

Field Setup

1. *Note*: the infrared sensor is sensitive to direct sunlight; therefore the unit should not be pointed in the direction of early morning or late afternoon sun.
2. The CamTrakker should be setup along the approach to active rock scents or scrape sites and along game trails and ridgelines.
3. The CamTrakker should be placed approximately 3 to 5 meters away from the rock scents. This is a judgment call and user should place camera so that the entire snow leopard will be photographed. See figures 4-6 in Chapter 4.
4. Set up the CamTrakker at the approximate chest height of an adult snow leopard, e.g. 40 cm above the game trail or above the ground where a snow leopard will pass, and about 3 meters from the leopard's anticipated travel pathway.
5. Clear out any vegetation, rocks, etc. that might interfere with or falsely trigger the sensor.
6. After the CamTrakker has been setup at the desired location, test the unit by removing the Velcro patch (camera should be turned on) and walk in front of the unit at the location the snow leopard would walk. A red light on the bottom right side of the unit should light up when you are directly in front of the unit. If the red light does not come on, then re-align the CamTrakker to point at or just below your knees.
7. Once setup is complete, turn the unit on by pressing the On/Off button on the side. The red light should now turn green when you pass your hand in front of the infrared sensor.
8. Replace the Velcro patch.
9. Remember, you will have a short time to get out of the area before the CamTrakker will activate and take pictures after you turn it on, so leave the area quickly.

Fill out a Datasheet for each Camera Station!!

Camera Trap Site Form 1

Appendix 2-A: Camera Trap Site Characteristics

Form Number: ______________________ Date (DD/MMM/YR): ______________________
Site Number: ______________________ Location Name: ______________________
Name of Person(s): ______________________ GPS Lat/Long: ______________________
Elevation: __________ Sensor ID: __________ Camera ID: __________ & __________
If sensors/cameras are moved to new site, list new location here: ______________________

Type of Feature Attracting Snow Leopard:
(Check those items best describing the site)

- ☐ Travel Corridor
- ☐ Rock scents
- ☐ Scrape Site
- ☐ Kill
- ☐ Trail
- ☐ Corral
- ☐ Other (describe):

Trail Type: (Check only one that best describes site)

- ☐ Well defined
- ☐ Moderately well defined
- ☐ Poorly defined or hard to see

Dominant Substrate: (Check only one that best describes site)

- ☐ Rocky
- ☐ Gravelly
- ☐ Sandy
- ☐ Fine grained: (fine silt, loam or dust producing very good tracks)

Snow Leopard Sign Present: (Record all sign present, including number & age within 15 m)

Pugmarks:
Size:
Age Class:

Scrapes:
Number present:
Size:
Age Classes:

Rock scents:
Number present:
Age Classes:

Feces:
Number present:
Age Class:

Prey Sign Present: (List species & sign type):

Position on slope:

☐ Lower ☐ Middle ☐ Upper

Habitat ruggedness:

☐ Cliff ☐ Broken ☐ Very broken
☐ Rolling ☐ Flat or Valley Floor

Topographic Feature:

☐ Cliff ☐ Ridgeline ☐ Hill-slope
☐ Valley Floor ☐ Stream Bed ☐ Scree/boulders

Vegetation Type:

☐ Barren ☐ Grassland ☐ Scrubland
☐ Woodland ☐ Cropland / fallow field
☐ Other (describe):

Rangeland (Grazing) Use:
(Check those items best describing the site)

Seasonal: ☐ Spring ☐ Summer ☐ Winter
Non-seasonal: ☐ Year-round Use ☐ No Use

Human Presence (including herders):
(Check those items best describing the site)

☐ Daily ☐ Several times/week
☐ Once a week ☐ Once a month ☐ Rarely visited

Draw a brief diagram of the site:
(Include sensor and camera locations)

Camera Trap Site Form 2

Appendix 2-B: Form 2 - Camera Trap Site Monitoring

Use this form when checking for visitations

Form Number: ______________Link Data Number: ______________

Information to be recorded during each visit ☐ **TrailMaster** ☐ **CamTrakker**

Site Num-ber:	Set-up Form No: Location:			Camera Numbers:	Film Roll Number:	Set-Up Time: Set-Up Date: Date Ended:
Date Checked	**Name of Person(s) Checking**	**Frame & Event #'s**	**Sign Present**	**Type & Age Class**	**Pugmark mea-surement & tracing no.**	**Comments**

Settings:

TrailMaster: P=_____, cd=_____, Record Times: Time 1=_______to_______, Time 2=_______to_______

CamTrakker: ☐ Continuous, ☐ Day Only, ☐ Night Only ☐ Fast, ☐ Slow Time Delay= _________

Aspect: _________ **Height above Trail:** ____________ **Distance to Trail 1:** _________**Trail 2=**_________

Film: Brand: _________________________ **Speed:** _______ **No. Exposures:** _________

☐ Color or ☐ Black & White ☐ Print or ☐ Slide Film

Other Notes:

Appendix 2-C: Definitions and Data Codes

Scrape Site

Non–relic	0	Usually only one scrape is present at the site or all the scrapes (and feces) are about the same age. No evidence of repeated use.
Relic	1	Usually there are numerous (3–10) scrapes present of various ages. Due to remarking, some or most scrapes have a sculptured appearance. Feces of many different ages may also be present.

Type of sign present at site:

Scrape	SC	Scrape made by a snow leopard or other felid.
Scratch (canid only)	SR	Scratch made by a canid.
Feces (scat)	FE	Scat or dropping.
Urine	UR	Urination mark.
Scent spray	RC	Scent mark.
Claw rake	CL	Claw mark made on a tree trunk or rock face and left by a felid
Pugmark	PU	Track impression

Sign age or visibility (by type of sign present):

Scrape

Very old	0	Extensive weathering and disintegration, scrape features poorly defined, often with vegetation growth in the depression and on the pile (age = at least 3 to 6 months).
Old	1	Moderate weathering and disintegration, with the scrape showing a rounded form, occasionally with vegetation in the depression or on the pile (age = several months or more).
Fresh	2	Slight weathering. Scrape has a well–defined form with "sharp" edges, is easily recognizable, and has no new vegetation growing in the scrape depression or pile (age = 1 to 4 weeks).
Very fresh	3	Little or no weathering has occurred, so that the scrape has a very sharp and "clean" form, is very easily recognizable, and has no vegetation in its depression or pile. Sand or gravelly material may cover some vegetation, causing it to "bend-down". Other ephemeral sign such as tracks or urine may be observed, while scats deposited at the same time are obviously still fresh or very fresh (age = less than 1 week).

Pugmark

Old	0	Pugmark is very poorly defined, with an obviously "weathered" appearance (more than 2 weeks old).
Fresh	1	Pugmark has sharply defined edges and shape (several days, but less than one week old).
Very fresh	2	Pugmark is very fresh, showing fine surface details and having a very sharp edge (made less than 24 hours previously).

Feces

Old	0	Scat is mottled and cracked, with a hard, dull surface and dry interior (several weeks to several months of age).
Fresh	1	Scat is odoriferous and "fresh-looking", with a glossy, sheen inside (more than 2 days but less than 10 days of age).
Very fresh	2	Scat is still wet outside and moist inside (no older than 2 days).

Scent-sprayed Rocks

None	0	No detectable odor (more than 3 months old).
Slight	1	Odor is just detectable.
Moderate	2	Odor is readily detectable.
Strong	3	Odor is unmistakable.
Very strong	4	Odor is very strong (can be detected from 25 cm or more away; less than several weeks old).

Substrate type:

Rock	1	Ground surface consists largely of rock.
Sandy soil	2	Sandy appearance with particles having a diameter of less than 2 mm.
Gravelly soil	3	Mixture of small pebbles (particle diameter more than 2 mm) and soil.
Fine or silty soil	4	Soil consists of fine or very fine particles (clay, silt, and dust).
Snow	5	Snow dominates.
Vegetation	6	Vegetation dominates.

Pugmark Measurement

Measure the greatest length & width of the overall print as well as the width and length of heelpad. Note whether the print is right or left and whether it is a fore- or hindpad (forepad is larger and more rounded than hindpad). The best way to tell left from right feet is to look at the position of the leading toe: if it is on the right, one is looking at the left foot; if it is on the left, you have the right foot. Also, there is a tendency for the cat to point its foot toward the center of the body when walking.

Example of Completed Form (showing results of 2 check-up visits)

Appendix 2-D: Example of Monitoring Form

Use this form when checking for visitations

Form Number: ______1______ **Link Data Number:** ____________

Information to be recorded during each visit ☒ **TrailMaster** ☐ **CamTrakker**

Site Number: 2004-H3	Set-up Form No: Location Husing, middle gorge			Camera Numbers: TM-11	Film Roll Number: 05-11-1	Set-Up Time: 1345 Set-Up Date: 03 Jan 2005 Date Ended:
Date Checked	**Name of Person(s) Checking**	**Frame & Event #'s**	**Sign Present**	**Type & Age Class**	**Pugmark measurement & tracing no.**	**Comments**
18 Feb 05 JD	12 Events	Cam 1: 6 Cam 2: 6	Yes	SC-2, RC-1	N/A	New scrape, ~ 4 days old. Rock scent has not been re-scented. Recorded and reset TrailMaster events.
18 Feb 05 JD, RW	65 Events	Cam 1: 21 Cam 2: 21	Yes	SC-1, RC-3 PU-2	6.5 x 8 cm	SL passed through within last two days. Rock scent re-scented. Film nearly used up. Replaced film, labeled 05-11-2.

Settings:

TrailMaster: P=_8___, cd=__0.3__, **Record Times:** Time 1=__0400_to__0700_, Time 2=_1900_to 2200_

CamTrakker: ☐ Continuous, ☐ Day Only, ☐ Night Only ☐ Fast, ☐ Slow Time Delay= _________

Aspect: __220°____ **Height above Trail:** _____40cm_____ **Distance to Trail 1:** __3.2 m___ **Trail 2**=____ N/A_

Film: Brand: _____Fujicolor______ **Speed:** _400___ **No. Exposures:** ___ 24___

☒ Color or ☐ Black & White ☒ Print or ☐ Slide Film

Other Notes: _____

There are 3 scrapes at this site, but they are covered with snow and cannot be seen at the time of set up.

CAPTURE File formats

Appendix 2-E: Example of CAPTURE Input File

Information from the Capture History (Table 4, Chapter 4) must be entered into an ASCII file in the format shown below for analysis by CAPTURE. These data represent the capture histories for 6 snow leopards (labeled 1 through 6), for 9 trapping occasions of 5 days each. Thus, Snow Leopard # 1, an adult male was photographed during 7 of the 9 sampling occasions, while # 6 was only captured once by a camera trap, and then during the last trapping occasion. The input file should be prepared using an ASCII text editor such as Microsoft Notepad.

Capture files can be entered interactively according to the screen prompts provided, or via "batch" files. See the CAPTURE manual for details, which can be downloaded from: http://www.mbr-pwrc.usgs.gov/software/

The file for capture history presented in Table 4 looks as follows(the terms are explained in more detail below):

```
title='Snow Leopard Survey Example'
task read captures occasions=9 x matrix
format='(a5,4x,9f1.0)'
read input data
1 AdM      111011011
2 AdF      011100011
3 Sub?     011010010
4 SubM     000100001
5 AdF      100010000
6 Ad?      000000001
task closure test occasions=1-9
task model selection occasions=1-9
task population estimate occasions=1-9 NULL JACKKNIFE REMOVAL ZIPPEN DARROCH
task population estimate occasions=1-9 MT-CH MH-CH MTH-CH
```

`title='Snow Leopard Survey Example'` (*Title you give to the survey*)

`task read captures occasions=9 x matrix` (*Refers to x matrix format of the data, in this case having 9 sampling occasions for each animal)*

`format='(a5,4x,9f1.0)'` (*Format information needed by software to process the data, where*

- `a5` indicates the number of characters in the ID;
- `4x` the number of spaces between the ID and data, which the program will skip over
- `9` the number of trapping occasions
- `f1.0` indicates single integer or data without any decimal points where 1 = captured during sample occasion, 0 = not captured during sample occasion

`read input data` (*PLACE DATA HERE* – take special care to ensure it is formatted corrected. This is best done in a text editor that adds no special formatting and records characters in their simple ASCII format)

`task closure test occasions=1-9` (*This instructs CAPTURE to run the closure test for all occasions*)

`task model selection occasions=1-9` (*This confirms population estimates will be based on all sampling occasions*)

`task population estimate occasions=1-9 NULL JACKKNIFE REMOVAL ZIPPEN DARROCH`

(*This instructs CAPTURE to estimate populations of the listed models: Null Model (M_0), Heterogeneity Model (M_h), Trap Response or Removal Model (M_b), and the Schnabel Model (M_t) respectively*)

`task population estimate occasions=1-9 MT-CH MH-CH MTH-CH`

(*This instructs Capture to estimate the three models without population estimators, namely Time variation in captures or recaptures (M_{tb}), Time and Heterogeneity Model (M_{th}), and the All Effects Model (M_{tbh})*)

An alternative would be the statement "`Task population estimate ALL`" To get the most appropriate model, the command would be "`Task population estimate APPROPRIATE`"

See CAPTURE User's Guide for Detailed instructions.

The website site operated by the USGS allows one to run data interactively, without downloading and installing the CAPTURE software. Visit: http://www.mbr-pwrc.usgs.gov/software/capture.html

Appendix 3: The Next Generation of Camera Traps

Based on the delay to get film developed while in the field, digital cameras offer an alternate means of obtaining nearly real-time data from infrared camera traps. Unfortunately the current generation models are prone to three major factors that presently limit their efficacy for camera trap surveys (Urs Breitenmoser, personal communication):

- Most manufacturers incorporate automatic shutoff circuitry, thereby requiring the camera to be "reactivated" at short intervals. Subsequent "wake-up" is often slow, as well as requiring considerable energy. The alternative is to use an external battery such as a car or truck-sized sealed lead battery system for maintenance of power.
- Compared to a shutter camera, cheaper digital cameras have a long burst rate, i.e. the time delay between the moment when the shutter is depressed or "triggered" and the time the picture is actually taken. Many store-bought digital cameras have a burst rate of 1-10 seconds, which is too slow for an animal that may be passing through the camera trap quickly; although this is rapidly improving.
- Digital cameras usually do not perform well at low temperature.

There is little doubt that the technology will improve. In the meantime, we offer our thoughts for the ideal system!

3.1 Characteristics of the Ideal Analog and Digital Remote Camera Trap Systems

Analog Unit:

Minimum Features (Price range of $150-300):

- Low power consumption, e.g. should last at least 1 month in the field, and operate down to -20 and over 90 degrees Fahrenheit (-30 to 32 degrees Celsius).
- Preferred battery size "D" cell (current models use a "C" cell which is harder to find overseas).
- Passive infrared & motion sensor trigger, but a active infrared trigger would be preferable even in the most basic unit (current CamTrakker models have a passive trigger).
- All components contained in square waterproof housing that can be rested on a flat rock platform and not only attached to trees as is the case with current models like CamTrakker or TrailMaster.
- Option for imprinting date and time on picture (or recording digitally).
- Receiver should be shielded as best possible from stray infrared interference from the sun.
- Easy to aim accurately (i.e., view coverage through rangefinder).
- Window in top of housing to enable one to determine current frame number.
- Cameras should energy efficient.

Preferred Features (Price not to exceed $400 per unit):

- Active infrared trigger (such as that as used on the TrailMaster 1550).
- Non-volatile memory & battery life of at least 2-4 months.
- Solar panel as an optional power source.
- Insulated housing, allowing unit to operate in conditions down to –40 and well over 90 degrees Fahrenheit (-40 to 32 degrees Celsius).
- Should have a delay setting that allows for a dead period after a picture has been taken.
- Built-in data logger for record date & time of all "events" and if a picture has been taken every time the trigger is tripped (like TrailMaster 1550).
- Capacity to program time of day/night when camera (as opposed to data logger) should be operational (minimum 1 time period, 2 preferred as per TrailMaster 1550).
- There should be a low battery indicator or maybe a voltage readout.
- There has to be an instant response meaning that once the trigger is tripped a picture should be taken immediately.
- Trigger should be usable up to 50 feet, and allow several cameras to be linked using a multi-trigger similar to that of TrailMaster 1550.

Digital Unit

Minimal Features (Cost not to exceed $400 per unit)

- Low power consumption, e.g. should last a month in the field; use of rechargeable batteries; single battery pack (as opposed to 3 packs required by CamTrakker).
- Solar panel as an optional power source.
- Temperature range same as analog model.
- Active infrared trigger (as used on the TrailMaster 1550) – ability to place detector well ahead of camera view field, so unit can power up in time and reduce chances of missing capturing a moving (walking) animal.
- Housing configuration as per Analog unit.
- Camera should be programmable to record data & time picture was taken.
- Receiver should be shielded as best possible from stray infrared interference from the sun.
- Easy to aim accurately (i.e., view coverage through rangefinder).
- Window in top of housing to enable one to determine current frame number.

Preferred Features (Cost not more than $500-600):

- Near instantaneous response, meaning that once the trigger is tripped a picture should be taken immediately (within several seconds at most).
- Lens could feed into a digital storage device such as a Compact Flash card which can be easily exchanged in the field. Too many problems exist when off the shelf digital cameras are used.
- Camera with zoom capability that could be overridden (i.e. set at fixed focus if conditions dictated)
- Temperature range same as preferred analog unit.
- Lens/camera should be easy to aim and setup in the field (bearing in mind one has to use good gloves in cold winter conditions!).
- Should have a delay setting that allows for a dead period after a picture has been taken.
- Date and time should imprint on picture (or digital database).
- Built-in data logger as described for analog unit.
- Low battery indicator or maybe a voltage readout.
- Trigger should be usable up to 50 feet, and allow multi-camera triggering (at least 2 linked units).

3.2 Assessment of Homemade Active Infrared Camera System

Prepared by Jerry Roe and Scott Slattery, Snow Leopard Conservancy

Introduction:

We designed and constructed homemade infrared camera traps for the 2000-2001 field season. The goal was to design a simple to use, easily manufactured, low cost alternative to non-invasively monitor wild snow leopards. We used the TrailMaster 1500 Active Infrared Game Monitor as the basis for our design. Given the harsh field conditions, e.g. intense solar radiation, low temperatures, and heavy snowfall, active infrared monitors have been the most reliable at photo-documenting wild snow leopards. Passive infrared monitors have proven less reliable under these conditions, and are also more complicated and expensive to build. The Snow Leopard Conservancy employs several TrailMaster 1500/1550 Active Infrared Game Monitor each with two Canon 35mm cameras connected via a TM Multi-Camera Trigger II. The cost for one complete TrailMaster setup is just under $900. We estimated that homemade units could be made for less than half the cost, the limiting factor being the cost of the cameras.

Materials and Methods:

We used the Canon Owl SureShot 35mm camera for its weather-resistant, automatic focus, and date/time stamp features. We modified the cameras according to Moruzzi (2000). The reader is referred to York et al. (2001) for an evaluation of the performance of these cameras. A bypass circuit was soldered across the shutter release button and connected to an externally mounted modular phone jack for ease of connection and setup in the field.

The infrared transmitter and receiver were constructed using off-the-shelf electronic components purchased at Radio Shack (Riverfront Campus World Headquarters, 300 RadioShack Circle, Fort Worth, Texas 76102-1964 USA) and Fry's Electronics (Fry's Electronics Corporate Office, San Jose, California). The transmitter consisted of low cost television remote control modified to transmit continuously by shorting a circuit. The infrared LED used with the remote functions by sending a pulsed infrared beam in a wide arc, estimated to be 150 degrees. To compensate for this and to decrease the likelihood of false triggering, a parallel circuit was constructed and two commercially available infrared LED transmitters were mounted within a one-inch long by ¼ inch diameter sections of aluminum conduit. The conduits were mounted in parallel approximately two inches apart inside a 4x3x2 inch plastic food storage container. The circuit board was cut to the size of the vital components and connected to a nine-volt battery. The entire assembly was mounted in the storage container and mounting brackets were externally attached.

The receiver was more complex since it had to perform a series of basic functions. We used a BASIC Stamp from Parallax, Inc. (599 Menlo Drive, Suite 100, Rocklin, California, 95765 USA) to perform these functions. BASIC Stamps are programmable microcontrollers, which use PBASIC digital logic commands similar to DOS-based systems to execute a variety of commands. In this manner we programmed the Stamp to monitor the infrared receiver (purchased from Radio Shack). If the receiver failed to detect a signal from the transmitter for 0.5 seconds, the Stamp sent an electronic signal to the camera, which triggered a picture to be taken. Simultaneously, a two-minute delay clock was initiated to prevent multiple pictures being taken of non-target animals such as domestic livestock. The unit was powered by two D cell batteries, which were enclosed in a separate container similar to the one previously described. The receiver was hardwired to the battery housing and was enclosed in a slightly larger storage container. Approximately 20 feet of twisted pair phone cable with a modular phone jack was hardwired to the unit. This cable could then be attached to control the camera in the field.

Results:

The units were tested under a closed canopy environment within a riparian corridor prior to field use in India. Field testing was successful with only a few apparent false triggers. However, when these units were used in the field to monitor snow leopards in Ladakh, India, the units failed to perform reliably. Within a day the entire roll of film had been exposed due to false triggering. This problem was most likely due to the low quality of the components and infrared solar interference. Although precautions were taken to reduce false triggering, the need to use higher quality, more expensive components proved to be an integral design flaw. The event counter and time zone selection features available on the TrailMasters would require PBASIC programming knowledge. However, these features could be developed in the homemade units. The key problem lies in the availability and power requirements of better quality infrared transmitter and receiver components. The trade off is such that those components that would be more reliable in the field would require a significantly larger power budget, so that battery capacity and expenditure become the limiting factors. Homemade camera traps would probably work reliably within a more controlled environment such as a moderate to completely closed canopy. Alpine habitats, especially at the high elevations of the Himalaya, are subject to nominally higher levels of solar radiation, which are easily reflected by bare rock, snow and ice.

Recommendations:

Homemade passive or active infrared camera traps potentially represent a viable alternative to the more expensive commercially available models; however, a detailed understanding of basic electronics is required. Our units proved reliable under controlled environmental field conditions, but were not effective in open canopy environments. However, we were able to construct simple, low-cost homemade units that could be fabricated for use in controlled environments when presence/absence information is needed.

References:

Moruzzi, T. L. 2000. Surveying Carnivore Distribution in Southern Vermont Using Remotely Triggered Cameras. Master of Science Thesis. University of Massachusetts. February.

York, Y.C., T.L. Moruzzi, T.K. Fuller, J.F. Organ, R.M. Sauvajot and R.M. DeGraaf. 2001. Description and evaluation of a remote camera and triggering system to monitor carnivores. Wildlife Society Bulletin 29(4):1228-1237.

Camera Manufacturers, Maps, GPS tools & Capture Analysis Software

Appendix 4: Resources for Camera Trapping

Note: URLs may change when websites are updated. If so, we recommend that you search for it on a web browser such as www.yahoo.com or www.google.com. The URL prefix http:// is assumed.

The Snow Leopard Conservancy does not endorse nor in any way guarantee any of these products.

4.1 Camera Manufacturers and Websites (adapted from Henschel and Ray, 2003)

The following website offers a detailed description for many cameras, but it is clearly targeted at the needs of the hunter rather than the biologist: www.jesseshunting.com/reviews/gear/category6

For information on the 3 or 4 makes that are most often or widely deployed in wildlife photo-trapping studies, we suggest the following:

CamTrakker - passive infrared motion detector; 35 mm and digital cameras (see Table 14) www.camtrakker.com

Crow Systems – design and manufacture custom field research electronics: www.crowsystems.com/cameras.htm

TrailMaster – offer trail monitoring systems for field researchers, photographers & hunters. Active and passive infrared monitors and a remote trigger video trail monitor (See Table 14 for TM 1550) www.trailmaster.com

Non Typical DeerCam Game Cameras - target hunters, passive sensor records events and allows for setting camera activation times (see Table 14) www.nontypicalinc.com

Stealth Cam Game Cameras - target hunters www.stealthcam.net

Some other remote camera makes are:

Highlander Photosentry: target hunters. www.highlandersports.com

Moultrie Got-cha: www.moultriefeeders.com

Trail MAC digital and 35 mm camera models www.trailsenseengineering.com

Trail Timer - Game Monitors; also have a system that lets you use your own camera www.trailtimer.com

Vigil - Trail Infrared Monitor www.roc-import.com/gb/monitor/index.php

4.2 Homemade Camera Traps

Hag's House: a web site dedicated to homemade cameras and sensors, with a forum for questions and answers: www.hagshouse.com/Hags%20House/My%20Sensors.htm

The Home Brew Game Trail Camera Project: web site providing instructions on how to build your own camera trap: www.jesseshunting.com/site/homebrew-cams.html

Field Pix Game Camera Systems: offers entire systems, partial systems, or just circuit boards for those who wish to build the camera themselves www.fieldpix.com.

PixController: electronic circuit boards for 35 mm Cameras, electronic shutter control of Digital Cameras, and Video Camcorders. swarnke.sasktelwebsite.net/pixcontroller.html

4.3 Analytical Software

The programs CAPTURE and PRESENCE can be downloaded free from the web at the site of the USGS Patuxent Wildlife Research Center, Laurel, Maryland:
www.mbr-pwrc.usgs.gov/software.html

The software CAPTURE, MARK, JOLLY, JOLLYAGE, etc. and the out of print Wildlife Monograph of Otis *et al.* (1978) are available from the Web Site of Gary White at Colorado State University, Fort Collins, Colorado. The site is maintained by Gary White who also maintains the MARK list server discussion group at the Colorado site that deals with capture-recapture issues:
www.cnr.colostate.edu/~gwhite/mark/mark.htm

4.4 Maps and Satellite Imagery for Snow Leopard Areas

Topographic Maps at scales of 1:50,000 to 1:250,000 are critical tools for undertaking snow leopard surveys. Unfortunately, most range-country governments greatly restrict their use or distribution, making it very difficult even for national residents to get maps unless they are employed by the government or are able to obtain the necessary clearance. Clearly, such policies are out-of-step with this age of satellites and digital mapping, and serve more to hinder the progress of conservation and management of natural resources than protect information deemed as a national secret.

With the dissolution of the Soviet Union, good quality topographic maps have become widely available, and may be of value where in-country topographic maps are not available. The Russian maps range in scale from 1:100,000 to 1:1,000,000, and are now available for many, but not all areas. They cost from about $75 to $100 or more per map sheet, and can be provided as images (tiff files) or geo-referenced images which can be imported into GIS (Geographic Information System) software such as ArcView and ArcGIS™ trademarks of ESRI, considered by most as the world leader in GIS software and web-mapping applications (www.esri.com). However, there are many other good products on the market.

A few sites offering Russian maps for sale are:
FourOne Ltd. Mostly 1:200,000 scale. www.fourone.com/cn/cnkm1000.htm
Omnimap. www.omnimap.com/catalog/russia/
EastView Maps: To get a more detailed idea of what is available for your area of interest, we recommend you visit their website by visiting the following link. www.cartographic.com/products/topographic/overview.asp

Some university and public libraries also carry hardcopy or digital versions available to registered users. For example, the University of California, Berkeley carries many of the Russian maps series:
www.lib.berkeley.edu/EART/topo.html

Some companies may offer available off-the-shelf digital geospatial data sets, known as DEM's or Digital Elevation Models, or have the ability to build custom DEM's based on customer requirements from the in-house base map collection. For example, see the URL to EastView maps: www.cartographic.com/data/geospatial/catalog.asp

With the advent of the global 90 meter resolution Shuttle Radar Topographic Mission (SRTM) DEM data (yet incomplete pending release of the African and Australian continents) and Global Land Cover Facility (GLCF), finding DEM data and satellite image overlay material has become much easier. However, the supply of global topographic maps has remained virtually the same: the availability (of free data at least) is poor, quality varies, available maps are expensive, and it is not clear where to go to get what you want. In fact, if it had not been for the release of large quantities of Russian topographic data sets about ten years ago, this data would not be available for much of the world. There are virtually no low-cost datasets covering snow leopard habitat, at least at the time of writing.

Another option involves charts developed for pilots, but these are very coarse scaled, and able only to indicate topography at a gross scale, which may help in delineating potential areas for surveying. The most widely used maps are the Air Navigation Charts prepared by the US government at scales of 1:500,000 or 1:1,000,000. The URL is:
geoengine.nima.mil/geospatial/SW_TOOLS/NIMAMUSE/webinter/rast_roam.html

The Tactical Pilotage Charts are 1:500,000 scale maps that are nominally meant for air navigation purposes. Since one of the primary responsibilities of the air navigator is to avoid flying into the ground, this type of chart features topographical information, as well as showing the location of major towns, roads, railroads, and other ground features that would be visible from the air. As a result, they make acceptable low-resolution general purpose topographical maps, particularly when nothing else is available. Although they lack the detail of higher-resolution Russian topographical maps, TPC's are valuable for showing snow leopard areas at a regional level.

To access these maps, enter the Geospatial Engine and check the 'TPC' check box under the 'NGA Coverages' tab. (also see www.terrainmap.com/newsinfo.html)

Satellite images:

A number of companies sell satellite imagery at resolutions of 1-30 meters. Not cheap, with prices ranging up to $22 per square kilometer for the latest high resolution images.

The following provides URL's to a few examples of commercial and government data sources:

Earthsat (now MDA Federal): www.mdafederal.com
EarthExplorer map service: edcimswww.cr.usgs.gov/pub/imswelcome/
Antrix Corporation Limited. www.antrix.org
Space Imaging, Inc: www.spaceimaging.com
Digital Globe, Inc: www.digitalglobe.com
Spot Image Corporation: www.spot.com/html/SICORP/_401_.php

Several snow leopard range countries, such as China and India have their own satellite imaging capabilities:
India's National Remote Sensing Agency. www.nrsa.gov.in
National Remote Sensing Center of China: www.nrscc.gov.cn/english/about.asp

Google Earth 3D Mapping Software: Google recently launched *Google Earth*, free software capable of producing remarkably high-quality world-wide 3D images of our globe. After logging on to the "Earth imaging" site (see below), users point and zoom to anyplace on the planet they wish to explore. Satellite images and local facts zoom into view, local points of interest and facts are available via online searches, and one can even view driving directions or fly along designated routes between two or more points.

We believe that Google Earth offers an extremely useful tool for helping identify and evaluate survey areas, planning travel routes, surveying logistics, and generating hardcopy satellite imagery maps of areas of interest to share among survey partners. The program requires a fast computer, a 3-D graphics card, a 1024x768 (or better definition) 32-bit true color screen, Windows 2000 or XP operating systems, and a download or network speed of at least 128 kbps (i.e., "Broadband / DSL or Cable Internet"). Macintosh and Linux operating systems are expected to be supported in the future. For further information, and to download the necessary software, visit: www.earth.google.com/earth.html.

NASA's *World Wind* allows any user to zoom from satellite altitude into any place on Earth, leveraging high resolution LandSat imagery and Shuttle Radar Topography Mission (www2.jpl.nasa.gov/srtm/)or SRTM elevation data to experience Earth in visually rich 3D, controlling your navigation using two button mouse. *World Wind* is designed to run on recent PC hardware with 3D acceleration. It can display a spectacular true-color image of the entire Earth at 1 km per pixel resolution as seen on NASA's Earth Observatory, Blue Marble. For more detail, zoom into Land Sat 7 imagery from 1999-2003 at an impressive 15 m per pixel resolution. *World Wind* (45 MB) can be downloaded from: worldwind.arc.nasa.gov/index.html

4.5 GPS Units:

GPS (Global Positioning System) are useful tools for recording precise locations on earth by triangulating with a system of 24 satellites in high earth orbit. Data captured using GPS units can be imported into a GIS, which provides spatial analysis capabilities of field data and make the computation of effective area trapped easy. There are numerous manufacturers, and here we only list three of the largest and most widely recognized manufacturers. You can always "Google" if you are interested in other companies making GPS's. The Federal Aviation Administration offers a good description of GPS basics: gps.faa.gov/GPSbasics/. Also GPS World offers a brief explanation of GPS and provides several links to online tutorials: www.gpsworld.com/gpsworld.

Currently available topographic maps of the Himalayan region are large scale at best. GPS allows for precise mapping of spatial locations in the absence of small scale field maps and high resolution satellite imagery. Depending on the level of precision these units can provide up to centimeter accuracy of data capture and GPS hardware is easily portable and durable. Not only does this equipment allow recording of point, line and polygon data in the field it is also capable as a tracking device in telemetry studies when a GPS device is imbedded in telemetry hardware. Tracking collared animals can be done real time with greater precision. In the United States circadian and social activity of wolves in Minnesota were recorded using GPS telemetry, www.npwrc.usgs.gov/resource/mammals/gpswolf/gpswolf.htm

The main drawback is the high cost ($4,000 or more) of portable GPS devices capable of submeter mapping accuracy. Fortunately, there are many GPS models in the $150 - $500 range that are quite adequate for obtaining locations and other applications associated with remote camera trapping. Examples of GPS Unit Manufacturers include:

Trimble: www.trimble.com
Garmin: www.garmin.com/outdoor
Magellan: www.magellangps.com/en

For information on GPS and their applications:
www.colorado.edu/geography/gcraft/notes/gps/gps_f.html
fwie.fw.vt.edu/tws-gis/wwwsrce.htm

Author Biographies

Dr. Rodney M. Jackson, Founder of the Snow Leopard Conservancy, is the leading expert on wild snow leopards and their high-mountain habitat. Recipient of the 1981 Rolex Award for Enterprise, his pioneering radio-tracking study of these big cats in the remote mountains of the Nepalese Himalaya led to the cover story in the June 1986 National Geographic. He prepared the snow leopard section of the IUCN-World Conservation Union's Status Survey and Conservation Action Plan for Cats, which serves as the definitive document on the needs and opportunities for preservation of the earth's remaining wild cats. He currently sits on the IUCN's Cat Specialist Core Group. He formerly served as Conservation Director for the International Snow Leopard Trust, leading the standardization of snow leopard sign survey methods (known as SLIMS) across the twelve snow leopard range countries. He has trained biologists in survey methods in nature reserves in Central Asia, with much of his attention now focused to taking camera trapping to the community level. The Snow Leopard Conservancy has grown out of Rodney's more than twenty years' experience gained in working closely with rural herders and farmers whose lives are directly impacted when snow leopards prey upon their livestock. His work has been funded by the National Geographic Society, Smithsonian Institution, U.S. Fish and Wildlife Service, U.S. Agency for International Development, Wildlife Conservation Society, WWF, and others.

Rod Jackson (L) and Jerry Roe

Jerry D. Roe: is a wildlife ecologist and cofounder of Nomad Ecological Consulting, and an associate wildlife biologist with the Snow Leopard Conservancy. He holds a B.S. in Conservation Biology and is an M.S. Candidate in Ecology, Conservation and Organismal Biology at San Jose State University in California. His interests include population ecology of snow leopards, non-invasive monitoring techniques, predator-prey relationships, and carnivore ecology. His Master's thesis is focused on the individual identification of snow leopards using distinct pelage patterns. He has nearly a decade of experience as a field biologist in fisheries, herpetology, mammalogy, ornithology and entomology. His diverse background combines field experience with a comprehensive understanding and knowledge of the regulatory laws and policies relating to natural resources, endangered species management and land stewardship. He has designed and conducted various scientific-based studies employing standard sampling methods for fisheries, botany and wildlife, and has managed several large-scale projects for private, public and non-profit sectors.

Rinchen Wangchuk

Rinchen Wangchuk: is Field Program Director of SLC- India, a locally registered charitable trust established to carry SLC's philosophy and projects forward in this important snow leopard range county. Based in Leh, Ladakh, Rinchen works closely with livestock herding communities to predator-proof nighttime corrals. He trains local people, especially women and young men, in ways of enhancing their income generation skills in activities closely linked with the conservation of snow leopards, and assists local non-government organizations build capacity for protecting India's rich mountain biodiversity. Rinchen is responsible for rural tourism initiatives under an acclaimed UNESCO-sponsored project that enabled SLC and its partners to launch the popular Himalayan Homestay program. Rinchen's commitment to working for the welfare of wildlife and rural people has grown out of his own Ladakhi village upbringing and his experiences as a skilled mountaineer and more recently, a nature tour guide. With fellow Indian climbers, he summited the 24,660 foot Saser Kangri II in Ladakh's Nubra region. He received special training in community-based tourism from The Mountain Institute (Nepal) and RECROFT (Thailand). Rinchen also assisted researchers to develop the Earth Watch program, "Land of the Snow Leopard." He has served as a naturalist and assistant on several documentaries filmed in Hemis National Park, including the widely acclaimed "Silent Roar: Searching for the Snow Leopard."

Don Hunter

Dr. Don O. Hunter: is an ecologist with the U.S. Geological Survey, Fort Collins Science Center. He received his doctorate in Ecology from Colorado State University. His career has taken a dual track over the past twenty years as both a technologist and research ecologist. Currently, he oversees a team of information technology specialists that develop web-based support systems for federal agencies that combine multiple databases and mapping tools (ecos.fws.gov). Dr. Hunter's studies in central Asia focus on mountain biodiversity conservation and collaborative research on the endangered snow leopard. His work with snow leopard in central Asia compliments his research on mountain lion in Rocky Mountain National Park. He is a member of the Snow Leopard Network, and has worked with Dr. Jackson in China, India and Pakistan, and in Mongolia on a snow leopard satellite telemetry study.

The Snow Leopard Conservancy is dedicated to community-based stewardship of the endangered snow leopard, its prey and habitat.

Snow leopards are vital components of the biologically rich yet often neglected alpine ecosystems of Central and South Asia. Poaching, declining prey populations, rangeland overuse, competition with livestock, and retributive killing are the main factors behind the species' continuing decline and classification as an endangered species.

The Snow Leopard Conservancy[1] (SLC), established in 2000, was founded on Director Rodney Jackson's twenty-five years of field experience and deep conviction that addressing root causes related to retributive killing and other people-wildlife conflict is key to conservation of the species.

Mountain communities depend heavily upon their livestock for meat, dairy products, wool, transport and fertilizer. But with wild prey depleted through poaching, snow leopards, wolves and other predators must increasingly depend on livestock for their sustenance. Although snow leopards are revered in popular folklore, they are despised by herders for their tendency to enter insecure livestock pens and kill, in a single incident, dozens of sheep and goats - a family's entire life savings. The SLC works directly with remote mountain communities to help them avoid this scenario by protecting the wild prey base and predator-proofing their most vulnerable corrals, so that all snow leopards sharing the same habitat will be protected permanently under strong community-based stewardship.

We link conservation action with improved livelihoods and income generation, working with in-country partners and building local skills essential for community stewardship. We use a highly participatory planning process, Appreciative Participatory Planning and Action (APPA), developed by The Mountain Institute, and that we pioneered for addressing people-wildlife conflicts initially in Tibet. The result is that local people are themselves empowered to change the conflict with wildlife, and become effective stewards of the snow leopard, its prey and habitat. Our approaches to livestock husbandry and income generation lead to communities that see the snow leopard less as a threat and more as a long-term asset - an attitude transformation crucial to protecting the species. SLC's conservation-linked tourism initiatives, including Himalayan Homestays, are perhaps the only ones in the world directly linked to conserving this endangered flagship species of Asia's high mountains (see www.Himalayan-Homestays.com).

Since 2002, SLC's remote camera-trapping has been a vital tool in gathering population data on the cats and at the same time providing a training ground for local people. Improved awareness, expertise, and knowledge of the snow leopard status empower communities with a greater interest and voice in decisions that affect their destiny.

SLC promotes environmental awareness using local language posters, children's books and teacher training to convey the basic principles of the high mountain food web and the snow leopard's place in it, all within the local cultural context.

However, there is no single blueprint for conserving snow leopards across the range. While solutions must be grounded in good science and crafted to fit local conditions, threats and other circumstances, the SLC's approach also embraces traditional knowledge and the meaningful participation of all members of each community.

[1] SLC operates within CAT-Cat Action Treasury, an IRS-certified non-profit 501(c) (3) public charity for the conservation of wild cats in their natural habitats. CAT supports projects that have been endorsed as high priority by the World Conservation Union's Cat Specialist Group, operating under the Species Survival Commission.

The Snow Leopard Conservancy designs and implements conservation initiatives according to five guiding principles:

1) Conditional Linkage with Biodiversity Conservation:

Project investment or activities must be closely linked with snow leopard conservation in ways benefiting the many other plants and animals which share the same space or habitat;

2) Reciprocal Contribution:

All stakeholders are expected to make a reciprocal contribution, within their means, to compliment the support provided by SLC. This may be in the form of cash or in-kind services like local materials and labor, valued using existing market rates;

3) Participatory Planning and Implementation:

Strong commitment to active and equitable participation from all stakeholder groups throughout the life of the project, with due regard to ethnicity, economic status and gender, to the benefit of all households. APPA builds upon the community's successes rather than highlighting it weaknesses, a process which better ensures projects are environmentally compatible, economically feasible and culturally appropriate, and equally importantly, locally owned and sustainable;

4) Assume Responsibility:

The beneficiary community must assume all or significant responsibility for maintaining any infrastructural improvements provided, including keeping the improved corrals in good condition; and

5) Monitoring & Evaluation:

Stakeholders must be willing to employ simple but realistic Indicators of Success for measuring project performance and impact, according to a mutually-agreeable Monitoring and Evaluation Plan that is part of the overall project Action Plan.

SLC's collaboration with other organizations is a highly effective way of stretching donor dollars and avoiding duplication of effort. The SLC has worked in China (including Tibet), Bhutan, Mongolia, and Tajikistan. We currently have projects in India, Pakistan and Nepal.

'The Snow Leopard Conservancy's realistic approach is imaginative and essential, and given the extensive experience upon which it is based, offers a solid prescription for success.'

George B. Schaller
Director of Science, Wildlife Conservation Society

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