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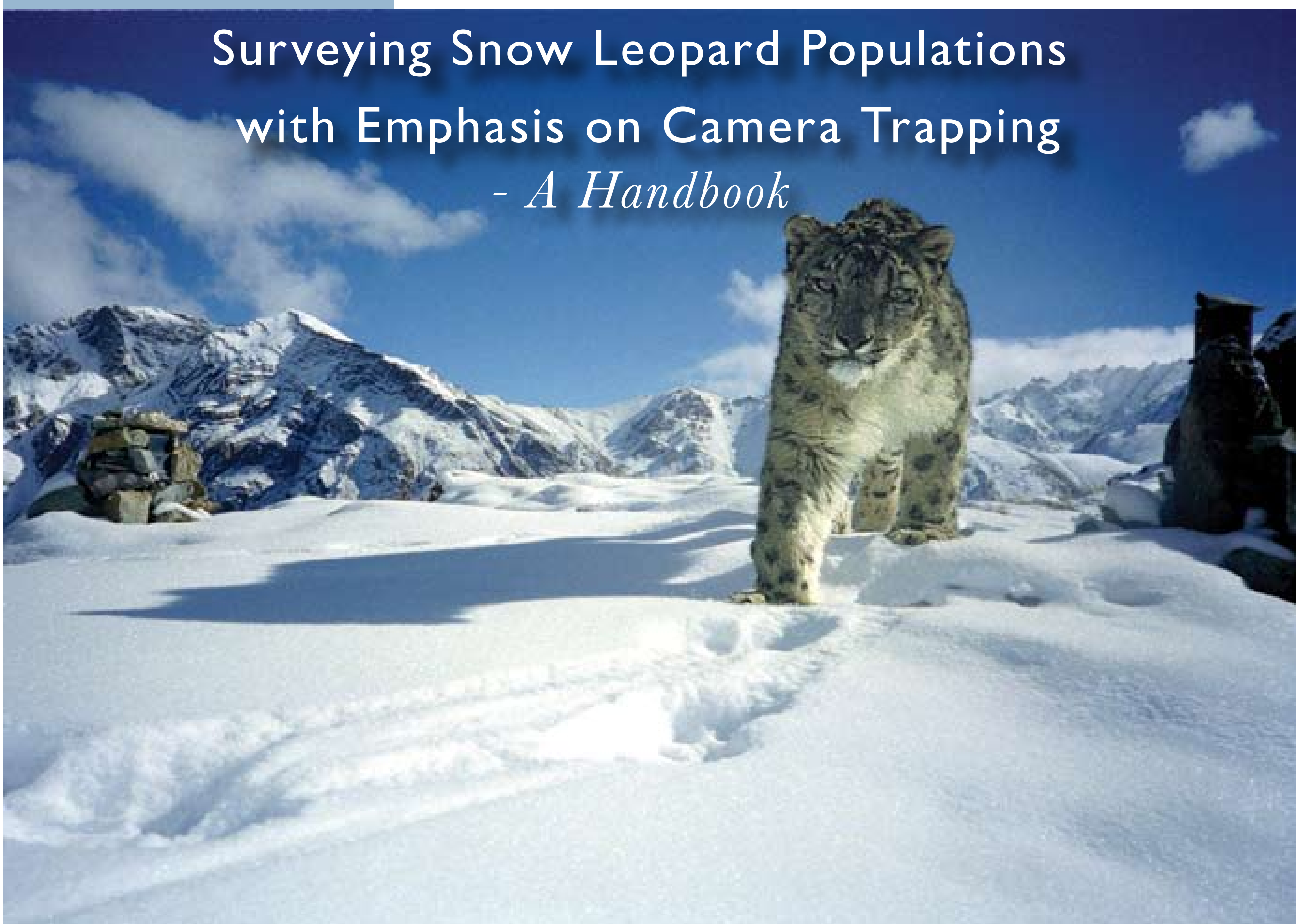
Surveying Snow Leopard Populations with Emphasis on Camera Trapping

- *A Handbook*



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SNOW LEOPARD CONSERVANCY

VERSION 1

Camera Traps are Effective Tools in Population Studies

Executive Summary

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 ± 0.22 individuals per 100 km^2 in 2003 to 4.45 ± 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.

Checking a camera trap after a heavy snowfall

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

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.

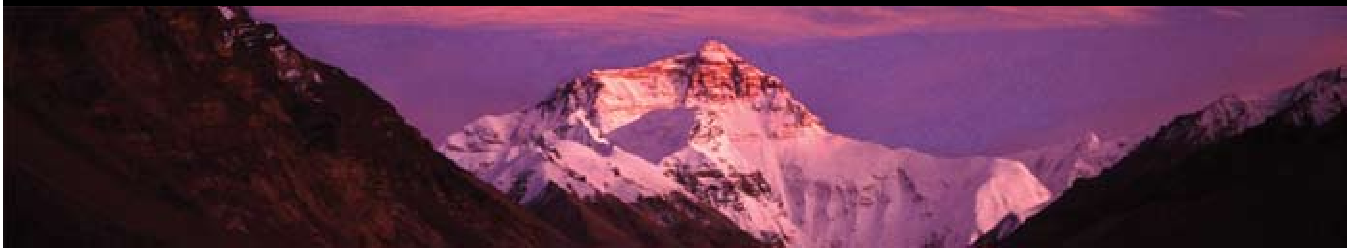
However, in order to generate reliable data for generating spatial projections, investigators must pay special attention to sampling design to ensure surveys are undertaken appropriately and systematically. The first step is to divide the larger area of interest in equal-sized cells of a manageable size, 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.

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

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).

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.

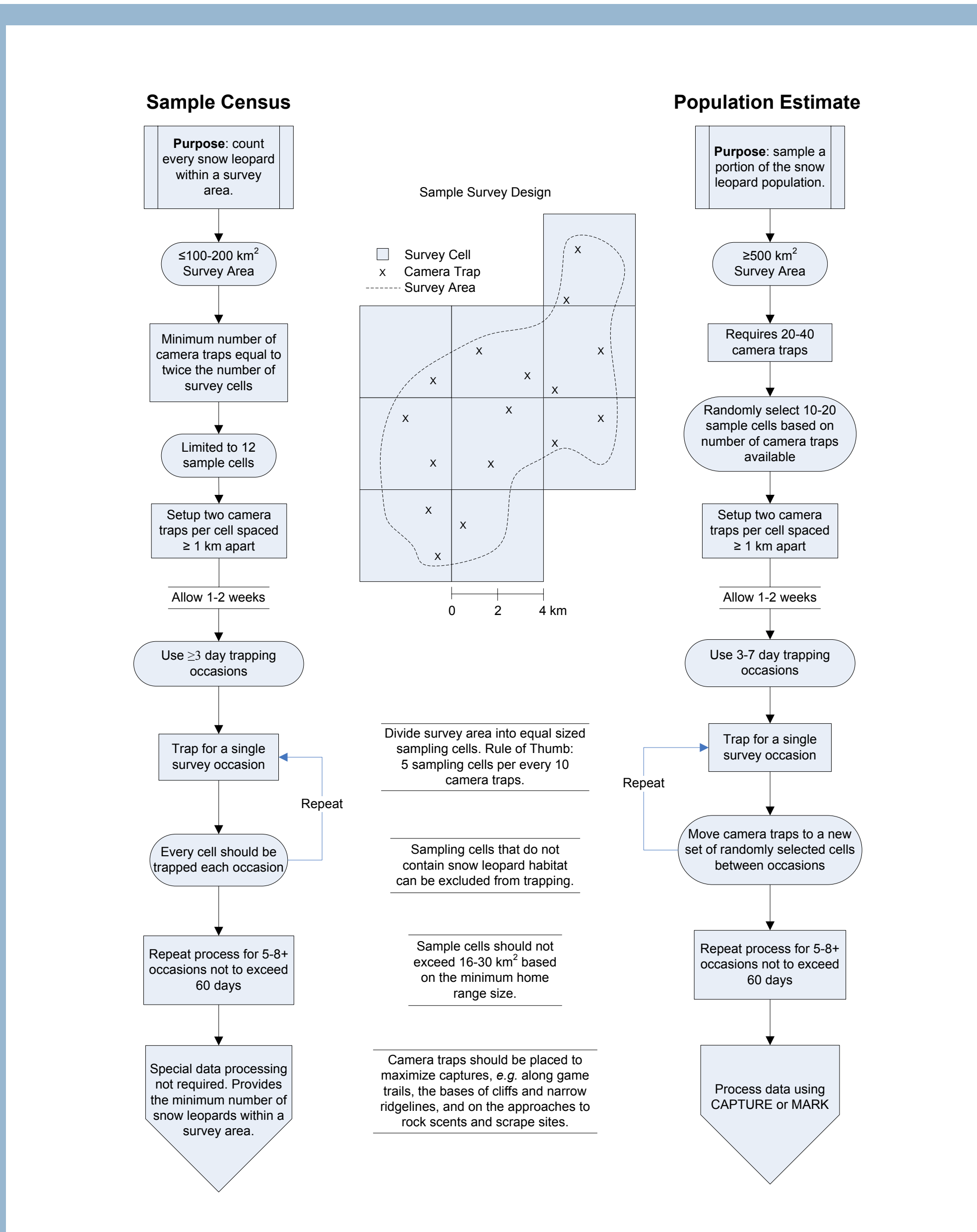


FIGURE 2

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.

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

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).

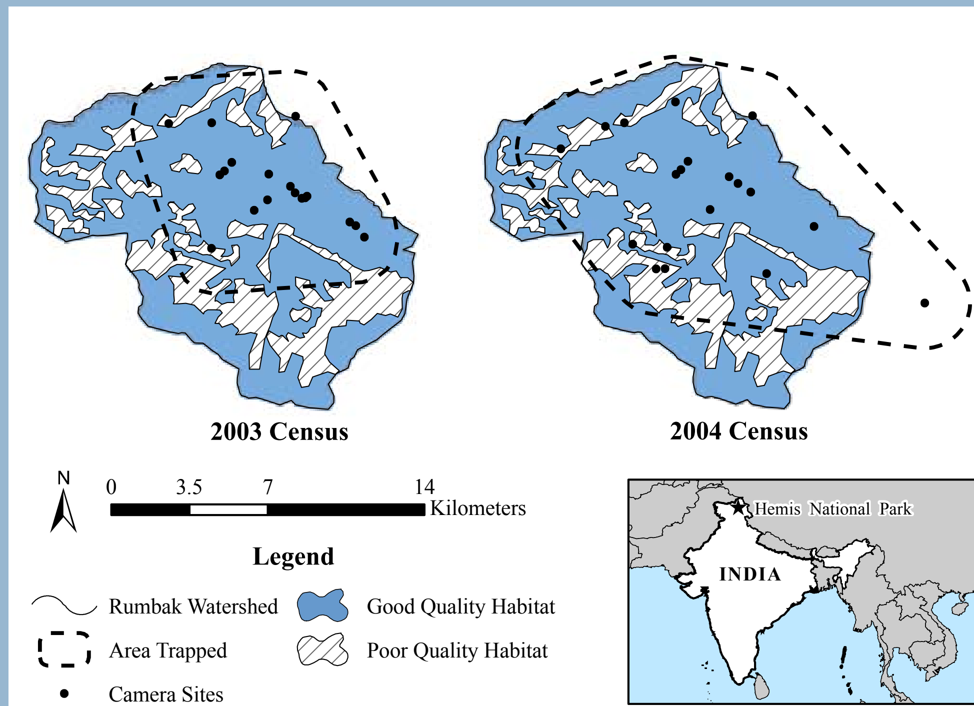


FIGURE 3
Survey area in Hemis National Park showing camera trap layout for the 2003 and 2004 census studies.

4.4 Timing of Camera Trap Surveys:

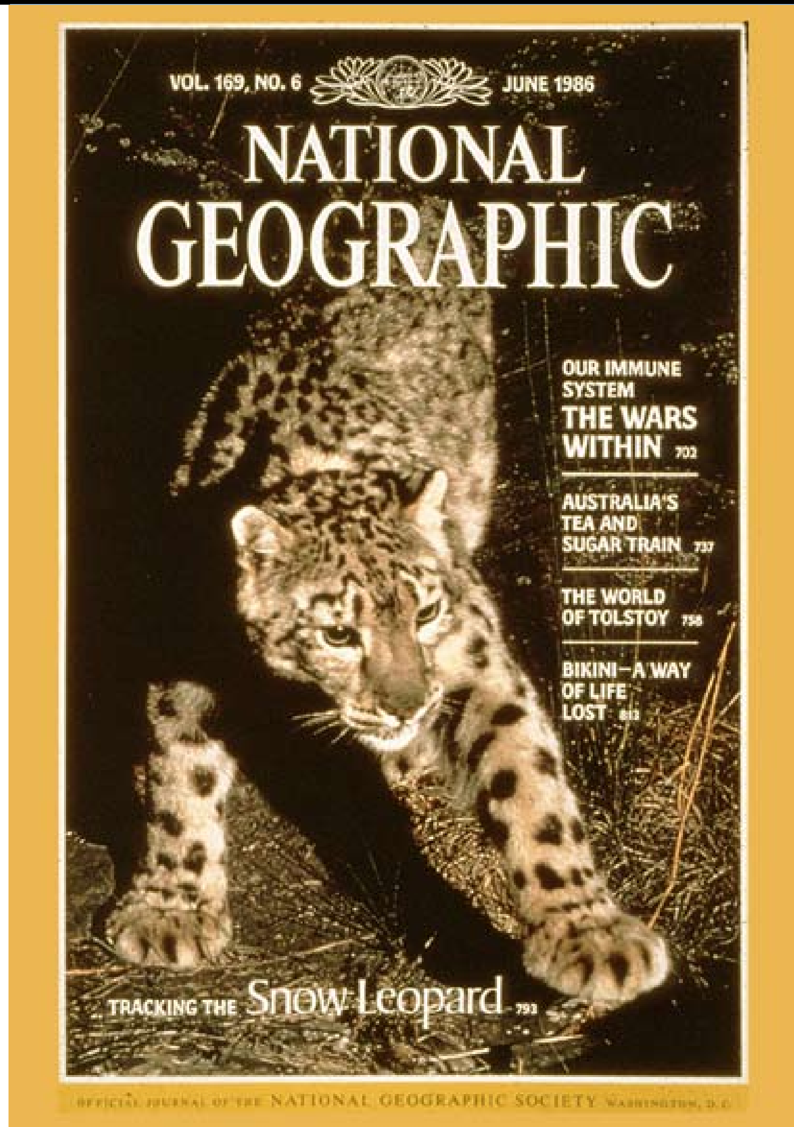
In our experience, camera trap surveys are best undertaken in late winter or early spring following peak snowfall but during mating which occurs from late January through March or early April. At this time (1) snow leopards are usually at lower elevation; (2) disturbance from livestock and attendant 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



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*

-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 windblown 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.

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

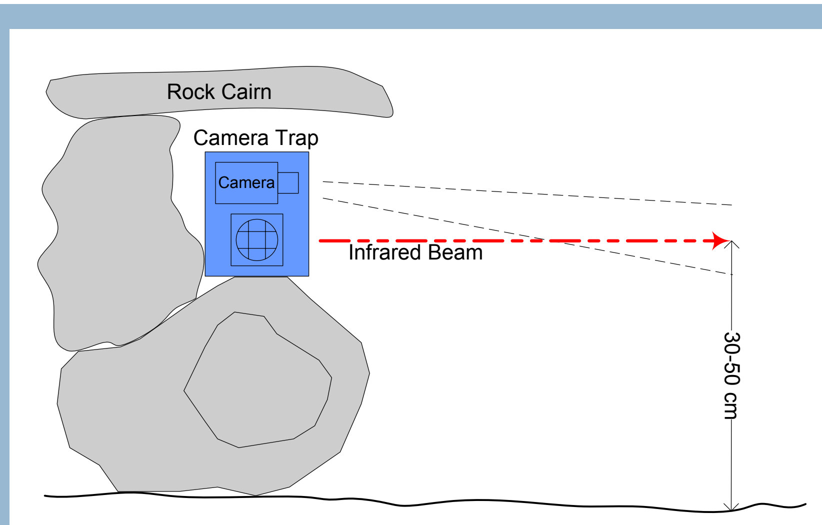


FIGURE 5
Example of a rock cairn to properly elevate, align and shelter a camera trap, e.g. a TrailMaster, CamTrakker or DeerCam. A flat rock or other structure should be placed over the sensor or camera to protect the unit from sun, rain and snow. The infrared beam should be set to intersect the travel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

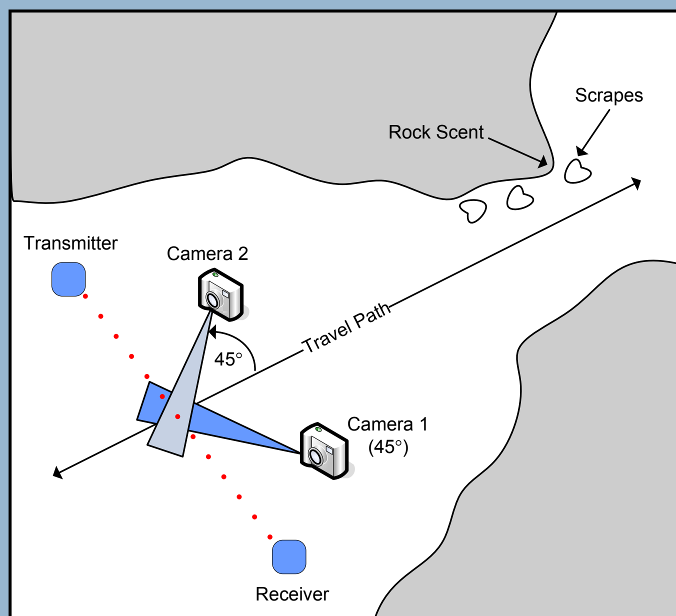
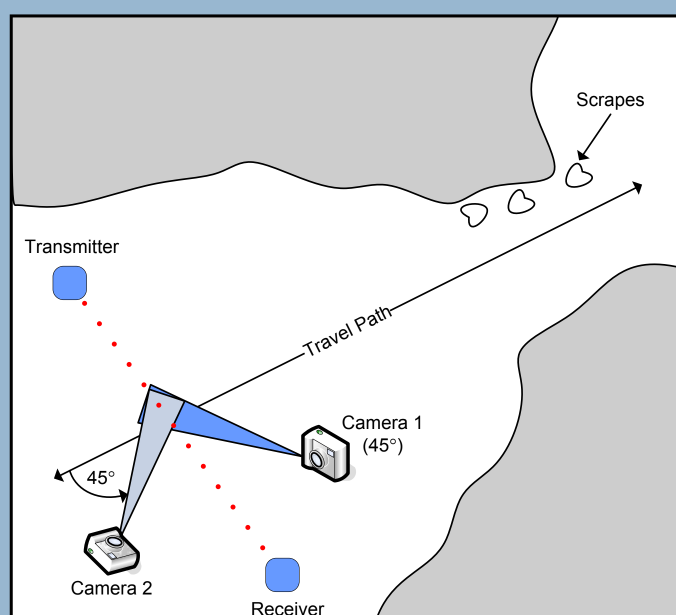


FIGURE 6B

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).

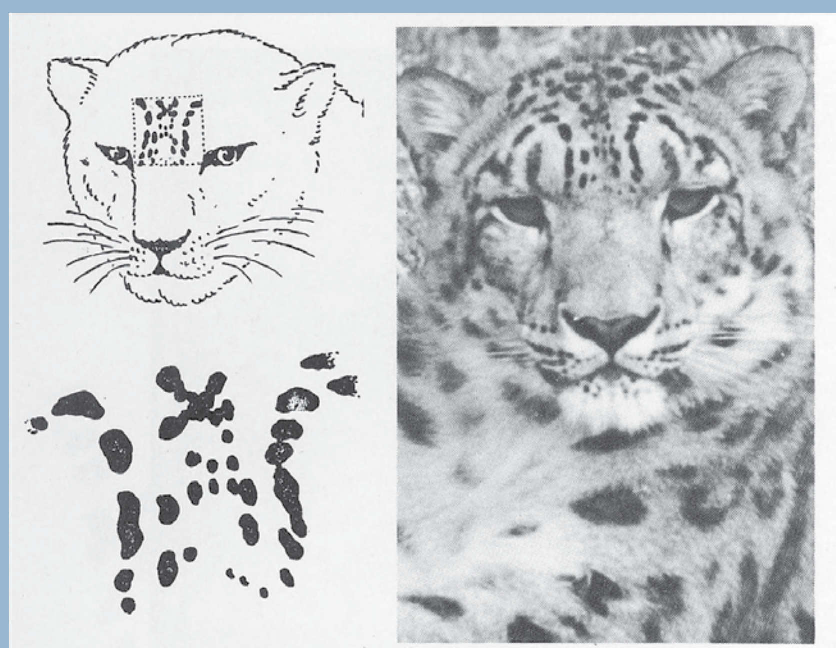


FIGURE 7
Facial Features used by Blomqvist and Nystrom (1980) to Distinguish Individual Snow Leopards in Captivity.

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

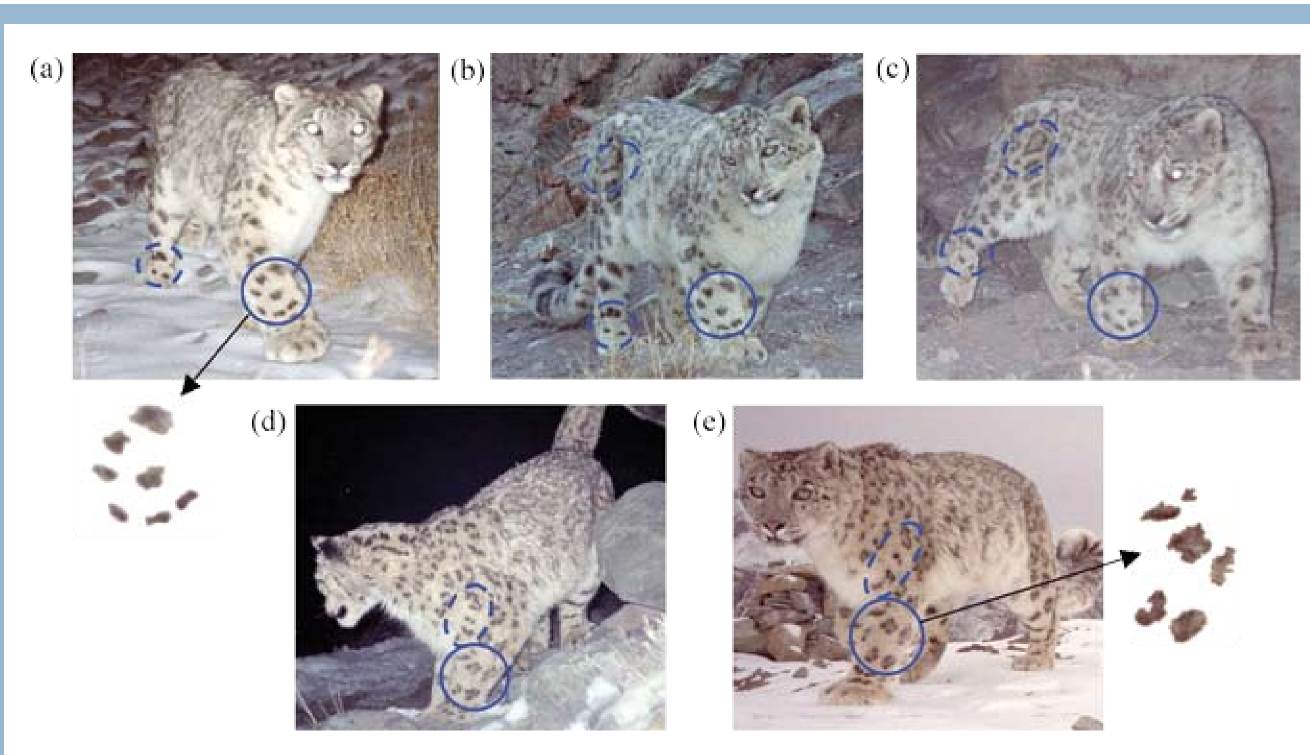


FIGURE 8
Example of identification of two separate individuals based on pelage patterns; snow leopard HNP-1 (a, b, c) and HNP-3 (d, e). All photographs were taken at different trap stations on different days. Solid blue lines indicate "primary" features and the dashed lines indicate "secondary" features. 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.).

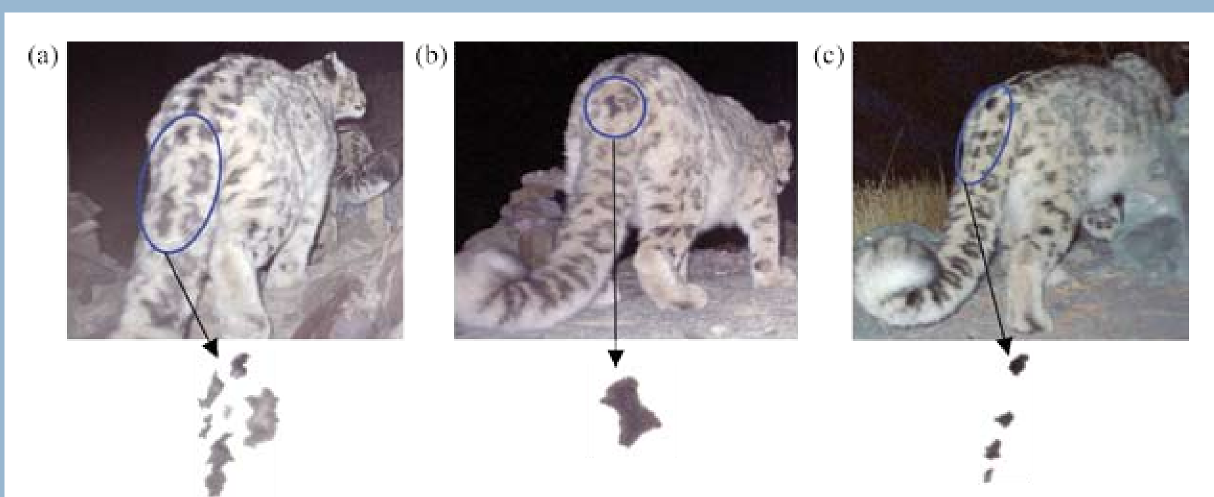


FIGURE 9
Example of distinct pelage pattern(s) on the dorsal surface of the tail of three different snow leopards, HNP-1 (a), HNP-5 (b) and HNP-7 (c). Useful markings may consist of an individual spot (b) or localized groupings of spots (c) and/or rosettes (a). It should be noted that some individuals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

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

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 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.

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 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

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, 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. 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.