Global Ecology and Conservation 35 (2022) e02080

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: www.elsevier.com/locate/gecco

Review of field methods for monitoring Asian bears

Michael F. Proctor [a,b,*], David L. Garshelis [a,c], Prachi Thatte [a,d], Robert Steinmetz [a,e], Brian Crudge [a,f,g], Bruce N. McLellan [a,h], William J. McShea [a,i], Dusit Ngoprasert [a,j], M. Ali Nawaz [k], Siew Te Wong [a,l], Sandeep Sharma [a,m], Angela K. Fuller [a,n], Nishith Dharaiya [a,o], Karine E. Pigeon [a,p], Gabriella Fredriksson [a,q], Dajun Wang [a,r], Sheng Li [a,r], Mei-hsiu Hwang [a,s]

[a] IUCN SSC Bear Specialist Group
[b] Birchdale Ecological, PO Box 606, Kaslo, British Columbia V0G1M0, Canada
[c] Cohasset, MN 55721, USA
[d] WWF India, 172 B, Lodhi road, Lodhi estate, New Delhi 110003, India
[e] WWF Thailand, Pisit Building, 11 Pradiphat Soi 10, Pradiphat Road, Phayatai, Bangkok 10400, Thailand
[f] Department of Natural Resources and Environmental Health, University of South-Eastern Norway, Norway
[g] Free the Bears, PO Box 015, Luang Prabang, Lao PDR
[h] British Columbia Ministry of Forests, Lands and Natural Resource Operations and Rural Development, D'Arcy, BC., Canada
[i] Smithsonian Conservation Biology Institute, Front Royal, VA 22630, USA
[j] Conservation Ecology Program, King Mongkut's University of Technology Thonburi, Bangkok 10150, Thailand
[k] Department of Biological and Environmental Sciences, College of Arts and Sciences, Qatar University, Doha, Qatar
[l] Bornean Sun Bear Conservation Centre, Sabah, Malaysian Borneo, Malaysia
[m] German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Leipzig
[n] US Geological Survey, New York Cooperative Fish and Wildlife Research Unit, Department of Natural Resources and the Environment, Cornell University, Ithaca, NY 14853, USA
[o] Hemchandracharya North Gujarat University, Patan, Gujarat, India
[p] British Columbia Ministry of Forests, Lands, Natural Resource Operations, and Rural Development, 3726 Alfred Ave., Smithers, BC V0J 2N0, Canada
[q] Pro Natura Foundation, Balikpapan, East Kalimantan, Indonesia
[r] School of Life Sciences, Peking University, 100871 Beijing, China
[s] Institute of Wildlife Conservation, College of Veterinary Medicine, National Pingtung University of Science and Technology, Pingtung 912, Taiwan, ROC

A R T I C L E I N F O

Keywords:
Asian bears
Camera-trapping
DNA hair trapping
DNA scat sampling
Expert opinion
Local traditional knowledge

A B S T R A C T

Efficient and effective monitoring methods are required to assess population status and gauge efficacy of conservation actions for threatened species. Here we review the spectrum of field methods useful for monitoring distribution, occupancy, abundance, and population trend for the five species of Asian terrestrial bears. Methods reviewed include expert opinion, local knowledge, bear sign, visual observations, camera traps, DNA-based methods (hair and scat derived), and radio telemetry. We examine the application of each method in terms of realizing specific

* Corresponding author at: IUCN SSC Bear Specialist Group, Canada.
E-mail addresses: mproctor@netidea.com (M.F. Proctor), dgarshelis.bsg@gmail.com (D.L. Garshelis), prachi.thatte@gmail.com (P. Thatte), robtyn@hotmail.com (R. Steinmetz), briancrudge@gmail.com (B. Crudge), brucenmclellan@gmail.com (B.N. McLellan), mcsheaw@si.edu (W.J. McShea), ndusit@gmail.com (D. Ngoprasert), nawazma@gmail.coms (M.A. Nawaz), wongsiew@hotmail.com (S. Te Wong), sandeeps17@gmail.com (S. Sharma), angela.fuller@cornell.edu (A.K. Fuller), Karine.Pigeon@gov.bc.ca (K.E. Pigeon), gabriella.fredriksson@gmail.com (G. Fredriksson), djwang.xiaga@gmail.com (D. Wang), shengli@pku.edu.cn (S. Li), hwangmh@mail.npust.edu.tw (M.-h. Hwang).

https://doi.org/10.1016/j.gecco.2022.e02080
Received 19 November 2021; Received in revised form 27 February 2022; Accepted 28 February 2022
Available online 8 March 2022
2351-9894/

Sign surveys
Telemetry-based population monitoring

monitoring objectives, their assumptions, challenges, and advantages. Our goal is to assist researchers in matching appropriate field methods with sought-after project objectives and to highlight shortfalls and trade-offs. Methods vary greatly in terms of cost, logistics, required number and expertize of staff, and the reliability of the data they provide. Many Asian bear population assessments have relied on expert opinion, local interviews, and sign surveys to provide estimates of distribution, abundance, and trend, in part because these are inexpensive and relatively easy to employ. However, increasing use of camera traps and DNA-based methods now allow for better monitoring via occupancy or rigorous capture–recapture population estimation, with the caveat that these methods may be restricted by inadequate budgets or logistical constraints. For distribution monitoring, camera traps and DNA yield the most definitive records of presence, but in low density bear populations, sign and local knowledge may be more effective. For occupancy, camera traps and DNA are advantageous in providing definitive detections in known time periods. For abundance/density or population trend monitoring in relatively small areas (<10,000 km^2), bears must be individually identified and used in a mark-recapture design. This requires DNA from collections of hair or scat, or a camera-based survey in which natural chest marks are clearly visible and individually distinguishable. DNA-methods or camera traps within individual identification is best for population trend when sufficient funding is available. Alternatively, careful use of local knowledge or expert opinion may be viable options, but come with greater uncertainty. For the foreseeable future, we believe that expert opinion will likely continue to play a large part in monitoring Asian bears, but these opinions should be informed by more rigorous data from the other methods we discuss.

1. Introduction

Monitoring trend in the abundance and distribution of wildlife populations is an increasingly important conservation objective as human influence on habitat and populations intensifies and expands globally (Venter et al., 2016; Theobald et al., 2020). Threats from poaching, habitat loss, and burgeoning human populations are especially severe for bears in Asia. Four of five Asian bear species (Asiatic black bear, *Ursus thibetanus*; sun bear, *Helarctos malayanus*; sloth bear, *Melursus ursinus*; and giant panda, *Ailuropoda melanoleuca*) are designated as Vulnerable on the IUCN Red List of Threatened Species, and range-wide all of these but the giant panda are thought to be decreasing (Swaisgood et al., 2016; Dharaiya et al., 2016, 2020). The brown bear, *Ursus arctos*, is designated Least Concern globally, but many Asian populations are classified as Vulnerable, Endangered, or Critically Endangered (McLellan et al., 2017). Distributions of several species are also generally shrinking and increasingly fragmented in southern Asia. However, much of our knowledge of the status of Asian bears is based on expert opinion rather than empirical data, and in part this is due to a lack of guidance about how to monitor Asian bear species and thus use of methods that do not produce reliable quantitative assessments (Garshelis et al., this issue). Since an objective of monitoring is to detect declines early enough for management action to impact the population, it is useful to review the utility of available methods to meet management objectives.

Ideally, monitoring would be accomplished via periodic data-based estimates of population size or density. Abundance analyses typically require repeated sampling of a population containing individuals that can be identified to inform a mark–recapture estimate with open or closed models (Burnham and Overton, 1987; Schwarz and Arnason, 1996). When repeated over years, abundance estimates can estimate trend, but detecting significant changes in population size can be challenging (Morin et al., this issue). There are also new methods to derive abundance or density estimates from sampling when animals are not individually identifiable (i.e., unmarked; reviewed by Morin et al., this issue). Geographic distribution and occupancy can also be estimated and monitored over time (McShea et al., this issue; Fuller et al., this issue). Distribution estimates utilize verifiable evidence of species' presence over a large sampling area. Similarly, occupancy estimates also use presence data but over a systematic and repeated sampling to estimate detection probability. Neither method requires individual identification. All the above mentioned objectives can inform conservation of threatened species such as Asian bears, be it to assess conservation status and thereby direct attention to populations most in need, or to evaluate responses to recovery actions.

A wide array of field methods have been used to study bear species and to gather appropriate data for monitoring distribution, occupancy, abundance/density, and population trend (rate of change). While advances in field and analytical methods to monitor bear abundance and distribution have proliferated (Lamb et al., 2019), not all are accessible across the globe. To ensure a monitoring program is successful at meeting its objectives (Legg and Nagy, 2006), field methods, analyses, field team expertize, and finances must be balanced within a viable study plan (Anderson, 2001; Reynolds et al., 2010). A method's ability to meet study objectives is of primary importance, but the best method may not always be feasible. Recognizing feasibility in advance will allow expectations and inferences to be modified accordingly; or conversely, more fundraising or field efforts employed to ensure that methods match the objectives.

In Asia, sign surveys and interviews with local people or experts have been the most commonly used methods for monitoring bears, whereas more expensive camera trapping and DNA-based methods are starting to be used more frequently (Garshelis et al., this issue). These more rigorous methods allow for more quantitative analyses, including assessments of error (confidence intervals) and power to detect real changes in occurrence or abundance (Fuller et al., this issue; Morin et al., this issue). As a result of advanced analytical approaches, researchers employing these methods may need to collaborate or hire personnel with the required quantitative skills.

Here we review a range of field methods available for monitoring Asian bears in an effort to assist researchers and managers in choosing methods that best fit their objectives, abilities, and finances. This paper is part of a series of papers born from an Asian Bear Monitoring Workshop held in Taipei, Taiwan in the fall of 2019. That workshop was motivated by the need for improved monitoring methods (both field methods and analytical methods), as presently many populations are thought to be in decline but evidence for this is lacking. Garshelis et al., (this issue) reviewed 102 population studies of Asian bears and found that only 10 over a 20 year period used a rigorous method to estimate abundance or density. Only 2 studies rigorously estimated population trend over time. And although the IUCN Red List designates 4 of 5 Asian bear species as Vulnerable, there have been no rigorous studies of trend that showed a decline in any of these species. Several of the methods discussed here (e.g., camera trapping, DNA-based methods) are well represented in the scientific literature, but they have not been employed effectively by Asian bear researchers. The principal aim of this review is synthesize and explore in depth the wide array of methodological approaches to monitoring, to enable comparisons and evaluation. It is our hope that this review helps move monitoring in the direction of more rigorous efforts, as well as towards a more effective pairing of methods with desired study objectives.

Specifically, we summarize eight field methods (expert opinion, local knowledge, bear sign, visual observation, camera trapping, DNA from hair, DNA from scat, and telemetry) to address four monitoring objectives (distribution, occupancy, abundance/density, and trend) across five terrestrial bear species in Asia (Table 1). We summarize how each field method is implemented, the types of applications it is used for, their underlying assumptions and how they can be achieved, the challenges they present and how they can be overcome, and the advantages and disadvantages of each method. We also discuss where and when each method is appropriate or inappropriate and the objectives and analyses each method can satisfy. We do not discuss study design or analytical methods (these are covered in companion papers in this series), or laboratory techniques, but mention these where they relate to field methods. We stress that new, creative nuances, variations, and applications undoubtedly exist for many methods and imagination and adaptation will help ensure methods can be more broadly and successfully applied. We cover these topics primarily through the lens of Asian bear species and therefore many of our suggestions and solutions to challenges are bear-specific, but our approach and discussion are relevant for other species.

2. Expert opinion

Expert knowledge or opinion is widely used in conservation because of the inherent complexity of systems and issues, paucity of data, and urgent need for decisions (Martin et al., 2012). Experts are presumed to have training, knowledge, or experiences that inform their judgment which is then used to fill in for data that are absent, incomplete, or so disparate that analytical approaches are not possible. Experts' knowledge regarding bears will vary, as will their ability to critically translate that information into a population assessment.

2.1. Applications

Expert opinion is often employed when empirical data are not available. Even if a data-based population estimate is available, that estimate may not inform trend, changing threats, or be representative of a larger area, and it may take an expert to extrapolate temporally and spatially to fill information gaps. For example, the recovery of European brown bears has been monitored in many countries through a combination of expert opinion in combination with more rigorous methods in local areas (Chapron et al., 2014).

Expert opinion is commonly used to create bear range maps (McLellan et al., 2017), identify main threats (Dharaiya et al., 2016), judge direction of population change, estimate rate of population change on a large scale (e.g., country, Garshelis et al., this issue), and project population trend into the future based on knowledge of threats and conservation efforts on the ground. Expert opinion is commonly relied upon for Red List assessments of bears as well as a host of other species (Dharaiya et al., 2016; Swaisgood et al., 2016, 2018; Garshelis and Steinmetz, 2020). However, except for possibly small, isolated and observable populations (e.g., McLellan et al.,

Table 1
Matrix of various methods relative to project objectives for monitoring Asian bears. The species of bear most appropriate for each method is shown in each cell. ABB – Asiatic black bear; BB – brown bear; SB – sun bear; SLB – sloth bear; GP – giant panda. Trend refers to detecting a directional change in population size or measuring growth rate. Costs are relative.

	Objective				
Method	Distribution or Range	Occupancy	Abundance or Density	Trend	Costs
Expert opinion	All+			All+	$
Local knowledge with evidence	All*	All*		All+	$
Visual observation	BB SLB	BB SLB	BB SLB	BB SLB	$$
Sign	All	All		All+	$$
Cameras without Ind ID	All*	All*	Debatable	All+	$$$
Cameras with Ind ID	ABB SLB SB* GP	ABB SLB SB* GP	ABB SLB SB* GP	ABB SLB SB* GP	$$$
Telemetry	All			All	$$$$
DNA scat	ABB SLB* BB GP*	ABB SLB* BB GP*	ABB SLB* BB GP*	ABB SLB* BB GP*	$$$$
DNA hair	ABB SLB BB* GP	ABB SLB BB* GP	ABB SLB BB* GP	ABB, SLB BB* GP	$$$$

(+) best used to detect extreme changes.
(*) denotes methods-species combinations that work particularly well

2017), expert opinion is rarely useful for estimating abundance.

2.2. Assumptions

The main assumption of expert opinion is that the person's experiential judgment is an adequate reflection of reality. It is beneficial to average the opinions of more than one expert. It is generally expected that experts know where bears occur, where they are absent, and that they can detect dramatic changes in distribution or population sizes.

2.3. Challenges

A principal challenge is that the information on which the opinions of experts was based is generally undefined. Consequently, there is often no measure of uncertainty or any way to judge likely accuracy (although see Ayyub [, 2001] for integration of uncertainty outside of Asian bear work). Additionally, there is limited ability to replicate the process in the future, and without other information, no way to determine whether a perceived change in population status is real. Range maps based on expert opinion may change based on the expert consulted, or even if the same expert is informed by new data or new interpretations of old data. Relying on expert opinions can be particularly misguided if opinions are based on scant or unreliable information, are economically or politically motivated, or have other inherent biases. For example, an increase in human–bear conflicts could lead a local expert to surmise that the bear population must also be increasing, but conflicts have been known to increase due to changes in natural foods, irrespective of bear population trend (Johnson et al., 2020). An expert might also be motivated to report a population increase if they were responsible for a program to conserve that species, or might be motivated to opine a large decline if they thought this would help strengthen lagging conservation actions. An 'accessibility bias' arises when an expert has easier access to, or a better memory of a portion of the data, and 'anchoring bias' occurs when an expert has an outdated benchmark such as a population estimate 20 years in the past (Martin et al., 2012). Experts may experience a shifting baseline if they do not notice gradual changes in status or conditions through time, thus continually resetting their view of the benchmark. Experts also may have unwarranted overconfidence, where, for example, they may lack recent experience but are still consulted (Speirs-Bridge et al., 2010). Using multiple independent people who are experts in the same area would be a potential solution to many of these problems, but often the reality is that only one or two experts exist for a given area, or if there are multiple people, they may have different levels of expertize.

There are few cases where expert opinion has been tested in the context of monitoring Asian bears. Moqanakia et al. (2018) found population size 'guesstimates' of rangers in a biosphere reserve in the Iranian Caucasus were 3–5 times higher than the estimate derived from a fecal genetic spatial capture-recapture study. The authors suggested that the rangers' estimate was for a larger area than just the reserve and included some double-counting (different rangers observing the same bears). Also, the high visibility and local concentrations of bears plus increasing damage claims gave the impression of a higher bear density than actually existed. Whereas rangers had first-hand sighting information, they did not integrate potential biases in converting that information to an estimate of population size.

Experts might have a good sense of population trend even if not able to reliably estimate abundance. In North America, most states and provinces with American black bears (*U. americanus*) have at least one bear expert, typically a government biologist. Garshelis and Hristienko (2006) polled these experts and compared their opinions of population trend to the trend observed empirically from a series of population estimates from each jurisdiction. Of those that opined an increasing number of bears (n = 32), data-based population estimates revealed increases in only 59%. This was especially surprising since the experts were aware, or even provided the population estimates and presumably used these when making their assessment of trend.

Mapping bear range is often based on expert opinion. Even in North America where enormous databases on bears exist, the most recent IUCN Red List range map for American black bears was drawn by experts in each jurisdiction without documented presence locations, although experts may have relied on agency databases (Scheick and McCown, 2014). In Asia, range maps drawn by experts may be more suspect because databases of presence locations are uncommon, and it is unclear whether or how the experts used the data. For example, multiple range maps for sloth bears in Bhutan, based on opinions of people with supposed first-hand knowledge, turned out to be wrong when camera trapping showed that the species probably is not resident in the country. Previous sightings were likely misidentified Asiatic black bears (Garshelis et al., 2015). In northeast India, three people, all with confidence and credibility, provided significantly different views on where sun bears existed. Some of the differences were related to how much information they had, but some was also related to different comfort levels or conceptual rules for extrapolating data beyond the known presence points (Garshelis and Steinmetz, 2020). In another example, the range for sun bears in Peninsular Malaysia, drawn by a very experienced expert (producing the IUCN map) was quite different than that estimated by a computer program (Maxent), based on presence locations. The chief differences occurred in areas with no presence data, where the expert and the model differed in their assessment of whether the habitat was suitable (Nazeri et al., 2012). In this case, it seems that the presence locations used to inform the model was biased toward more intact habitats, whereas the expert had a broader knowledge of the kinds of habitats where the species occurred. Conversely, a computer-drawn range map for Asiatic black bears in China that was informed by several thousand presence locations is probably more accurate than that drawn by an expert who used a much more limited set of data and experiences (Shen et al., 2021).

The reliability of expert opinions may be improved by (1) relying on experts that are recognized by their peers; (2) testing their reliability compared to empirical data; (3) documenting the information they used to make inferences; and (4) documenting their reasoning and justification for any conclusions.

Additionally, multiple experts may be useful if they are independent and reliable.

2.4. Advantages

Despite the challenges, there is clearly a place for expert opinion in monitoring Asian bears because empirical information is often inadequate to meet objectives and costly to obtain. In many cases, experts may be able to synthesize information through long, cumulative experiences, combining information that is difficult to quantify. For example, increased human–bear conflicts might occur together with anecdotal observations that natural food supplies remained normal, sightings of bears and bear sign was increasing, and known poachers had been apprehended. It may be challenging (or impossible) to gather and coalesce this type of data that a well-positioned expert may have. Moreover, expert opinion may be developed over decades, providing time for significant understanding of an entire system. In cases where scant empirical data are available, expert opinion can strengthen or modify patterns observed from limited datasets (Murray et al., 2009). In many circumstances, expert opinion can be the only low-cost option available to inform management decisions. In summary, expert opinion from credible experts that are recognized by their peers and that justify the basis for their conclusions may be most appropriate for distribution assessments and population trend when more rigorous data are not available or areas are too large for quantitative assessments (Table 1). Expert opinion should not be ignored when it is available, but it is not a substitute for more rigorous survey techniques just because it is expedient and inexpensive.

3. Local knowledge

Local Ecological Knowledge (LEK) is also opinion-based, but here the opinions are rendered by people who observe their local surroundings but have no formal data or training and no access to scientific literature or species experts. Local knowledge is usually limited to areas where people live, farm, hunt, or collect resources and thus represents sampling of a small area, in contrast to an expert's attempts to coalesce information over a broad area. LEK has the ability to tap into many long-term observers of the natural world, but it must be gathered by an experienced interviewer and assessed by an expert to draw appropriate inferences. LEK can be derived from questionnaires, semi-structured interviews, workshops, and collaborative fieldwork (Huntington, 2000) from people living and working in the habitats that are under study.

3.1. Applications

LEK is increasingly seen as an important source of information for conservation of rare and elusive species (Cano and Tellería, 2013; Turvey et al., 2015; Nash et al., 2016). People whose lives and livelihoods intersect with bears often have first-hand knowledge of bear presence, and may have an opinion as to population trends over some period of time (Hwang, 2003; Ratnayeke et al., 2007; Liu et al., 2011; Steinmetz et al., 2006; Crudge et al., 2016). Whereas other methods can only detect presence and possibly infer absence from non-detection, local people often know not only when bears are present but when they are not, from years of cumulative individual and shared experiences with their community. Likewise, local interviews can be used to gain insights into population trends from the past to present. Local people also can provide context relevant to understanding threats that are likely impacting the population trajectory as well as a way of gauging the reliability of the information provided by the interviewee.

In some instances LEK has been corroborated by more rigorous methods and shown to provide reliable results (Anadón et al., 2008; Ahmad et al., 2021). LEK can, under the appropriate study design, be used for occupancy estimates or distribution studies (Pillay et al., 2014; Crudge et al., 2016) if independent data can be gathered from targeted field investigations for verification or through several interviewees to serve as replicates for estimating detection. Bayesian networks and fuzzy rule-based models are well suited to integrating LEK, as well as expert opinion, with more scientifically rigorous data. These models rely on mathematical theories and probabilistic inference, respectively, to address complex systems, using qualitative data while dealing with uncertainty and imprecise variables (Belisle et al., 2018).

3.2. Assumptions

LEK relies on the assumption that people are knowledgeable about the information being sought and that they provide truthful answers. Further, investigators must ask questions in a way that extracts useful information without influencing how their questions are answered.

3.3. Challenges

The primary challenge of interviewing local people is to sort out what information is definitive and correct, versus misinformation or conjecture. Interviewees may provide erroneous information because their knowledge was incorrect, they misremember, they misunderstood the question, they wanted to appear as though they knew more than they really did, or they intentionally wanted to mislead or at least avoid answering truthfully. Additionally, people's opinions may be highly influenced by a few notable events (e.g., rare sightings). To rely on interviews, one must be cognizant of these avenues of incorrect information, and make efforts to minimize them.

It is important to interview people who are likely to have knowledge about bears. An efficient approach is to ask a community leader to recommend knowledgeable people such as hunters, farmers, and forest resource collectors. It is often beneficial to locate people who have recently given up hunting; they may have useful knowledge but a less-biased opinion, and may be more honest than current hunters, especially if the hunting is illegal. Interviews can also target rangers, forestry officials, military personnel, and others who live and work in bear habitat. Older people with decades of experience are especially valuable sources if the goals include an assessment of past population trends.

It is important to verify that interviewees can distinguish bears and bear sign from other species and, where more than one bear species occurs, distinguish bear species from each other. Bears are generally well-recognized but sympatric bear species are often not distinguished accurately if species-specific information is sought. For example, interviews of park rangers were not reliable for discerning the presence of sloth bears in Bhutan because most people confused them with Asiatic black bears, which were common (Garshelis et al., 2015). Further, in some areas people categorize species differently than scientists. For example, in Thailand, the binturong (*Arctictus binturong*) is regarded as a type of bear. Using photographs of bears to confirm species identification may be of limited value as it may be difficult to relate the image of a bear to the animals or sign observed by the interviewee. Generally, it is useful to ask people to describe the species before showing them photos, to avoid confirmation bias.

Interviews can be conducted one-on-one, or in small groups. The benefit of individual interviews is that information is more independent, so if many people say the same thing, it can be accepted with greater confidence. A benefit of small group interviews is that it may lead to a freer, open discussion where people are talking among their peers rather than to an interviewer. People may be less apt to provide baseless or inaccurate information if they know that someone else in the group is more knowledgeable, but age, gender, and power dynamics may inhibit some otherwise knowledgeable contributors. A free-ranging discussion may jog memories, enhance details, and possibly reduce barriers for topics that might otherwise be uncomfortable to discuss (e.g., bears being killed). Group interviews may also be useful to determine if multiple interviewees are reporting the same observation, in a way that is difficult to achieve in one-on-one interviews.

The spatial extent of local knowledge and observations must be defined, so maps may be a useful part of the interview process; however, in many places, local people may not be familiar with maps, especially the kinds that researchers use (e.g., satellite photo). Liu et al. (2009) used large grid cells (225 km^2) to delineate sampling units across a Chinese province and interviewed people in villages within each cell about the occurrence of bears in the vicinity (applicable to that grid cell). Alternatively, local people can be asked to map the boundaries of the area they refer to, based for example on traditional village resource use, territories, and familiar landmarks such as streams and mountain peaks (Steinmetz et al., 2006; Crudge et al., 2016).

Verifying the integrity of the information is the most difficult challenge. If the purpose is just to ascertain bear presence, then a simple way of confirming this is to ask the interviewee to lead the investigator to a place where bear sign could be found. Using that approach, Liu et al. (2009) found that local people in China were accurate and honest in reporting presence of Asiatic black bears. A more difficult issue arises in trying to confirm absence. This can be accomplished through a number of independent interviews of people who are judged to be knowledgeable of the forest based on other information that they provide, such as other wildlife living there. Additionally, people could bring the investigator to a good patch of forest where other wildlife live, and possibly where bears once lived, so that sign surveys or camera trapping can be used as further evidence of absence (Liu et al., 2009).

Verifying people's opinions of population trend, from past to present, is particularly difficult. The most straightforward situation to confirm would be either the apparent extirpation of bears, or reappearance following a previous extirpation (or very low abundance). Other assessments of population change can be difficult to judge, so it is important to ask how the person arrived at their opinion. The interviewee might mention recollections of bear sightings, sign, conflicts, poaching, or changes in habitat, all of which could really be related to trends in the bear population, but might also lead to misperceptions about the population. For example, local people may judge a population to be increasing because they experienced more damage to their crops lately or if there was a recent bear attack, or may surmise a population to be declining if they recently became aware of more poaching.

People might not answer some questions truthfully for a number of reasons: to preserve a positive self-concept, to avoid disappointing the interviewer, to hide illegal activity, or to show that they can see things foreigners or outsiders are not able to see. Questions about hunting are especially sensitive because bear hunting is illegal in most range countries. Trust can be built by spending time in the village and getting to know people (Hwang, 2003), and by making goals and intentions explicit. Specialized Questioning Techniques (SQT; Nuno and John, 2015) have been designed to allow people to answer sensitive questions more truthfully than they might otherwise feel comfortable. However, often SQT can be cumbersome, raise suspicions (because local people perceive it as trickery), and they generally require much larger samples than direct questioning (Davis et al., 2019; Nuno and John, 2015).

Response biases can be minimized with appropriate surveys designs (Browne-Nuñez and Jonker, 2008; Golden et al., 2013; Nuno and John, 2015); they should not lead the interviewee to answer in a certain way to please the interviewer (Arias et al., 2020), and should not prompt interviewees to speak about topics for which they have no real knowledge. When conducting LEK research, appropriate ethical standards, such as ensuring anominity and confidentiality, must be met to respect the rights of participants (Huntington, 2000). Research institutes and publishers may require ethical approval of survey designs.

3.4. Advantages

The key advantage of using LEK is that, if done properly with unbiased and informed interviewees, the data may represent many years of observation and experience. In that sense, local people can be viewed as long-term "detectors" in the forest habitat, whereas sign surveys and camera trapping (discussed below) are shorter-term detectors. Because bears tend to be rarer, more valuable, and more dangerous than other large wildlife species that they may encounter or hunt, local people may have particularly good memories of incidents with bears (Hwang, 2003). Hence, they may have a good basis by which to judge trends over time (e.g., 1–3 decades), especially if changes have been substantial. At a more modest time scale, interviews have provided reliable information on presence, often supplanting the need for a more costly effort, or at least providing guidance as to where other efforts (e.g., sign surveys, camera trapping) should be conducted. Due to cost-efficiency, interviews may be appropriate for sampling bear presence over large spatial

Table 2
Characteristic Asian bear sign by species that can be used in sign surveys. See Table 1 for species abbreviation used in footnotes.

Bear species	Sign													
	Tree claw marks	Tree social markings (rubs)	Tree nests / feeding platform	Ground nests	Chewed holes in tree	Bark stripping	Scat	Tracks* *	Shallow digs	Deep digs	Excavated termite mounds	Excavated marmot burrows	Broken apart logs	Predation site
Sun bear	1	1	1		1 *		1[#]	1	1	1			1	
Sloth bear	1						1 *	1	1	1	1[^]			
Asiatic black bear	1 *	1	1	1[#]	1[x]	1 *	1	1	1	1			1	1[x]
Brown bear		1					1	1	1	1		1 *	1	
Giant panda	1	1					1 *	1						

*Distinctive for species occurrence
[x] ABB excavate stingless bees in hollow trees while standing on ground, SB chew holes farther up the tree
[^] ABB and SB eat termites, only SLBs create larger holes in big mounds (Fig. 1)
[#] ABB ground nests and SB scat are only used as sign in a few areas
* * Tracks are easily identified except when bear species overlap

scales, as done by Liu et al. (2009) for an entire province of China, and Crudge et al. (2016) for 22 protected areas across Vietnam representing 52% of the country's Special Use Forest. Additionally, interviews with local people can provide an understanding of their attitudes towards bears, human-bear conflicts, and other threats, which may help explain population trends, or may help explain people's perception of population trends (Liu et al., 2011, Ali et al., 2018). In summary, LEK surveys can be appropriate to estimate distribution and significant long-term trends in abundance (Table 1), while also yielding useful contextual data. Although some investigators have used interviews to make rough guesses about bear abundance, especially in small isolated populations (McLellan et al., 2017) these are problematic for any monitoring program, because there is no way to gauge how people made their estimates and no way to ensure consistency over time.

4. Sign

Animal sign, an indicator of local presence, has been used throughout human history for hunting — interpreting animal sign has thus benefited human survival (Laughlin, 1968). Some hunting societies have maintained an ability to count, identify individuals, and reconstruct animal behaviors from sign, especially tracks and scats (Stander et al., 1997). Bears leave unique tracks, their scats are often distinctive (especially bamboo-filled scats of giant pandas, and ant and termite scats of sloth bears), and they create distinctive claw marks on trees or nests in trees that they climb for food or to rest (see Table 2 for species-specific sign, Fig. 1). They also may leave scratches, rubs, and hair on trees that they mark for social reasons. Broken-apart logs, where bears feed on insects, and sloth bear excavations in termite mounds, also are generally identifiable. Bears may create unique types of sign in certain areas, such as the ground nests made by Asiatic black bears in Taiwan (Hwang et al., 2002). Because so many types of bear sign are easily detected and identified, it is not surprising that sign surveys are the most common method employed in studies assessing the status of bears across Asia (Garshelis et al., this issue).

4.1. Applications

Bear sign is an excellent indicator of bear presence and a good way to confirm information obtained from interviews of local people or field staff (Nawaz, 2007; Liu et al., 2009; Islam et al., 2013). Sign is thus useful for mapping distribution (Puri et al., 2015) and, as such, for discerning changes in distribution that has the potential to be reflective of changes in population size (Kendal et al., 1992). Sign can also be used in an occupancy framework, where spatial replicates are used to estimate detection and has been achieved with several species of Asian bears (Das et al., 2014; Babu et al., 2015; Srivathsa et al., 2018; Bisi et al., 2019; Sharief et al., 2020). Such data may be employed in a Bayesian model that employs various measures of population status at different scales (e.g., Dey et al., 2017). Bear biologists in Asia also have relied on sign density as an indicator of differential habitat use (Ngoprasert et al., 2011), sometimes extending this to bear density (Stander, 1998). Ngoprasert et al. (2011) found that frequency of sign of Asiatic black bears was higher in

Fig. 1. Examples of bear sign: upper left - fresh and old claw marks on a tree; upper center – older claw marks; upper right – sloth bear excavating termite mound; lower left – bear tracks; lower center – bear scat; lower right – ground nest.

areas with higher fruit abundance, suggesting higher local density, and that Asiatic black bears had a wider distribution than sun bears inside a National Park in Thailand.

For other carnivores, track measurements have been used to reliably differentiate and count individuals in small populations (e.g., Sharma et al., 2005), but individually identifying and censusing bears solely from their sign is rare. The foremost example is the Chinese surveys of giant pandas. At approximately 10-year intervals, a 'National Survey' is conducted whereby a series of transects, covering their full potential range and all home ranges within it are searched for scats from every panda. Individuals are differentiated based on the average size of bamboo fragments in each fresh scat (idiosyncratic 'bite sizes') and whether other scats with fragments of the same size are too far away to be from the same individual (method described in Pan et al., 2014). It has been found through DNA analysis of panda scats, however, where panda density is high, the bite-size method fails to differentiate many individuals with similar bite-sizes, resulting in an underestimate (Zhan et al., 2006; Garshelis et al., 2008; Zhang et al., 2017).

4.2. Assumptions

The principal assumption of using sign as an indicator of bear presence is that it is correctly identified. This assumption is typically not hard to meet (see bear specific sign Table 2). A related assumption exists in being able to attribute sign to the correct bear species, as for example where Asiatic black bears and sun bears overlap. Additional assumptions of being able to accurately calibrate and estimate detection probability, and deposition and decay rates of different kinds sign apply when using sign in an occupancy framework or trying to relate sign density to bear density.

4.3. Challenges

Although bear sign is often very apparent, some types are harder to see, and some types decay quickly in certain environments. In Borneo, for example, some sun bear scats may last less than 2 days, and ground digs only last until the first hard rain, whereas claw marks on trees typically last at least a year or more (Wong, 2002; Fredriksson, 2012). Thus, habitats with more fruiting trees would tend to produce more identifiable sign (claw marks) just because that type of sign lasts longer and is easier to see. It is useful to conduct pilot studies to assess decay rates and staff training to assess detection rates of different sign (Steinmetz and Garshelis, 2010).

Whereas some sign is easily recognizable, some is potentially confused between bears and other species, or among sympatric species of bears (Table 3). For example, holes dug into the ground could be clearly from a bear (e.g., brown bear excavation of marmot burrows, see photo in Aryal et al., 2012), or may be shallow and quite similar to foraging sign left by other species such as wild boar (*Sus scrofa*). Careful observation of differences may prove helpful in distinguishing which sign can definitely be attributed to a bear, but some sign is likely to remain ambiguous even to experienced investigators. For sympatric Asiatic black bears and sun bears, the width of recent hind-foot claw marks on climbed trees can differentiate adult black bears with high reliability (Steinmetz and Garshelis, 2008), but narrower marks can be from either sun bears or young black bears. At a site in northeast India, the presence of many sun bear-sized claw marks on climbed trees, but no photos or local reports of sun bears, caused confusion over the presence of this species (Sharp et al., 2019). However, holes in trees well up on the trunk are signature signs of sun bears, which can climb and hold onto the tree while chewing the wood to excavate a nest of stingless bees; Asiatic black bears also excavate nests of stingless bees, but mainly from ground level. Deep dug-out holes (>30 cm) in large termite mounds (>50 cm, Fig. 1) are unmistakable indications of sloth bears anywhere this species occurs alone (and the presence of termite mounds and absence of holes is a good indication of the absence of sloth bears; Garshelis et al., 1999); both Asiatic black bears and sun bears also excavate termites, but do not dig deep holes in large mounds.

It is far more challenging to measure sign density than to simply use sign as an indicator of bear presence. As such, observed sign density may have a weak connection to bear density. Bears switch among a variety of food resources due to seasonal, annual, and supra-annual changes in food abundance (which can be very dramatic in some areas), and sign deposition changes accordingly, both in terms of type and quantity (e.g., Fredriksson et al., 2006). Thus, if an investigator concentrates on just one type of sign, such as claw marks which are long-lasting and obvious, and the bears switch to a food that creates another type of sign (e.g., digging), then density of the easily-observed sign type is no longer reflective of habitat use or local density. Hence, there is a potential problem both with summing different types of sign (that have different rates of detection and certainty), as well as focussing on just one type of obvious sign.

An associated issue with sign density is in differentiating separate sign events. Sign may be highly clumped along a survey transect, with clumps likely representing different events (e.g., set of tracks, group of scats, cluster of diggings; e.g., Garshelis et al., 1999).

Table 3
Countries where overlap occurs among Asian bear species, so caution much be used when assigning presence of a particular species from sign alone.

Overlapping species		Countries						
Sun bear	Sloth bear	India*						
Asiatic black bear	Sloth bear	India	Nepal*					
Asiatic black bear	Brown bear	China	India	Pakistan	Nepal	Afghanistan	Russia	N Korea
Asiatic black bear	Sun bear	India	Bangladesh	Myanmar	Thailand	Cambodia	Laos	Vietnam
Asiatic black bear	Giant panda	China						

* Minimal overlap.

Counting sign in these situations may require sub-sampling rules (Fredriksson, 2012) and these can greatly affect perceived sign density. Alternately, instead of counting sign and trying to ascertain where one clump ends and another begins, one can simply record the presence or absence of sign along shorter segments of transects (Guharajan et al., 2018; Hwang et al., 2021).

The relationship between sign density and bear density is likely to be area-specific, and as such cannot be assumed without verification. In Thailand, Ngoprasert et al. (2013) found that the densities of Asiatic black bears and sun bears estimated from photographic mark–recapture were proportional to their species-specific sign density. Conversely, Garshelis et al. (1999) obtained very different mark–resight density estimates for sloth bears in two different habitats (forest and grasslands) within Chitwan National Park, Nepal, but found sign density (holes in termite mounds) to be similar, possibly because bears ate other foods (ants, fruits) that did not leave sign. Sign density, however, was considerably lower in forested areas outside Chitwan where bears were present but likely at much lower density. Most bear sign is associated with feeding events (Table 2), and so is clumped in space and time with varying food availability. Also, sign is produced at different rates for different types of food. For example, bears spend much time in a single tree filled with fruit versus short time breaking several logs to eat beetles. Thus, bear sign density is a function of food availability, bear behavior, and bear abundance and is therefore not likely to be a reliable index of bear density.

To use sign density to measure bear density, we urge investigators to attempt to closely observe bears in the field and record the rates and types of sign produced, and then monitor the decay of different kinds of sign in different habitats and seasons. This has been done in few instances for Asian bears (Joshi et al., 1997; Wong et al., 2002; Fredriksson, 2012). Sign production rates can also be estimated by repeating sign transects and recording new sign.

4.4. Advantages

Bear sign is potentially a rich source of easily distinguishable, species-specific data, including not just presence but also providing some understanding for why the species is present (Hwang et al., 2021). Its use requires no special equipment and is generally inexpensive relative to other methods. On the other hand, it does require experienced field staff and careful study design to meet study objectives while avoiding sometimes subtle but significant biases.

Because some bear sign is so distinctive, even for untrained people (and also widely recognizable by local people), it has been relied upon as a primary source of information about bears in Asia (Garshelis et al., this issue). But that advantage is also a potential pitfall in that sign surveys can be viewed as a simple approach that almost anyone can employ with little recognition of potential biases, and thus a temptation to use sign surveys instead of methods that seem more difficult or costly. In summary, sign surveys may be applicable to occupancy distribution and trend estimates derived from occupancy, but generally not trend from sign density, unless sign density changes dramatically (Table 1).

5. Visual observations

Throughout human history observations of animals have been used to ascertain distribution and relative abundance. Observations of bears may have a large impact on the opinions of local people and experts, but unless habitats are so open as to provide unobstructed views, incidental observations of bears are unlikely to provide much useful information for monitoring. However, some investigators working on brown bears have taken advantage of special conditions that have yielded reliable information about population size and trend.

5.1. Applications

Visual sightings of bears have been used in a number of different contexts for several purposes: (1) to confirm bear presence or reproduction in an area; (2) periodic counts as a possible index of population size; (3) counts of identifiable individuals (based on markings or presence of cubs); or (4) a means of estimating the proportion marked individuals in a mark–resight framework. Bears have been observed from elephant-back (Garshelis et al., 1999), from hilltops in gently rolling terrain (Yavuz et al., 2017), from foot and then following them to better recognize individuals to inform resightings (Nawaz et al., 2008; Farhadinia and Valizadegan, 2015), and from aircraft (Knight et al., 1995; Miller et al., 1997; Walsh et al., 2010; Becker and Crowley, 2021).

Some Asian landscapes are particularly suitable for observing brown bears. Alpine meadows and other sparsely forested areas provide good visibility due to gentle terrain, dwarf vegetation, and clear air. For example, bears can be spotted from 2 to 3 km with binoculars in the Deosai Plateau in northern Pakistan (Nawaz, 2008). Asian brown bears often have morphological characteristics such as body size, pelage color, and distinctive white patches that wrap around the back that enable individual recognition of some individuals (Sterndale, 1884; Schaller, 1998; Nawaz et al., 2008). Body size has been used to estimate age cohort by well-trained observers allowing them to track reproductive parameters and even population trend (Sellers and Aumiller, 1994; Nawaz et al., 2008; Farhadinia and Valizadegan, 2015).

To optimize observation efficiency with maximum area covered, Yavuz et al. (2017) used GIS to identify observation sites.

Sightings have been included as more definitive evidence of presence to augment sign surveys (Stevens et al., 2011; Waseem et al., 2020) or combined with sign, cameras, and mortality locations, to identify core and corridor habitats (Mohammedi et al., 2021). Visual observations have been used to resight marked and unmarked bears and thereby estimate abundance (Garshelis et al., 1999). The Yellowstone Ecosystem in North America has employed visual observations mainly from systemic air surveys of females with cubs-of-the-year, distinguished as individuals, as a means of monitoring population trends over decades (Knight et al., 1995; Keating et al., 2002; Schwartz et al., 2008). This method also has been used but via ground surveys in several small isolated populations of brown bears in Europe to assess population trend (Palomero et al., 2006; Tosoni et al., 2017).

5.2. Assumptions

Visual sightings rely on observers making accurate observations. Depending on study objectives, additional assumptions may include: correct identification of sex and presence of cubs, correct identification of individual bear based on physical attributes, and not double counting individuals.

5.3. Challenges

In forested habitats bear sightings are generally very limited so visual observations are unlikely to contribute much to species monitoring. Hence this method is generally applicable only in open habitats. Errors can arise with species identification, where two similar-looking bear species are sympatric (Table 3), although well-experienced field staff should be able to distinguish the species in their area. Accurate individual identification can be much trickier. Unlike photographs, there is no way to go back and confirm what was seen. Furthermore, with individual identification, different observers may cue on different characteristics, possibly leading to confusion when surveys are done by different people. Sketching and/or photographing individuals and their characteristics can help with individual identification (Farhadinia and Valizadegan, 2015). Blind tests of two or more observers can be used to assess consistency of individual identification. The lack of markings, or similar markings on some bears makes individual recognition difficult. Identification over several years can be a challenge as color variation may shift over time (Nawaz et al., 2008). Except for females with cubs and very large males, it is rarely possible to identify sex accurately.

Some sampling designs require that individuals are only counted once, but due to the wide movements of bears, this can be challenging. Using watersheds as geographic dividers and having multiple teams of observers in radio or cell phone contact is helpful (Lamichhane et al., 2016). The double-observer approach (Forsyth and Hickling, 1997; Williams et al., 2002) uses two independent observers who search simultaneously, thereby enabling an estimate of how many bears were seen by both, by one, or by neither (Suryawanshi et al., 2012). This method has been used in brown bear aerial (Quang and Becker, 1997; Walsh et al., 2010) and ground surveys (Hameed et al., 2013). If attempting a total count without a correction for detection (i.e., census), an intense and prolonged field sampling, possibly over multiple years, may be required (Nawaz et al., 2008). Furthermore, because of a lack of geographic closure in most cases, one may never know if a bear died, emigrated, or simply was not seen, or if a newly identified bear was a new immigrant or just one that was not previously observed or properly identified. Additionally, it can be difficult to maintain a constant level of expertize and effort among field staff over time: detection and recognition of bears is likely to vary among observers, but is rarely accounted for. Hence, estimates based on total counts often lack a measure of precision.

5.4. Advantages

Observations can be a cost-effective and easy-to-implement method where conditions are suitable. The technology and expertize required can be minimal, but with that there is also a risk of misinterpretation. Observations can augment information on distribution, but beyond that, the method only works well in certain habitats. Information on population age and sex structure, breeding activity, foraging ecology, and social behavior can be recorded, but actual population monitoring is limited to very particular circumstances where bears can be seen from reasonably long distances and reliably distinguished as individuals (Nawaz et al., 2008).

6. Camera traps

Since the advent of digital cameras, cameras have increasingly been used to collect data for wildlife study, conservation planning, and management (Seydack, 1984; Long et al., 2008; O'Connell et al., 2011; Rovero and Zimmermann, 2016; Agha et al., 2018). Camera traps have a sensor that detects movement across the field of view, activating the unit to focus and take a digital image with a time and date stamp, and in some cases a GPS location. These metadata, stored with the image, allow for archived camera trap images to be reused, subsampled, sorted, and reanalyzed for multiple purposes. Moreover, whereas camera trapping may or may not target bears, images may be obtained of bears that pass by, generating what is called "by-catch" data.

6.1. Applications

Camera traps are fast becoming the key tool to obtain documented detection/non-detection records for a large number of Asian species, including bears. Photos can be used to confirm locations identified by experts or through local interviews, which otherwise might have been unproven. Camera trapping can provide new records for places where the previous presence record was decades old, and also new records for places where bears were thought to have been extirpated or never occurred. Without a substantiated photo, records in such areas should be treated with skepticism.

Use of camera traps throughout Asia is rapidly increasing, and with that a massive accumulation of data. For example, in mainland China it is estimated that there are more than 50,000 operating cameras in the field, and at least ten regional or province-wide networks have been established, resulting in over 11,000,000 images over 7,500,000 camera-days by 2020 (Li, 2020). Although most of these monitoring activities are not specifically designed for bears (except for the giant panda, see Li et al., 2010, 2020a), camera networks will generate numerous occurrence records of bears as by-catch, which can be used to determine their distribution, for habitat prediction and potentially for habitat modeling if variability in design can be accounted for and overcome.

Additionally, each camera is continually sampling its very local area, and because cameras have time stamps, the data can be used to create a series of detections and non-detections in time periods defined by the investigator. These data can then be used to derive detection histories for use in an occupancy framework. Beyond a host of studies that obtained bear data as by-catch (e.g., Tilker et al., 2019), camera trapping has been employed on bear-targeted studies in Asia (Linkie et al., 2007; Burton et al., 2018; Srivathsa et al., 2018; Bisi et al., 2019; Sharief et al., 2020). Until recently, instead of estimating occupancy, investigators more often calculated a 'relative abundance index' based on the number of bear photographs obtained for a given camera trapping effort, which was taken to be related to bear density but suffers the inherent problem of not accounting for variable detection and local shifts in bear use (Morin et al., this issue).

Cameras can also be used to identify individual bears based on their unique chest marks, thus providing a means of estimating population size using a mark-recapture approach (Ngoprasert et al., 2012). This approach requires a specialized camera set-up with bait, which induces bears to stand up, thereby exposing their chest marks (Fig. 2). So far this method has been used only for Asiatic black bears and sun bears in Thailand. This method is labor intensive and expensive, because three cameras plus bait are required at each of numerous camera stations. However, it is one of the few currently available methods which yield estimates of bear abundance and density; such data are highly valued for monitoring bear population changes (Morin et al., this issue).

6.2. Assumptions

The most basic assumption of camera trapping is that images of bears are correctly identified. Whereas it is straightforward to identify a "bear", the different species of bears may be confused on camera trap photos in areas where they occur sympatrically (Table 3, Ngoprasert and Steinmetz, 2012; Sharp et al., 2016). If photos are used for mark–recapture, then error-free identification of individual animals becomes necessary, which is a much more difficult assumption to meet and even to test.

6.3. Challenges

The challenge of identifying the species of bear on a photo can be overcome through consultation with experts. But this challenge can also be made somewhat easier by ensuring that cameras are set to take a burst of photos, or even video (Bisi et al., 2019). The primary disadvantages of video is that it consumes more memory and battery, is time consuming to process the data, and is not available for all types of cameras.

Identifying individual bears on photos can benefit from a group of observers, with people who fully understand the nuances of markings, and how bears may look different at different angles and in different lighting conditions. Computer software has been developed to aid in this process and has recently been applied to Asiatic black bears (Teintipsiri et al., 2015) and giant pandas (Hou et al., 2020) with some success. A technological advancement with potential to improve individual identification from photographs is machine learning or artificial intelligence. Several recent studies have shown that animals captured on camera traps can be automatically identified, counted, and behaviorally classified using deep convolutional neural networks — a form of machine learning (Norouzzadeh et al., 2018). Two recent studies have used deep neural network and computer vision for automatic face recognition and identifying individual brown bears on photographs (Clapham et al., 2020) and giant pandas (Chen et al., 2020).

A further challenge of camera trapping is the massive amount of photographs that may be obtained. Crowd-sourcing (Swanson et al., 2015) or artificial intelligence may be useful to detect bears in photographs or to identify 'empty' photos (Green et al., 2020). Another obstacle is that cameras are relatively expensive, so investigators without a large budget may be limited by sample size. Sample size is an important design consideration since bears often live at low densities with low detection rates, requiring many

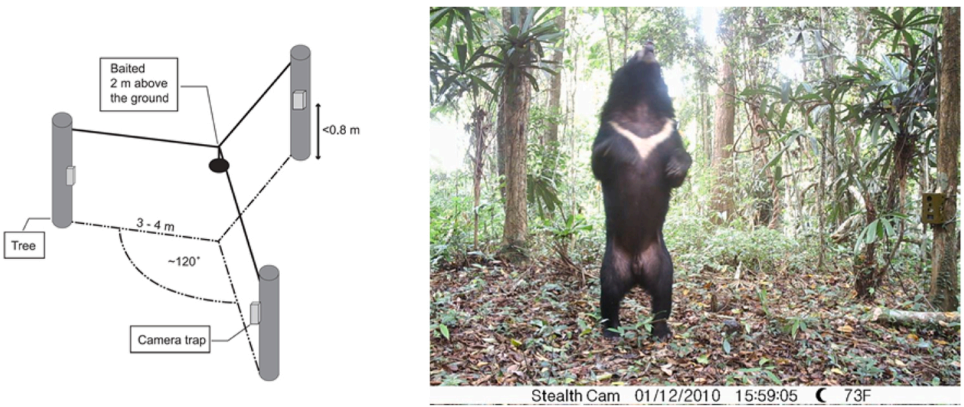

Fig. 2. Study design using a multiple camera trap design to identify Asiatic black bears and sun bears by their unique chest markings. Bears stand up to investigate the central hanging bait and expose their chest marks to one of the cameras.
(Adapted from Ngoprasert et al., 2012).

cameras to yield adequate samples sizes and long periods to develop evidence of absence. Further, loss of cameras to theft or damage can be costly to replace.

6.4. Advantages

Unlike interviews or sign surveys, cameras provide solid evidence of presence, and a record that can be archived, accumulated through time, re-examined and relied upon in the future. Cameras can be set using a grid design to ensure systematic sampling, they are simple to use, and can be set and checked by field staff or citizen scientists with little training (McShea et al., 2016). Moreover, the images can be viewed immediately, so field staff can be part of the discovery process.

Except in the case of a mark–resight study where the photos require bears to stand up and face the camera to allow for individual identification (Ngoprasert et al., 2012, 2013), camera surveys can be deployed without bait or lure, which is preferential in terms of occupancy studies, and also logistically easier. Cameras can be left in the field for many months, with only batteries and SD cards changed periodically, thus minimizing human scent at sites.

Many researchers and even individual protected areas may have a supply of cameras, used for a variety of purposes, including animal surveys as well as anti-poaching efforts. A major advantage is not only that the cameras can be deployed for a great many purposes, as for example a specific bear survey, but also that they obtain, with no added effort, "by-catch" data. Indeed, it was by-catch camera trapping data that yielded the only photos of sloth bears in Bhutan (Garshelis et al., 2015) and sun bears in China (Li et al., 2017). Another advantage of cameras is the diversity of other relevant information that can be obtained. One example is the documentation of poaching. Cameras set out in a park in Northeast India, intended to ascertain what bear species lived there, photographed people walking by with guns, far into the interior of the park where park officials had claimed there to be very little human use and virtually no poaching (Sharp et al., 2019).

Camera data can also illuminate other aspects of bear ecology and behavior including scent marking (Clapham et al., 2014; Hou et al., 2021), rubbing behavior (Tattoni et al., 2015; Taylor et al., 2015), scavenging (Wang et al., 2012; Huang et al., 2014), predation (Naing et al., 2020; Kunde and Goossens, 2021), sex ratio (Ngoprasert et al., 2012), reproduction, and activity patterns (Carter et al., 2015; Bu et al., 2016; Torretta et al., 2017; Azevedo et al., 2018), all of which may be useful in providing context for a monitoring program. A possibly promising avenues for the near future is to use photographs of unmarked (not individually identifiable) animals to produce a density estimate based on how large an area the camera samples and some assumptions or data about how animals move about when a portion of the population is individuay identifiable, or whein local telemetry data is available (Morin et al., this issue). This would be a game-changer for monitoring many species of wildlife, but currently requires more development and validation before it can be reliably used and would be probelnatic for low density populations commen with Asian bears. In summary, cameras traps can be used effectively to achieve all of the monitoring objectives covered in this paper.

7. DNA

DNA has been a useful tool for monitoring wildlife including bear species. We discuss its use primarily from two sources proven to be useful in wildlife studies, either hair roots or scat. Potential sources also exist in environmental DNA (eDNA) from trace amounts of DNA from shed epithelial cells, saliva, or urine that can be sampled from water, soil, snow, and air (Bohmann et al., 2014; Ushio et al.,

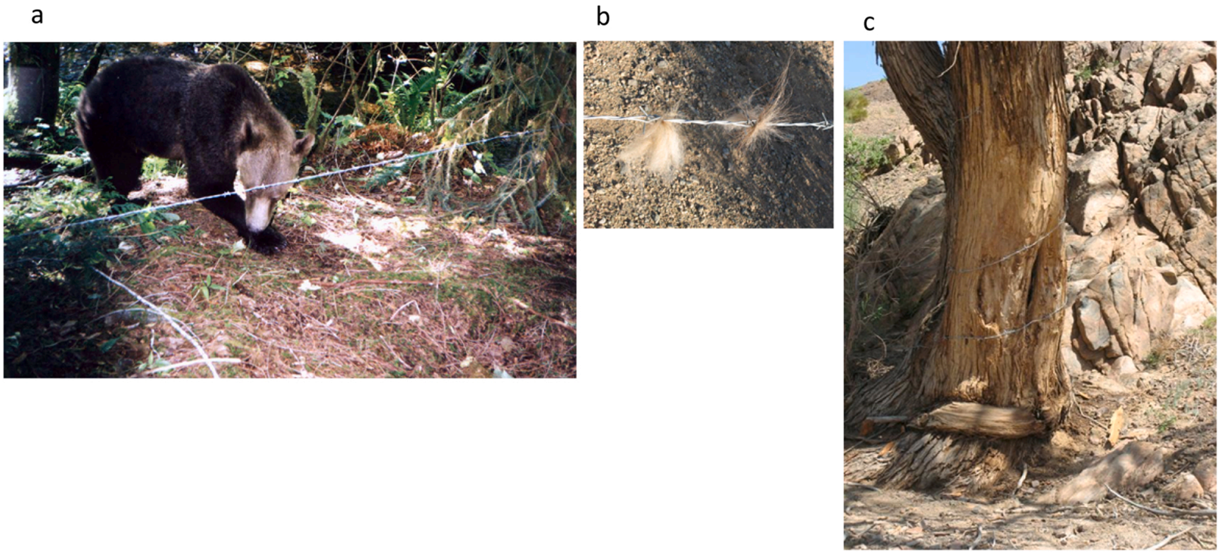

Fig. 3. (a) Brown bear entering a barbed wire hair sampling station, b) hair sample on barb wire, and c) natural brown bear rub tree in the Gobi Desert of Mongolia, wrapped with barb wire for efficient hair sampling.

2017; Rupert et al., 2019; Sales et al., 2020; Clare et al., 2021; Mena et al., 2021). Invertebrate-derived DNA (iDNA, Schnell et al., 2015) using blood-feeding leeches (*Haemadipsa picta*), blow-flies (Diptera: Calliphoridae) have been used to detect sun bears and Asiatic black bears (Drinkwater et al., 2020; Tilker et al., 2020) as well as dung beetle-derived DNA to sample forest vertebrates (Lee et al., 2016; Ji et al., 2020; Drinkwater et al., 2021). Neither eDNA nor iDNA is considered a viable population monitoring methods as yet and is not discussed further.

7.1. DNA from hair

A few hairs with roots can provide sufficient nuclear DNA (nDNA) to identify individual bears. This provides a sex-specific individual mark from birth to death and, if collected and analyzed properly, can be very accurate. Such a mark is most often used in a multi-session mark–recapture design to estimate density, or to estimate trend using an open model or series of density estimates over many years. This mark can also be used to estimate distribution and occurrence, even though individual identification is not required for these questions.

7.1.1. Applications

Beginning in 1996, specialized traps made with barbed wire have been used to remotely collect bear hair to inform DNA-based population estimates (Fig. 3a and b, Woods et al., 1999). Since then, DNA hair trapping has been used across the world with several bear species (Miura and Oka, 2003; De Barba et al., 2010; Kopatz et al., 2014; Dutta et al., 2015; Kadariya et al., 2018; Lee et al., 2020; Vaeokhaw et al., 2020). Originally, hair was collected across a grid of single strand barbed-wire corrals (~30 m circumference) surrounding a scent lure. Sites were revisited, samples collected and re-lured on several occasions (Woods et al., 1999). This basic field sampling design has not changed much over the decades, with the biggest modification being the addition of collecting hairs from rub trees that bears used for scent marking (Kendall et al., 2010; Yang et al., 2011; Sato et al., 2014; Morehouse and Boyce, 2016a). Roots of hairs yield permanent individual identification through nDNA fingerprinting (i.e., an individual mark, Paetkau, 2003), so capture histories can be used in a mark–recapture analysis to estimate abundance, density (Boulanger et al., 2004a), or trend over years (Boulanger et al., 2004b; McLellan et al., 2019).

This method revolutionized the ability to obtain a rigorous population estimate in one season, or trend, without physically catching and marking bears for individual identification. While most often used on study areas $< 10{,}000\ km^2$, recent advancements in the use of spatially explicit capture recapture have allowed use over larger areas (e.g., across ~$40{,}000\ km^2$, Humm et al., 2017). Facilitating the spread of the technique, microsatellite markers have been identified for most Asian bear species (Paetkau et al., 1998; Wu et al., 2010; Shih et al., 2017; Yang et al., 2011; Sharma et al., 2013; Thatte et al., 2018; Huang et al., 2015; Lee et al., 2020). One notable Asian bear DNA-based population estimate and trend estimate was carried out between 2009 and 2017 on brown bears in the Gobi Desert of southwestern Mongolia (Tumendemberel et al., 2016, 2021). The study was focused on a small, isolated, and critically endangered population (McLellan et al., 2017). This project began with a pilot study (highly recommended) to ensure field and lab methods were successful, followed by a thorough mark–recapture the following year and subsequent samplings to estimate trend. Contributing to this project's success was that brown bears in the Gobi region frequent rare water sources (springs) that have supplemental feeding stations and hair sampling stations focussed on these sites, ensuring visitation by bears.

7.1.2. Assumptions

The DNA hair method is most appropriate for objectives requiring individual identification (Table 1). Therefore the method carries with it the assumption of unambiguous individual identification.

Another important assumption is that the population of interest can be adequately sampled. This entails having sufficient access to sampling sites across the study area, that hair-grab methods are effective at sampling hair with ample DNA, and that field methods are not biased for size or age of bears.

7.1.3. Challenges

Challenges in meeting the assumption of unambiguous individual identification can occur in populations where genetic diversity is low, so more genetic markers (e.g. more microsatellite loci when genotyping) may be required to attain a sufficiently high probability of distinguishing individuals with similar genotypes (Waits et al., 2001; Paetkau, 2003). Genotyping errors can also create 'false' individuals, but careful laboratory techniques can overcome this challenge (Paetkau, 2003; Kendall et al., 2009). Further challenges associated with this assumption can occur due to degradation of samples by sun and rain as they await collection in the field, leading to failed or partial genotyping; collection frequencies should be considered and even tested with this in mind, particularly in warm moist environments (Stetz et al., 2015; Shih et al., 2017).

Although the barbed wire corral trap has been highly successful for American black and brown bears (Proctor et al., 2010; Van Manen et al., 2012), the technique has seen limited use in Asia (Garshelis et al., this issue). Obstacles to its use in Asia include:

- the difficult accessibility of many field sites (hence hampering the hauling of barbed wire and lures);
- the need for repeated collection of samples;
- the low success of lures in some areas;
- barbed wire may not be a useful hair trap for some species (i.e., sun bears, with short tight fur);
- the cost of genetic analysis, and the lack of an in-country lab (and restrictions on sending genetic samples out of country).

Overcoming these challenges may require experimentation within a pilot study. For example, developing a hair sampling method (other than the original barb wire method) that works efficiently on the target species may be required. Vaeokhaw et al. (2020) employed a spring-barb hair trap for Asiatic black bears, and Tee et al. (2020) used duct tape wrapped around trees to collect hair of sun bears that were enticed to rub on the tree (but only hair of males was obtained when deployed in the wild). Other methods to obtain hair samples have been developed for other species and some of these, or others yet to be designed, may work well on Asian bear species, and could be explored. As one of many examples, alligator clips combined with barbed wire has been successful for wolverine (*Gulo gulo*) in the winter when they have very tight fur (Magoun et al., 2011). Identifying an effective lure for local bears may benefit from local knowledge on what bears eat and are attracted to. A pilot study with various lures can be very effective and save time and energy while helping ensure adequate samples sizes to meet study objectives.

Challenges presented by remote rugged terrain may require creativity in study design, but also may include use of local citizens (villagers) who already use the study area. Spatially explicit capture recapture analysis allows for cluster sampling which is a logistically efficient sampling design (Sun et al., 2014; Humm et al., 2017; Clark et al., 2019). Workable field methods can be obtained by integrating analysts and field teams. Funding challenges related to DNA laboratory costs can be overcome through developing a diversity of partners to provide personnel, equipment, lab time or technicians, other in-kind contributions, or direct cash.

When relying on the use of lures or natural rubbing behavior to obtain hair samples, the results may be biased by a number of factors, including age and sex of bears. Again, a pilot study can be useful, for example to test the sex ratio of bears visiting rub trees. Rubbing behavior can be sex-biased or not, depending on the season (Kendall et al., 2009; Morehouse and Boyce, 2016a). Also, the height of the wire is a critical element in the design of hair traps. If too low or too high, large bears can pass over or small bears can pass under without leaving a sample (Quinn et al., 2022). A question also remains about the potential benefit of using two wires at different heights. Studying American black bears, Laufenberg et al. (2016) determined that with a single wire, cubs-of the-year were not sampled and therefore should not be included in an abundance estimate. Conversely, two brown bear surveys concluded they did sample cubs and were included in their estimates (Boulanger et al., 2006; Kendall et al., 2009). The addition of a second wire at a lower height may overcome this issue. At least for brown bears, the addition of a second wire increased the numbers of bears sampled by 10%, but did not significantly change the population estimate (Boulanger et al., 2006).

7.1.4. Advantages

The main advantage of DNA is that it is a permanent mark, lasting from birth to even after death (i.e., a carcass). This enables not only a 1-year population estimate with confidence intervals (Woods et al., 1999, Boulanger et al., 2002), but long-term monitoring (, Boulanger et al., 2004b; McLellan et al., 2019, Tumendemberel et al., 2021). Relative to live capture and marking, this method is usually cost effective, requires a less skilled field team, and is less-invasive (i.e., does not harm or stress bears unnecessarily). Also, compared to sampling DNA from feces (see next section), DNA from hair is usually less degraded, ensuring a higher genotyping success rate, and hair traps can be set where desired (e.g., in a grid), fostering equal or systematic sampling across a broad area (i.e., not just where feces happen to be found). This has been accomplished even when suitable trees for erecting hair traps are uncommon (e.g., using rocks instead; Burton et al., 2018). This technique can be especially advantageous for assessing and monitoring the conservation status of small, isolated populations (De Barba et al., 2010; Dutta, 2015; Proctor et al., 2018; McLellan et al., 2019). Downstream analyses from DNA analyses have also become prolific and include fragmentation and connectivity (Kopatz et al., 2012, 2014; Proctor et al., 2012), dispersal (Proctor et al., 2004; Costello, 2010), and understanding conflicts (Caniglia et al., 2013; Morehouse et al., 2016b). In summary, DNA obtained from hair is a rigorous field method that can be used for all monitoring objectives, if financial challenges can be accommodated, if access to field sampling sites is reasonable, and if bears can be lured in sufficient numbers to obtain adequate samples. Where individual identity is not required, such as in an occupancy framework, DNA methods may not be cost effective. However, where 2 or more species overlap (Table 3) or the sex of bears is important, DNA may be useful and cost effective because complete genotyping would not be necessary (Durnin et al., 2007; Nie et al., 2012). In this situation, using scat samples for species identification may be more effective than hair.

7.2. DNA from scat

DNA obtained from scat has great potential for conservation research and management (Kindberg et al., 2011). Like DNA from hairs, if collected and processed properly, DNA from scat provides a life-long sex, species, and individual-specific identity mark. DNA from scats can be used for most of the same objectives as DNA from hair, but an important difference is the way it is collected.

7.2.1. Applications

Scat has been used as a source of genetic data to study bear populations for over two decades. DNA is obtained from sloughed intestinal cells of the animal on the outer layer of the scat. Scat-sourced mitochondrial DNA (mtDNA) is often used for species identification because it is more abundant (many copies) in a cell and therefore yields a more reliable result than when attempting to get individual identification from scat-derived nDNA with only 1 copy per cell. Advances in collection, storage, and amplification have allowed individual identification from nDNA from cells within scat (Shih et al., 2017; Thatte et al., 2018). In Asia, scat DNA has been used to obtain mark–recapture population estimates (Bellemain et al., 2006; Moqanakia et al., 2018) and to assess the movement of bears between separated reserves (Dutta et al., 2015; Thatte et al., 2020).

7.2.2. Assumptions

The basic assumptions for scat-derived DNA are the same as with hair-derived DNA – namely that the genetic material and the process used to analyze it are sufficient to clearly distinguish among individuals. Meeting this assumption is however, more challenging with scat-derived DNA and depends on the quality of the DNA in the sample, the genetic diversity in the population, and the skills and procedures used by the lab.

7.2.3. Challenges

The often low quality and quantity of DNA in scat can hamper obtaining adequate and reliable individual identification. Particularly in tropical regions of Asia, scats decay (and disappear) rapidly, as does the quality of the DNA. Low yield of DNA, high amplification error rates, and difficulty in scoring genotypes that are associated with low levels of template (nDNA) may yield unreliable individual identification (Taberlet et al., 1996). Hence, the basic assumption of unambiguous individual identification is more difficult to meet with fecal than hair-derived DNA.

Several studies have investigated ways to increase yield of DNA by comparing the impact of different collection, storage, and processing methods (Shih et al., 2017). Pilot testing is imperative to demonstrated and maximize genotyping success rate (Zhu et al., 2017). Repeat testing of the same fecal samples has been used extensively to reduce genotyping errors (Taberlet et al., 1996; Pompanon et al., 2005; Zhan et al., 2010). Forgacs et al. (2019), however, show that this technique (multi-tube approach) may be insufficient to reduce genotyping errors, and highlight the benefits of a rigorous marker panel. Recent model developments such as the genotype spatial partial identity model, uses information on the spatial proximity of genetic samples to reduce genotype uncertainty (Augustine et al., 2020). While obtaining reliable results from scat-derived DNA is quite variable across labs (34–80%, Skrbinsek et al., 2010; Wheat et al., 2016), and transferability of genotype data across platforms and labs is also challenging, advances are improving reliability and standardization (De Barba et al., 2016).

Finding scats can also be a challenge in many areas. Scats are difficult to see in environments with a dense understory. Scat detection may be mainly limited to trails, which may be lacking or not used much by bears. In low density populations, the number of scats found is likely to be low, as compared to hair sampling with a lure. However, sloth bear researchers have had no difficulty obtaining an adequate sample of scats (Dutta et al., 2015; Thatte et al., 2020). In spite of the significant challenges associated with using scat as a source of DNA, microsatellite genotyping success rates from bear scat over the last decade have been reasonably high and population study objectives met (Kindberg et al., 2011; Dutta et al., 2015; Moqanakia et al., 2018; Thatte et al., 2020).

7.2.4. Advantages

The paramount advantage of fecal sampling is that it can be relatively easy, requiring minimal equipment or training. Scats can be collected by staff patrolling nature reserves in the course of their normal activities (Malcolm et al., 2014), or by volunteer citizen scientists (Kindberg et al., 2011). Unlike sign surveys, scat collectors require little expertize, and the samples can be checked later for correct species identification; moreover, most sampling would likely occur along trails, where scats would be visible. In more specialized situations, a trained scat-dog could be used to help find samples (Wasser et al., 2004; Long et al., 2010; Sentilles et al., 2021).

With fecal sampling there is no need to transport heavy materials into the field (rolls of barbed wire), no lures, and no need to even revisit the exact same sampling sites (e.g., as opposed to repeatedly checking a barbed wire or camera site). Besides individual identification and sex, the locations of scat samples can provide ancillary information on animal distribution, movement, habitat and resource use. As with DNA from hairs, scats also can be used for a great variety of population genetic topics (Murphy et al., 2002; Kindberg et al., 2011; Dutta et al., 2015; Thatte et al., 2018), stress hormones (Malcolm et al., 2014) and diet. In the special case of giant pandas, scats are highly visible and common, and have been used in an ad hoc approach of population estimation; genetic analysis of these samples provided a clear step-up in rigor (Zhan et al., 2006).

Although DNA yield from scat is often lower than from hair samples, this can be outweighed by the advantage of the lower labor of scat collecting than hair sampling with snares (Phoebus et al., 2020). In summary, DNA from scat can be as useful as DNA from hair to meet objectives discussed here if rigorous laboratory challenges can be managed (Table 1).

8. Radio telemetry

Radio telemetry is a field method that can provide a great deal of information on bear behavior and ecology, as well as data directly useful for monitoring. Population monitoring entails capturing and radio-collaring female bears, and using the radio collars to enable observations of their subsequent reproduction and survival, as well as the survival of accompanying cubs and juveniles (until they disperse from their mother). Age-specific reproductive rates and mortality rates are incorporated into a female population matrix model to estimate population growth rate (males are not used for this analysis; Caswell, 2001). The estimate generally does not account for immigration and emigration. Population growth is calculated from the demographic rates and population structure at the present time, and has thus been called a measure of “demographic vigor” or how well the population is coping with its current circumstances (Caughley, 1977).

8.1. Applications

Telemetry-based estimates have been the most frequently used method to estimate trend of North American brown bears (Craighead, 1976; Knight and Eberhardt, 1985; McLellan, 1989, 2015; Garshelis et al., 2005; Schwartz et al., 2006; Mace et al., 2012), and have also been used on brown bears in Pakistan (Nawaz et al., 2008). Gaining sufficient reliable data on vital rates usually takes a decade or more (Harris et al., 2011). Five telemetry studies of > 30 radio-collared giant pandas greatly enhanced our knowledge on their movements, dispersal, social network, and habitat selection but were insufficient to estimate the vital rates needed to estimate trend (Connor et al., 2016).

Radio-collared animals can also be used as marked animals in a mark–recapture or mark–resight framework, for example using visual sightings (Miller et al., 1997) or camera traps (Mace et al., 1994). An advantage of using collars and not just tags to mark animals is that the collars provide information on the area used by each bear relative to the boundaries of the study area where the resightings occur. This provides a means of estimating density, and not simply abundance for a vaguely defined area (Garshelis, 1992; Ivan et al., 2013; Whittington et al., 2018).

8.2. Assumptions

The telemetry-based matrix method assumes that an unbiased sample of female bears is monitored and that their observed age-specific reproduction and survival are representative of the population at large. This assumption inherently means that the sample size (number of collared bears) is large enough to represent the variation that exists in the population, and bears are tracked for long enough to capture normal year-to-year variability. Another assumption is that the age structure of the population is stable, and that the vital rates were not changing directionally through time. This assumption would be violated if, for example, poaching pressure was increasing during the study period.

8.3. Challenges

A principal challenge of this method is capturing and radio-collaring a sufficient sample of adult female bears and monitoring them over a long enough period of time (e.g., ≈10 adult females over a decade). Achieving this can be difficult or impossible in many areas of Asia. An even greater challenge may be gaining reliable data from these bears (i.e., reflective of the population at large), especially survival rates. Human-caused mortality is likely to be the main population driver, but since virtually all killing of bears is illegal in Asia, documenting mortality events in a small sample of radio-collared bears is apt to be fraught with difficulties, as poached collared bears may just disappear. Many of the bear populations that would be the subject of a monitoring project exist in remote areas with difficult access, severely hampering the monitoring of VHF-collared bears from the ground. Such bears can only be located when within range of human observers. Hwang et al. (2010) found that home ranges of Asiatic black bears in a national park in Taiwan were underestimated because they frequently traveled beyond the area where they could be monitored from the ground (including areas outside the park, where they would be most susceptible to being killed). GPS-satellite collars would address this problem; however, these more sophisticated collars have a higher failure rate, and not being able to distinguish collar failure from mortality in a small sample of bears could lead to crucial errors in estimation of population trend. Sometimes there are telltale signs of human activity, suggesting poaching, near a collar found on the ground; but such occasions are likely to be rare compared to collars that simply vanish, or are found in a place with no evidence of foul play (possibly being just slipped off by the bear). Equally challenging is the case where human-caused mortality is low, and female survival high, so in the course of study none of them die, thus yielding no useful estimate of survival.

Another challenge is obtaining accurate reproductive information. To accomplish this requires visually observing the bears, which is particularly difficult in situations with dense understory. Furthermore, observers must be able to count all of the cubs associated with each female at periodic time intervals, not just document whether cubs are present, as cub mortality can vary widely by geographic area.

8.4. Advantages

Estimating trend via vital rates is only one of many reasons that bears are captured and radio-collared. GPS-collared animals can be used to understand many aspects of a species' ecology, especially related to their use of habitat, which can be a critical component in terms of the size and trend of the population. Measuring population trend via estimates of vital rates may be effective only in circumstances with reasonable access, high visibility of bears, low levels of poaching, budgets able to support a sample of GPS-satellite collared animals, and an experienced capture team. Collared animals may provide ancillary data that, combined with other data, help in understanding distribution, abundance, and population trend (Kasworm et al., 2020) and may be particularly useful in helping to inform density estimates derived from unmarked camera trapping data (Morin et al., this issue).

9. Conclusions and recommendations

Selecting a field method to monitor Asian bears requires that project objectives are articulated and a good match with the chosen method. In practice though, some methods may be financially prohibitive to employ or simply beyond the abilities of project staff. Hence, selecting an appropriate method is an iterative process, considering a number of variables that may change over time. A chief focus of this paper was to provide researchers and managers information on the inherent limitations in inferences provided by the various field methods to inform selection of the most appropriate method.

In practice, while population monitoring is important to assess conservation status and to direct conservation actions to the highest priority areas, few studies of Asian bears have employed data-based monitoring of trends with estimates of precision (Garshelis et al., this issue). To a large extent this is due to the resources required. For example, while DNA-based methods can yield accurate population estimates over a defined area (e.g., reserve size) within one season, a single estimate is relatively expensive, and repeat or continual surveys across the same area can become very costly, and therefore requires a commitment of dedicated financial and personnel resources (Fig. 4). There are few examples of these methods being applied to Asian bears, especially long-term (Tumendemberel et al., 2021).

Smaller-scale monitoring efforts are generally more feasible than large scale efforts. Thus, using a data-intensive method to monitor across a species distribution is very unlikely (McShea et al., this issue). Larger-scale efforts (e.g., periodic IUCN Red List assessments of species) are more likely to be derived from a combination of methods such as a melding of small-scale data-intensive surveys, local knowledge, and expert opinion, all synthesized by a team of experts to infer species-level trends.

We are hopeful that bear monitoring in Asia will evolve as it did for bears in North America and Europe, from simpler to more sophisticated and robust methods, yielding stronger, more reliable inferences. Some of the conditions in Asia are unique from those in North America and Europe, so the suite of methods that eventually move to the forefront may also be unique. For example, we think that for Asian bears there might always be a place for sign surveys and local knowledge, but instead of being used as direct indicators of population size and trend, they may be better applied in an occupancy framework. Camera trapping, though, seems to be the method of rapidly increasing preference across Asia, because it allows monitoring multiple species simultaneously, providing by-catch data on non-target species. Bear monitoring could benefit by ensuring the most efficacious use of these data.

We encourage standardization of methods across study areas and countries within regions, which should provide data analysis at spatial scales not previously possible. Whereas it is not completely necessary that the same techniques be used, there can be great benefits to employing a standard technique, where the details of sampling and analysis have a clear link to the objective, and potential biases and pitfalls are well understood. Any regional estimates will likely involve pooling data from multiple projects and shared protocols will make this process more viable.

We synthesize the complex nature of selecting field methods to match project objectives considering financial and logistical constraints (Fig. 5). If distribution monitoring is the goal, we suggest using a regional scale where a large number of reliable presence points can be obtained. If the target area is too large, the intensity of sampling will be too uneven to detect changes in distribution, and if too small, the scale needed to detect a change will be finer than the normal home range of a bear (McShea et al., this issue). The most definitive presence records can be obtained through camera trapping or DNA (to identify species) sampled from hair traps or scat. Expert opinion or an appropriate model extrapolation may be needed to fill in gaps where data are lacking. If finances limit the use of these methods, local knowledge corroborated with sign can yield reliable presence points as long as sign of the target bear species is unique and easily recognizable.

If occupancy is the chosen objective, camera trapping or DNA are again the best choices. Local knowledge and sign can be used under financial constraints, but they are secondary choices mainly because they lack a true temporal component. However, in a very low density area, where camera or hair trapping may yield inadequate samples or require too much effort to produce a desired number of samples, sign and local knowledge may be a viable alternative.

If an abundance or density estimate is required for a small area (< 10,000 km^2), then DNA-based mark–recapture methods may be employed effectively. The choice of using hair or scat depends largely on the field conditions. Hair is a more reliable source of DNA, so is the preferred option if it is possible to set and check hair traps spread across the study area, if a lure attracts bears, and if the trap is effective in snagging hair (with roots). Lacking these conditions, scat is an alternative if there is enough of it to be found easily, via walking trails or using scat detection dogs. Cameras are a possibility if bears can be individually distinguished by their natural markings, if a lure can be used to entice them to stand, and if it is practical to use three cameras per sample site. Presently, the use of

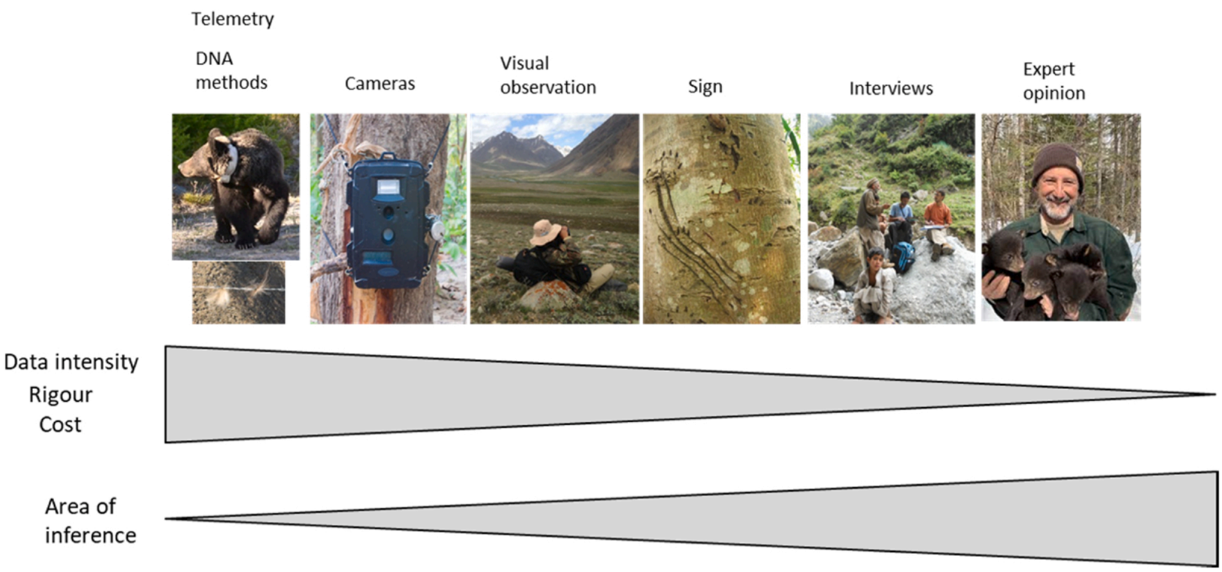

Fig. 4. Schematic of the generalized relationship between data intensity, cost, rigor, and typical area covered by Asian bear monitoring methods.

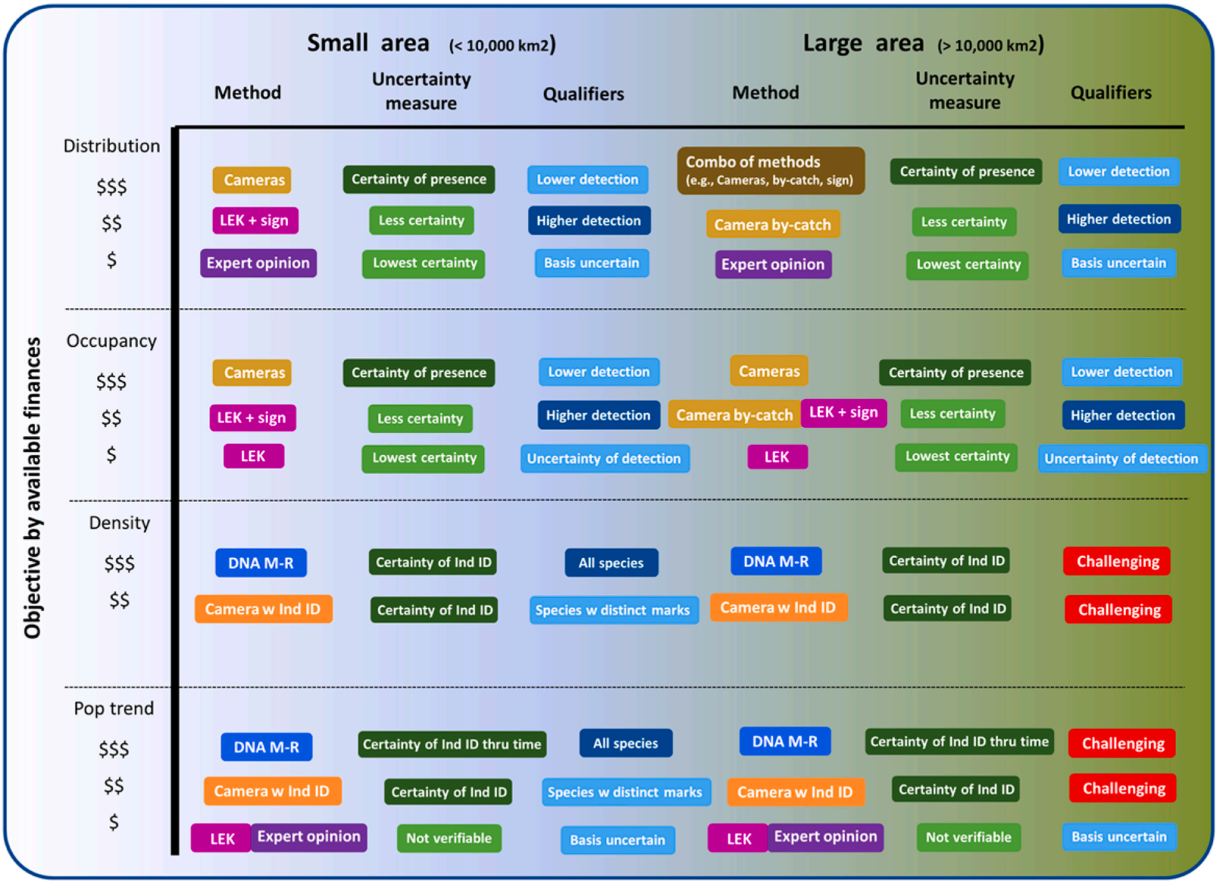

Fig. 5. Recommended field methods for monitoring Asian bears. We consider study areas at two scales, small (<10,000 km^2, blue shaded background) and large (> 10,000 km^2, green shaded background). Relative costs within each method is indicated as low ($), medium ($$), and high ($$$). 'Uncertainty measure' refers to uncertainty reflective of the method's ability to sample bears, not the analytics that the method allows. The "Qualifiers" column distinguishes between the methods within any one objective not between objectives. LEK' is Local Ecological Knowledge, 'M-R' is Mark-recapture, 'w' is with, 'Ind' is individual, 'ID' is identification, 'Camera by-catch' refers to incidental bear photos taken during a remote camera survey designed to photograph either another species or many species and 'Basis uncertain' refers to the uncertainty of the basis for an expert's opinion.

methods without individual identification from cameras lack the precision necessary for monitoring (Morin et al., this issue).

If population trend is sought over a small area (<10,000 km^2), a clustered spatially explicit sampling design using individual identification from either DNA or cameras has made this more feasible (Humm et al., 2017; Clark, 2019). Such an undertaking requires a substantial investment of resources in DNA or camera trap sampling. Whereas this objective could also be accomplished with collared bears, the investment is even greater, and requires the mostly untenable assumption that enough bears will die to yield a precise estimate of mortality, and all mortalities and reproduction will be observed. Eventually, future telemetry movement data can be used to inform unmarked camera trapping methods, yielding sufficiently precise estimates of density for monitoring purposes (Morin et al., this issue).

If population trend is required over a large area (> 10,000 km^2), the above mentioned clustering design could be employed across years, but with substantially increased financial resources required. Otherwise, expert opinion supported by empirical data from portions of the larger area is the most financially and logistically viable option. Experts who are employed in any monitoring effort require access to data to inform their opinion, or should have personal experience or observations that generate new data. Additional data may include a combination of approaches (e.g., occupancy and density, Chandler et al., 2014). Expert opinion is not a substitute for more rigorous survey techniques, but rather it can occur in concert with rigorous surveys in select areas. Experts can increase their knowledge and become more reliable at assessing bear populations if they are able to witness some case studies yielding reliable and precise quantitative data.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We thank members of the IUCN bear specialist group who contributed to conversations regarding population monitoring of Asian bear species. This work is a product of a workshop held in Taiwan in November 2019, hosted and supported by the IUCN Species Survival Commission Bear Specialist Group, the Taiwan Black Bear Conservation Association, Forestry Bureau, Yushan National Park Headquarters, Taipei Zoo, Ministry of Interior/Construction and Planning Agency, and E. SUN Bank, Everest Textile Co., LTD. DJM contributions supported by USDA National Institute of Food and Agriculture, McIntire Stennis project (1020959). This research did not receive any specific grant form funding agencies in the public, commercial or not-for-profit sectors.

References

Agha, M., Batter, T., Bolas, E.C., Collins, A.C., da Rocha, D.G., Monteza-Moreno, C.M., Preckler-Quisquater, S., Sollman R, S., 2018. A review of wildlife camera trapping trends across Africa. J. Nat. Sci. 56, 694–701.
Anadón, J.D., Giménez, A., Ballestar, R., Pérez, I., 2008. Evaluation of local ecological knowledge as a method for collecting extensive data on animal abundance. Conserv. Biol. 23617–23625.
Anderson, D.A., 2001. The need to get the basics right in wildlife studies. Wildl. Soc. Bull. 29, 1294–1297.
Arias, M., Hinsley, A., Milner-Gulland, E.J., 2020, Implementing the ballot box method to reduce social desirability when researching sensitive behaviours in conservation. Tools and Guidance for Illegal Wildlife Trade. Illegal Wildlife Trans, Oxford Martin Program, Oxford, UK.
Aryal, A., Hopkins, J.B., Raubenheimer, D., Ji, W., Brunton, D., 2012. Distribution and diet of brown bears in the upper Mustang Region, Nepal. Ursus 23, 231–236.
Augustine, B.C., Royle, J.A., Linden, D.W., Fuller, A.K., 2020. Spatial proximity moderates genotype uncertainty in genetic tagging studies. PNAS 117, 17903–17912.
Ayyub, B.M., 2001. Elicitation of Expert Opinions for Uncertainty and Risks. CRC Press, Boca Raton.
Azevedo, F.C., Lemos, F.G., Freitas-Junior, M.C., Rocha, D.G., Azevedo, F.C.C., 2018. Puma activity patterns and temporal overlap with prey in a human-modified landscape at Southeastern Brazil. J. Zool. 305, 246–255.
Babu, S., Karthik, T., Srinivas, G., Kumara, H.N., 2015. Linking critical patches of sloth bear Melursus ursinus for their conservation in Meghamalai hills, Western Ghats, India. Curr. Sci. 109, 1492–1498.
Becker, E.F., Crowley, D.W., 2021. Estimating brown bear abundance and harvest rate on the southern Alaska Peninsula. PLoS ONE 16, e0245367. https://doi.org/10.1371/journal.pone.0245367.
Bellemain, E., Nawaz, M.A., Valentini, A., Swenson, J.E., Taberlet, P., 2006. Genetic tracking of the brown bears in northern Pakistan and implications for conservation. Biol. Conserv. 134, 537–547.
Belisle, A.C., Asselin, H., LeBlanc, P., Gauthier, S., 2018. Local knowledge in ecological modeling. Ecol. Soc. 23, 14.
Bisi, F., Cremonesi, G., Gaffi, L., Zibordi, F., Gagliardi, A., Gueli, L., Martinoli, A., Preatoni, D.G., 2019. Watching a movie or going for a walk? Testing different Sun bear (Helarctos malayanus) occupancy monitoring schemes. Hystrix Ital. J. Mammal. 30, 178–182.
Bohmann, K., Evans, A., Gilbert, M.T.P., Carvalho, G.R., Creer, S., Knapp, M., Yu, D.W., de Bruyn, M., 2014. Environmental DNA for wildlife biology and biodiversity monitoring. Trends Ecol. Evol. https://doi.org/10.1016/j.tree.2014.04.003.
Boulanger, J., Stenhouse, G., Munro, R., 2004. Sources of heterogeneity bias when DNA mark–recapture sampling methods are applied to grizzly bear (Ursus arctos) populations. J. Mammal. 85, 618–624.
Boulanger, J., Himmer, S., Swan, C., 2004. Monitoring of grizzly bear population trends and demography using DNA markrecapture methods in the Owikeno Lake area of British Columbia. J. Can. Zool. 1267–1277.
Boulanger, J., Proctor, M., Himmer, S., Stenhouse, G., Paetkau, D., Cranston, J., 2006. An Empirical test of DNA Mark-recapture sampling strategies for grizzly bears. Ursus 17, 149–158.
Browne-Nuñez, C., Jonker, S.A.A., 2008. Attitudes toward wildlife and conservation areas across Africa: a review of survey research. Hum. Wildl. Inter. 13, 49–72.
Bu, H., Wang, F., McShea, W.J., Lu, Z., Wang, D., Li, S., 2016. Spatial co-occurrence and activity patterns of mesocarnivores in the temperate forests of southwest China. PLoS One 11 e0164271-e0164271.
Burnham, K.P., Overton, S., 1987. Estimation of the size of a closed population when capture probabilities vary among animals. Biometrika 65, 625–633.
Burton, A.C., Fisher, J.T., Adriaens, P., Treweek, J., Paetkau, D., Wikstrom, M., Callender, A., Vardanyan, R., Stepanyan, A., 2018. Density and distribution of a brown bear (*Ursus arctos*) population within the Caucasus biodiversity hotspot. J. Mammal. 99, 1249–1260.
Caniglia, R., Fabbri, E., Mastrogiuseppe, L., Randi, E., 2013. Who is who? Identification of livestock predators using forensic genetic approaches. Forensic Sci. Int. 7, 397–404.
Cano, L.S., Tellería, J.L., 2013. Local ecological knowledge as a tool for assessing the status of threatened vertebrates: a case study in Vietnam. Oryx 47, 177–183.
Carter, N., Jasny, M., Gurung, B., Liu, J., 2015. Impacts of people and tigers on leopard spatiotemporal activity patterns in a global biodiversity hotspot. Glob. Ecol. Conserv. 3, 149–162.
Caswell, H., 2001. Matrix Population Models: Construction, Analysis, and Interpretation, 2nd, illustr ed. Sinauer Associates,, Sunderland, Massachusetts.
Caughley, G., 1977. Analysis of Vertebrate Populations. Wiley, London, UK.
Chapron, G., Kaczensky, P., Linnell, J.D.C., et al., 2014. Recovery of large carnivores in Europe's modern human-dominated landscapes. Science 346, 1517–1519.
Chen, P., Swarup, P., Matkowski, W.M., Kong, A.W.K., Han, S., Zhang, Z., Rong, H., 2020. A study on giant panda recognition based on images of a large proportion of captive pandas. Ecol. Evol. 10, 3561–3573. https://doi.org/10.1002/ece3.6152.
Clapham, M., Nevin, O.T., Ramsey, A.D., Rosell, F., 2014. Scent-marking investment and motor patterns are affected by the age and sex of wild brown bears. Anim. Behav. 94, 107–116.
Clapham, M., Miller, E., Nguyen, M., Darimont, C.T., 2020. Automated facial recognition for wildlife that lack unique markings: A deep learning approach for brown bears. Ecol. Evol. 10, 12883–12892. https://doi.org/10.1002/ece3.6840.
Clare, E.L., Economou, C.K., Faulkes, C.G., Gilbert, J.D., Bennett, F., Drinkwater, R., Littlefair, J.E., 2021. eDNAir: Proof of concept that animal DNA can be collected from air sampling. PeerJ 9, e11030. https://doi.org/10.7717/peerj.11030.
Clark, J.D., 2019. Comparing clustered sampling designs for spatially explicit estimation of population density. Popul. Ecol. 61, 93–101.
Connor, T., Hull, V., Liu, J., 2016. Telemetry research on elusive wildlife: a synthesis of studies on giant pandas. Integr. Zool. 11, 295–307.
Costello, C.M., 2010. Estimates of dispersal and home-range fidelity in American black bears. J. Mammal. 91, 116–121.
Craighead, F., 1976. Grizzly bear ranges and movement as determined by radio tracking. Int. Conf. Bear. Res. Manag. 3, 97–110.
Crudge, B., Wilkinson, N.M., Do, V.T., Cao, T.D., Cao, T.T., Weegenaar, A., Hunt, M., 2016. The status and distribution of bears in Vietnam, 2016. Technical Report. Free the Bears/Animals Asia, Viet Nam.
Das, S., Dutta, S., Sen, S., A. S., J., Babu, S., Kumara, H.N., Singh, M., 2014. Identifying regions for conservation of sloth bears through occupancy modelling in north-eastern Karnataka, India. Ursus 25, 111–120. https://doi.org/10.2192/URSUS-D-14-00008.1.
Davis, E.O., Crudge, B., Lim, T., O'Connor, D., Roth, V., Hunt, M., Glikman, J.A., 2019. Understanding the prevalence of bear part consumption in Cambodia: A comparison of specialised questioning techniques. PLoS One 14, e0211544.
De Barba, M., Waits, L.P., Garton, E.O., Genovesi, P., Randi, E., Mustoni, A., Groffs, C., 2010. The power of genetic monitoring for studying demography, ecology and genetics of a reintroduced brown bear population. Mol. Ecol. 19, 3938–3951.

De Barba, M., Miquel, C., Lobreaux, S., Quenette, P.Y., Swenson, J.E., Taberlet, P., 2016. High-throughput microsatellite genotyping in ecology: improved accuracy, efficiency, standardization and success with low-quantity and degraded DNA. Mol. Ecol. Res. 17, 492–507. https://doi.org/10.1111/1755-0998.12594.
Dey, S., Delampady, M., Parameshwaran, R., Kumar, N.S., Srivathsa, A., Karanth, K.U., 2017. Bayesian methods for estimating animal abundance at large spatial scales using data from multiple sources. J. Agric. Biol. Environ. Stat. 22, 111–139. https://doi.org/10.1007/s13253-017-0276-7.
Dharaiya, N., Bargali, H.S., Sharp, T., 2016. *Melursus ursinus*. IUCN Red List Threat. Species 2016 e.T13143A45033815. https://doi.org/10.2305/IUCN.UK.2016-3.RLTS.T13143A45033815.en.
Drinkwater, R., Jucker, T., Potter, J.H.T., Swinfield, T., Coomes, D.A., Slade, E.M., Gilbert, M.T.P., Lewis, O.T., Bernard, H., Struebig, M.J., Clare, E.L., Rossiter, S.J., 2020. Leech blood-meal invertebrate-derived DNA reveals differences in Bornean mammal diversity across habitats. Mol. Ecol. 13, 3299–3312. https://doi.org/10.1111/mec.15724.
Drinkwater, R., Clare, E.L., Chung, A.Y., Rossiter, S.J., Slade, M., 2021. Dung beetles as vertebrate samplers-a test of high throughput 1 analysis of dung beetle iDNA. bioRxiv. https://doi.org/10.1101/2021.02.10.430568.
Durnin, M.E., PalsbØll, P.J., Ryder, O.A., McCullough, D.R., 2007. A reliable genetic technique for sex determination of giant panda (*Ailuropoda melanoleuca*) from non-invasively collected hair samples. Conserv. Gen. 8, 715–720.
Dutta, T., Sharma, S., Maldonado, E.H., Panwar, S., Seidensticker, J., 2015. Genetic variation, structure, and gene flow in a sloth bear (*Melursus ursinus*) meta-population in the Satpura-Maikal landscape of Central India. PLoS ONE 10, e0123384.
Knight, R.R., Eberhardt, L.L., 1985. Population dynamics of Yellowstone grizzly bears. Ecology 66, 323–334.
Farhadinia, M.S., Valizadegan, N., 2015. A preliminary baseline status of the Syrian Brown Bear Ursus arctos syriacus (Mammalia: Carnivora: Ursidae) in Golestanak, northern Iran. J. Threat. Taxa 7, 6796–6799. https://doi.org/10.11609/jott.o3708.6796-9.
Forgacs, D., Wallen, R.L., Boedeker, A.L., Derr, J.N., 2019. Evaluation of fecal samples as a valid source of DNA by comparing paired blood and fecal samples from American bison (*Bison bison*). BMC Genet. 20, 22. https://doi.org/10.1186/s12863-019-0722-3.
Forsyth, D.M., Hickling, G.J., 1997. An improved technique for indexing abundance of Himalayan thar. N. Z. J. Ecol. 21, 97–101.
Fredriksson, G.M., Wich, S.A., Trisno, 2006. Frugivory in sun bears (Helarctos malayanus) is linked to El Niño-related fluctuations in fruiting phenology, East Kalimantan, Indonesia. Biol. J. Linn. Soc. 89, 489–508.
Fredriksson, G.M., 2012, Effects of El Nino and large-scale forest fires on the ecology and conservation of Malayan sun bears (*Helarctos malayanus*) in East Kalimantan Indonesian Borneo. PhD thesis, University of Amsterdam.
Fuller, A.K., Augustine, B.C., Morin, D.J., Pigeon, K., Boulanger, J., Lee, D.C., Bisi, F., Garshelis, D.L. 2022. The occupancy-abundance relationship and sampling designs using occupancy to monitor populations of Asian bears. Global Ecology and Conservation (in this issue).
Garshelis, D.L., 1992. Mark-recapture density estimation for animals with large home ranges. In: McCullough, D.R., Barrett, D.R., R.H. (Eds.), Wildlife 2001: populations. Elsevier Applied Science, London, pp. 1098–1111.
Garshelis, D.L., Hristienko, H., 2006. State and provincial estimates of American black bear numbers versus assessments of population trend. In: Ursus, 17, pp. 1–7.
Garshelis, D., Steinmetz, R., 2020. *Ursus thibetanus* (Amend. Version 2016 Assess.). IUCN Red List Threat. Species 2020. e.T22824A166528664. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T22824A166528664.en.
Garshelis, D.L., Joshi, A.R., Smith, J.L.D., 1999. Estimating density and relative abundance of sloth bears. Ursus 11, 87–98.
Garshelis, D.L., Gibeau, M.L., Herrero, S., 2005. Grizzly bear demographics in and around Banff National Park and Kananaskis Country, Alberta. J. Wildl. Manag. 69, 277–297.
Garshelis, D.L., Hao, W., Dajun, W., Xiaojian, Z., Sheng, L., McShea, W.J., 2008. Do revised giant panda population estimates aid in their conservation. Ursus 19, 168–176. https://doi.org/10.2192/07PER011.1.
Garshelis, D.L., Dhariaya, N.A., Sharp, T.R., Steinmetz, R., Wangdi, Y., Wangchuk, S., 2015. Sloth bears at the northern edge of their range: status of the transboundary population linking northeastern India to Bhutan. Final Report to International Association for Bear Research and Management,.
Garshelis, D.L., Pigeon, K., Hwang, M.-H., Proctor, M., McShea, W.J., Fuller, A.K., Morin, D.J., 2022. The need to step-up monitoring of Asian bears. Glob. Ecol. Conserv. (in this issue).
Golden, C., Wrangham, R.W., Brashares, J.S., 2013. Assessing the accuracy of interviewed recall for rare, highly seasonal events: the case of wildlife consumption in Madagascar. Anim. Conserv. 16, 597–603.
Green, S.E., Rees, J.P., Stephens, P.A., Hill, R.A., Giordano, A.J., 2020. Approaches: the integration of citizen science and artificial intelligence. Animals 10, 132.
Guharajan, R., Arnold, T.W., Bolongon, G., Dibden, G.H., Abram, N.K., Teoh, S.W., Magguna, M.A., Goossens, B., Wong, S.T., Nathan, S.K.S.S., Garshelis, D.L., 2018. Survival strategies of a frugivore, the sun bear, in a forest-oil palm landscape. Biodivers. Conserv. 27, 3657–3677. https://doi.org/10.1007/s10531-018-1619-6.
Hameed, S., Abbas, K., Younas, M., Murtaz, G., Mahdi, G., Nawaz, M.A., 2013, Himalayan brown bears in Deosai National Park: current status and threats. Snow Leopard Foundation.
Harris, R.B., Schwartz, C.C., Mace, R.D., Haroldson, M.A., 2011. Study design and sampling intensity for demographic analyses of bear populations. Ursus 22, 24–36.
Hou, J., He, Y., Yang, H., Connor, T., Gao, J., Wang, Y., Zeng, Y., Zhang, J., Huang, J., Zheng, B., Zhou, S., 2020. Identification of animal individuals using deep learning: A case study of giant panda. Biol. Conserv. 242, 108414.
Hou, J., Hull, V., Connor, T., Yang, H., Gao, J., Zhao, F., Liao, Y., Chen, S., Huang, J., Zeng, Y., Zhou, S., Zhou, J., Zhang, J., 2021. Scent communication behavior by giant pandas. Glob. Ecol. Conserv. 25, e01431.
Huang, Z.-P., Qi, X.-G., Garber, P.A., Jin, T., Guo, S.-T., Li, S., Li, B.-G., 2014. The use of camera traps to identify the set of scavengers preying on the carcass of a golden snub-nosed monkey (*Rhinopithecus roxellana*). PLoS ONE 9, e87318.
Huang, J., Li, Y.-Z., Du, L.-M., Yang, B., Shen, F.-U., Zhang, H.-M., Zhang, Z.-H., Zhang, X.-Y., Yue, B.-S., 2015. Genome-wide survey and analysis of microsatellites in giant panda (*Ailuropoda melanoleuca*), with a focus on the applications of a novel microsatellite marker system. Genomics 16, 16.
Humm, J., McCown, J.W., Scheick, B.K., Clark, J.D., 2017. Spatially explicit population estimates for black bears based on cluster sampling. J. Wildl. Manag. 81, 1187–1201.
Huntington, H.P., 2000. Using traditional ecological knowledge in science: methods and applications. Ecol. Appl. 10, 1270–1274.
Hwang, M.-S., 2003, Ecology of Asiatic black bears and people-bear interaction in Yushan National Park, Taiwan. PhD Dissertation, University of Minnesota. Minneapolis, USA.
Hwang, M.H., Garshelis, D.L., Wu, Y.-H., Wang, Y., 2010. Home ranges of Asiatic black bears in the Central Mountains of Taiwan: Gauging whether a reserve is big enough. Ursus 21, 81–96.
Hwang, M., Ditmer, M.A., Teo, S., Wong, S.T., Garshelis, D.L., 2021. Sun bears use 14–year-old previously logged forest more than primary forest in Sabah, Malaysia. Ecosphere 12. https://doi.org/10.1002/ecs2.3769.
Islam, M.A., Uddin, M., Aziz, M.A., Muzaffar, S.B., Chakma, S., Chowdhury, S.U., Chowdhury, G.W., Rashid, M.A., Mohsanin, S., Jahan, I., Saif, S., Hossain, M.B., Chakma, D., Kamruzzaman, M., Akter, R., 2013. Status of bears in Bangladesh: going, going, gone? Ursus 24, 83–90. https://doi.org/10.2192/URSUS-D-12-00010.1.
Ivan, J.S., White, G.C., Shenk, T.M., 2013. Using auxiliary telemetry information to estimate animal density from capture–recapture data. Ecology 94, 809–816.
Ji, Y., Baker, C.C.M., Ji, Y., Popescu, V.D., Wang, J., Wu, C., Wang, Z., Li, Y., Wang, L., Hua, C., Yang, Z., Yang, C., Xu, C.C.Y., Diana, A., Wen, Q., Pierce, N.E., Yu, D.W., 2020. Measuring protected-area outcomes with leech iDNA: large-scale quantification of vertebrate biodiversity in Ailaoshan nature reserve. bioRxiv. https://doi.org/10.1101/2020.02.10.941336.
Johnson, H.E., Lewis, D.L., Breck, S.W., 2020. Individual and population fitness consequences associated with large carnivore use of residential development. Ecosphere 11, e03098.
Joshi, A.R., Garshelis, D.L., Smith, J.L.D., 1997. Seasonal and habitat-related diets of sloth bears in Nepal. J. Mammal. 78, 584–597. https://doi.org/10.2307/1382910.

Kadariya, R., Shimozuru, M., Maldonado, J.E., Abdallah, M., Moustafa, M., Sashhika, T., Tsubota, M., 2018. High genetic diversity and distinct ancient lineage of Asiatic black bears revealed by non-invasive surveys in the Annapurna Conservation Area, Nepal. PLoS ONE 13 (12), e0207662. https://doi.org/10.1371/journal.pone.0207662.
Kasworm, W.F., Radandt, T.G., Teisberg, J.E., Vent, T., Welander, A., Proctor, M., Cooley, H., Fortin-Noreau, J., 2020. Cabinet-Yaak grizzly bear recovery area 2019 research and monitoring progress report. U.S. Fish and Wildlife Service Grizzly Bear Coordinator's Office, University of Montana, Missoula,, Montana, USA.
Keating, K.A., Schwartz, C.C., Haroldson, M.A., Moody, D., 2002. Estimating numbers of females with cubs-of-the-year in the Yellowstone grizzly bear population. Ursus 13, 161–174.
Kendal, K.C., Metzgar, L.H., Patterson, D.A., Steele, B.M., 1992. Power of sign to monitor population trend. Ecol. Appl. 2, 422–430.
Kendall, K.C., Stetz, J.B., Boulanger, J., MacLeod, A.C., Paetkau, D., White, G.C., 2009. Demography and genetic structure of a recovering grizzly bear population. J. Wildl. Manag. 73, 3–17.
Kindberg, J., Swenson, J.E., Ericsson, G., Bellemain, E., Miquel, C., Taberlet, P., 2011. Estimating population size and trends of the Swedish brown bear *Ursus arctos* population. Wildl. Biol. 17, 114–123. https://doi.org/10.2981/10-100.
Knight, R.R., Blanchard, B.M., Eberhard, L.L., 1995. Appraising status of the Yellowstone grizzly bear population by counting females with cubs-of-the-years. Wildl. Soc. Bull. 23, 245–248.
Kopatz, A., Eiken, H.K., Hagen, S.B., Ruokonen, M., Esparza-Salas, R., Schregel, J., Kojola, I., Smith, M.E., Wartianinen, I., Aspholm, P.E., Wikan, S., Rykov, A.M., Makarova, O., Polikarpova, N., Tirronen, K.F., Danilov, P.I., Aspi, J., 2012. Connectivity and population subdivision at the fringe of a large brown bear (Ursus arctos) population in North Western Europe. Conserv. Genet. 13, 681–692.
Kopatz, A., Eiken, H.G., Aspi, J., Kojola, I., Tobiassen, C., Torronen, K.F., Danilov, P.I., Hagen, S.B., 2014. Admixture and gene flow from Russian in the recovering northern Europe brown bear (*Ursus arctos*). PLoS ONE 9, e97558.
Kunde, M.N., Goossens, B., 2021. Sun bear predation on an oriental pied hornbill nest. Ursus 32, 1–4. https://doi.org/10.2192/URSUS-D-19.00018.1.
Lamb, C.T., Ford, A.T., Proctor, M.F., Royle, J.A., Mowat, G., Boutin, S., 2019. Genetic tagging in the Anthropocene: scaling ecology from alleles to ecosystems. Ecol. Appl. 29, e01876 https://doi.org/10.1002/eap.1876.
Lamichhane, B.R., Gurung, A., Poudel, S., Pokheral, C.P., Subedi, N., 2016. Sloth Bear Sightings as a Population Index in Chitwan National Park, Nepal. Int. Bear. N. 25, 25–27.
Laufenberg, J.S., Clark, J.D., Hooker, M.J., Lowe, C.L., O'Connell-Goode, K.C., Troxler, J.C., Davidson, M.M., Chamberlain, M.J., Chandler, R.B., 2016. Demographic rates and population viability of black bears in Louisiana. Wildl. Monogr. 194, 1–37.
Laughlin, W.S., 1968. Hunting: an integrating biobehavior system and its evolutionary importance. In: Lee, R.B., Devore, I. (Eds.), Man the Hunter. Routledge, New York, pp. 304–320.
Lee, P.S., Gan, H.M., Clements, G.R., Wilson, J.J., 2016. Field calibration of blowfly-derived DNA against traditional methods for assessing mammal diversity in tropical forests. Genome 59, 1008–1022. https://doi.org/10.1139/gen-2015-0193.
Lee, T.L., Lai, W.L., Wei, T.K.J., Shern, O.Z., van Manen, F.T., Sharp, S.P., Wong, S.T., Chew, J., Ratnayeke, S., 2020. An evaluation of non-invasive sampling techniques for Malayan sun bears. Ursus 31, e16.
Legg, C.J., Nagy, L., 2006. Why most conservation monitoring is, but not need be, a waste of time. J. Environ. Manag. 78, 194–199.
Li, S., 2020. Development progress and outlook of the wildlife camera-trapping networks in China. Biod, Sci. 28, 1045–1048.
Li, F., Zheng, X., Jiang, X.-L., Chan, B.P.L., 2017. Rediscovery of the sun bear (*Helarctos malayanus*) in Yingjiang County, Yunnan Province, China. Zool. Res 38, 206–207. https://doi.org/10.24272/j.issn.2095-8137.2017.044.
Li, S., Wang, D., Gu, X., McShea, W.J., 2010. Beyond pandas, the need for a standardized monitoring protocol for large mammals in Chinese nature reserves. Biodiverse. Conserv. 19, 3195–3206.
Li, S., McShea, W.J., Wang, D., Gu, X., Zhang, X., Zhang, L., Shen, X., 2020a. Retreat of large carnivores across the giant panda distribution range. Nat. Ecol. Evol. 4, 1327–1331.
Li, S., McShea, W.J., Wang, D., Shen, X., Bu, H., Guan, T., Wang, F., Gu, X., Zhang, X., Liao, H., 2020b. Construction progress of the Camera-trapping Network for the Mountains of Southwest China. Biodivers. Sci. 28, 1049–1058.
Linkie, M., Dinata, Y., Nugroho, A., Haidir, I.A., 2007. Estimating occupancy of a data deficient mammalian species living in tropical rainforests: Sun bears in the Kerinci Seblat region, Sumatra. Biol. Conserv. 137, 20–27.
Liu, F., McShea, W., Garshelis, D., Zhu, X., Wang, D., Gong, Je, Chen, Y., 2009. Spatial distribution as a measure of conservation needs: an example with Asiatic black bears in south-western China. Divers. Distrib. 15, 649–659.
Liu, F., McShea, W.J., Garshelis, D.L., Zhu, X., Wang, D., Shao, L., 2011. Human-wildlife conflicts influence attitudes but not necessarily behaviors: Factors driving the poaching of bears in China. Biol. Conserv. 144, 538–547.
Long, R.A., MacKay, P., Ray, J.C., Zielinski, W.J., 2008. Noninvasive Survey Methods for Carnivores. Island Press, Washington, DC, USA.
Long, R.A., Donovan, T.M., MacKay, P., Zielinski, W.J., Buzas, J.S., 2010. Effectiveness of scat detecting dogs for detecting forest carnivores. J. Wildl. Manag. 71, 2007–2017. https://doi.org/10.2193/2006-230.
Mace, R.D., Minta, S.C., Manley, T.L., Aune, K.E., 1994. Estimating grizzly bear population size using camera sightings. Wildl. Soc. Bull. 22, 74–83.
Mace, R.D., Carney, D.W., Chilton-Radant, T., Courville, S.A., Haroldson, M.A., Harris, R.B., Jonkel, J., McLellan, B.N., Madel, M., Manley, T.L., Schwartz, C.C., Servheen, C., Stenhouse, G., Waller, J.S., Wenum, E., 2012. Grizzly bear population vital rates and trend in the Northern Continental Divide Ecosystem, Montana. J. Wildl. Manag. 76, 119–128.
Magoun, A.J., Long, C.D., Schwartz, M.K., Pilgrim, K.L., Lowell, C.E., Valkenburg, P., 2011. Integrating motion-detection cameras and hair snags for wolverine identification. J. Wildl. Manag. 75, 731–739. https://doi.org/10.1002/jwmg.107.
Malcolm, K.D., McShea, W.J., Garshelis, D.L., Luo, S.-J., Van Deelen, T.R., Liu, F., Li, S., Miao, L., Wang, D., Brown, J.L., 2014. Increased stress in Asiatic black bears relates to food limitation, crop raiding, and foraging beyond nature reserve boundaries in China. Glob. Ecol. Conserv. 2, 267–276.
Martin, T.G., Burgman, M.A., Fidler, F., Kuhnert, P.M., Low-Choy, S., McBride, M., Mengersen, K., 2012. Eliciting expert knowledge in conservation science. Conserv. Biol. 26, 29–38.
McLellan, B.N., 1989. Population dynamics of grizzly bears during a period of resource extraction development. III. Natality and rate of change. Can. J. Zool. 67, 1865–1868.
McLellan, B.N., 2015. Some mechanisms underlying variation in vital rates of grizzly bears on a multiple use landscape. J. Wildl. Manag. 79, 749–765.
McLellan, B.N., Proctor, M.F., Huber, D. Michel, S., (IUCN SSC Bear Specialist Group). 2017. *Ursus arctos*. The IUCN Red List of Threatened Species 2016. IUCN website. ⟨https://www.iucnredlist.org/species/41688/121229971#population⟩.
McLellan, M.L., McLellan, B.N., Sollmann, R., Lamb, C.T., Apps, C.D., Wittmer, H., 2019. Divergent population trends following the cessation of legal grizzly bear hunting in southwestern British Columbia, Canada. Biol. Conserv. 233, 247–254.
McShea, W., Forrester, T., Costello, R., He, H., Kays, R., 2016. Volunteer-run cameras as distributed sensors for macrosystem mammal research. In: Landscape Ecol, 31, pp. 55–66. ⟨https://link.springer.com/article/10.1007/s10980-015-0262-9⟩.
McShea, W.J., Hwang, M.-H. Liu, F., Li, S., Lamb, C.T., McLellan, B., Morin, D.J., Pigeon, K., Proctor, M.F., Hernandez-Yanez, H., Frerichs, T., Garshelis, D.L., 2022. Is the delineation of range maps useful for monitoring Asian bears? Global Ecology and Conservation (in this issue).
Mena, J.L., Yagui, H., Tejeda, V., Bonifaz, E., Bellemain, E., Valentini, A., Tobler, M.W., Sánchez-Vendizú, P., Lyet, A., 2021. Environmental DNA metabarcoding as a useful tool for evaluating terrestrial mammal diversity in tropical forests. Ecol. Appl., e2335 https://doi.org/10.1002/eap.2335.
Miura, S., Oka, T., 2003. Evaluation of apple bait hair-traps for genetic tagging of Asiatic black bears in the Kitakami Highland, northern Honshu, Japan. Mammal. Study 28, 149–152.
Miller, S.D., White, G.C., Sellers, R.A., Reynolds, H.V., Schoen, J.W., Titus, K., Barnes Jr., V.G., Smith, R.B., Nelson, R.R., Ballard, W.B., Schwartz, C.C., 1997. Brown and black bear density estimation in Alaska using radio telemetry and replicated mark–resight techniques. Wildl. Monogr. 133.

Mohammedi, A., Almasieh, K., Nayeri, D., Ataei, F., Khani, A., Lope, J.V., Penteriani, V., Cushman, S.A., 2021. Identifying priority core habitats and corridors for effective conservation of brown bears. Sci. Rep. 11, 1044. ⟨https://www.nature.com/articles/s41598-020-79970-z⟩.
Moqanakia, E.M., Jiménez, J., Bensch, S., López-Bao, J.V., 2018. Counting bears in the Iranian Caucasus: Remarkable mismatch between scientifically-sound population estimates and perceptions. Biol. Conserv. 220, 182–191.
Morehouse, A.T., Boyce, M.S., 2016. Grizzly bears without borders: spatially explicit capture-recapture in southwestern Alberta. J. Wildl. Manag. 80, 1152–1166.
Morehouse, A.T., Graves, T.A., Mikle, N., Boyce, M.S., 2016b. Nature vs. Nurture: evidence for social learning of conflict behaviour in grizzly bears. PLOS ONE 11, e0165425.
Morin, D.J., Boulanger, J., Bischof, R. Lee, D.C., Ngoprasert, D., Fuller, A.K., McLellan, B., Steinmetz, R., Sharma, S., Garshelis, D.L., Gopalaswamy, A.M., Nawaz, M. A., Karanth, U., 2022, Comparison of methods for estimating density and population trends for low-density Asian bears. Glob. Ecol. Conserv. (in this issue).
Murphy, M.A., Waits, L.P., Kendall, K.C., Wasser, S.K., Higbee, J.A., Bogden, R., 2002. An evaluation of long-term preservation methods for brown bear (*Ursus arctos*) faecal DNA samples. Conserv. Genet 3, 435–440. https://doi.org/10.1023/A:1020503330767.
Murray, J.V., Goldizen, A.W., O'Leary, R.A., McAlpine, C.A., Possingham, H.P., Choy, S.L., 2009. How useful is expert opinion for predicting the distribution of a species within and beyond the region of expertise? A case study using brush-tailed rock-wallabies (Petrogale penicillata). J. Appl. Ecol. 46, 842–851.
Naing, H., Htun, S., Kamler, J.F., Burnham, D., Macdonald, D.W., 2020. Large carnivores as potential predators of sun bears. Ursus 3, 51–57.
Nash, H.C., Wong, M.H., Turvey, S.T., 2016. Using local ecological knowledge to determine status and threats of the Critically Endangered Chinese pangolin (*Manis pentadactyla*) in Hainan, China. Biol. Conserv. 196, 189–195.
Nawaz, M.A., 2007. Status of the brown bear in Pakistan. Ursus 18, 89–100.
Nawaz, M.A., Swenson, J.E., Zakaria, V., 2008. Pragmatic management increases a flagship species, the Himalayan brown bears, in Pakistan's Deosai National Park. Biol. Conserv. 141, 1130–1141.
Nazeri, M., Jusoff, K., Madani, N., Mahmud, A.R., Bahman, A.R., Kumar, L., 2012. Predictive modeling and mapping of Malayan sun bear (*Helarctos malayanus*) distribution using maximum entropy. PLoS ONE 7, e48104. https://doi.org/10.1371/journal.pone.0048104.
Ngoprasert, D., Steinmetz, R., 2012. Differentiating Asiatic black bears and sun bears from camera trap photographs. Int. Bear. N. 21, 18–19.
Ngoprasert, D., Steinmetz, R., Reed, D.H., Savini, T., Gale, G.A., 2011. Influence of fruit on habitat selection of Asian bears in a tropical forest. J. Wildl. Manag. 75, 588–595. https://doi.org/10.1002/jwmg.83.
Ngoprasert, D., Reed, D.H., Steinmetz, R., Gale, G.A., 2012. Density estimation of Asian bears using photographic capture-recapture sampling based on chest marks. Ursus 23, 117–133.
Ngoprasert, D., Steinmetz, R., Gale, G.A., 2013. Estimating the abundance of Asiatic black bears and sun bears in Thailand. Int. Bear. N. 22 (3), 30–32.
Nie, Y., Swaisgood, R.R., Zhang, Z., Hu, Y., Ma, Y., Wei, F., 2012. Giant panda scent-marking strategies in the wild: role of season, sex and marking surface. Anim. Behav. 84, 39–44.
Norouzzadeh, M.S., Nguyen, A., Kosmala, M., Swanson, A., Palmer, M.S., Packer, C., Clune, J., 2018. Automatically identifying, counting, and describing wild animals in camera-trap images with deep learning. PNAS 115, E5716–E5725.
Nuno, A., John, F.A.S., 2015. How to ask sensitive questions in conservation: A review of specialized questioning techniques. Biol. Conserv. 189, 5–15.
O'Connell, A.F., Nichols, J.D., Karanth, K.U., 2011. Camera Traps in Animal Ecology: Methods and Analyses. Springer Publishing, Tokyo, Japan.
Paetkau, D., 2003. An empirical exploration of data quality in DNA-based population inventories. Mol. Ecol. 12, 1375–1387.
Paetkau, D.H., Shields, G.F., Strobeck, C., 1998. Gene flow between insular, coastal and interior populations of brown bears in Alaska. Mol. Ecol. 7, 1283–1292.
Palomero, G., Ballesteros, F., Nores, C., Bianco, J.C., Herrero, J., Garcia-Serrano, A., 2006. Trends in number and distribution of brown bear females with cubs-of-the-year in the Cantabrian Mountains, Spain. Ursus 18, 145–157.
Pan, W., Lu, Z., Zhu, X., Wang, D., Wang, H., Long, Y., Fu, D., Zhou, X., 2014. In: McShea, W., Garshelis, D., Wang, D. (Eds.), A Chance for Lasting Survival: Ecology and Behavior of Wild Giant Pandas. Smithsonian Institution Scholarly Press.
Phoebus, I., Boulanger, J., Eiken, H.G., Floystad, I., Graham, K., Hagen, S.B., Sorensen, A., Stenhouse, G., 2020. Comparison of grizzly bear hair-snag and scat sampling along roads to inform wildlife population monitoring. Wildl. Biol. 2020. https://doi.org/10.2981/wlb.00697.
Pillay, R., Miller, D.A., Hines, J.E., Joshi, A.A., Madhusudan, M.D., 2014. Accounting for false positives improves estimates of occupancy from key informant interviews. Divers. Distrib. 20, 223–235.
Pompanon, F., Bonin, A., Bellemain, E., Taberlet, P., 2005. Genotyping errors: causes, consequences and solutions. Genotyping errors: causes, consequences and solutions. Nat. Rev. Genet. 6, 847–859. https://doi.org/10.1038/nrg1707.
Proctor, M.F., McLellan, B.N., Strobeck, C., Barclay, R., 2004. Gender-specific dispersal distances of grizzly bears estimated by genetic analysis. Can. J. Zool. 82, 1108–1118.
Proctor, M.F., McLellan, B.N., Boulanger, J., Apps, C., Mowat, G., Paetkau, D., Stenhouse, G., 2010. Ecological investigations of Canadian grizzly bears using hair-snagged DNA, 1995-2005. Ursus 21, 169–188.
Proctor, M.F., Paetkau, D., McLellan, B.N., Stenhouse, G.B., Kendall, K.C., Mace, R.D., Kasworm, W.F., Servheen, C., Lausen, C.L., Gibeau, M.L., Wakkinen, W.L., Haroldson, M.A., Mowat, G., Apps, C.D., Ciarniello, L.M., Barclay, R.M.R., Boyce, M.S., Schwartz, C.C., Strobeck, C., 2012. Population fragmentation and inter-ecosystem movements of grizzly bears in western Canada and the northern United States. Wildl. Monogr. 180, 1–46.
Proctor, M.F., Kasworm, W.F., Annis, K.M., MacHutchon, A.G., Teisberg, J.E., Radandt, T.G., Servheen, C., 2018. Conservation of threatened Canada-USA trans-border grizzly bears linked to comprehensive conflict reduction. Hum. Wildl. Interact. 12, 248–272.
Puri, M., Srivathsa, A., Karanth, K.K., Kumar, N.S., Karanth, K.U., 2015. Multiscale distribution models for conserving widespread species: the case of sloth bear Melursus ursinus in India. Biodivers. Res 21, 1087–1100.
Quang, P.X., Becker, E.F., 1997. Combining line transect and double count sampling techniques for aerial surveys. J. Agric. Biol. Environ. Stat. 2, 230–242. https://doi.org/10.2307/1400405.
Quinn, T.P., Wirsing, A.J., Proctor, M., 2022. Optimal barbed wire height for brown bear hair sample collection. Ursus 33e2, 1–6. https://doi.org/10.2192/URSUS-D-21-00007.1.
Ratnayeke, S., Van Manen, F.T., Pieris, R., Pragash, V.S.J., 2007. Landscape characteristics of sloth bear range in Sri Lanka. Ursus 18, 189–202.
Reynolds, J.H., Thompson, W.L., Russell, B., 2010. Planning for success: Identifying effective and efficient survey design for monitoring. Biol. Conserv. 144, 1278–1284.
Rovero, F., Zimmermann, F., 2016. Camera trapping for wildlife research. Pelagic Publishing, Exeter, UK.
Rupert, K.M., Kline, R.J., Rahman, M.S., 2019, Past, present and future perspectives on environmental DNA (eDNA) metabarcoding: A systematic review in methods, monitoring, and application of global eDNA. Glob. Ecol. Conserv. 17, e00547.
Sales, N.G., McKenzie, M.B., Drake, J., Harper, L.R., Browett, S.S., Coscia, I., Wangensteen, O.S., Baillie, C., Bryce, E., Dawson, D.A., Ochu, E., Hänfling, B., Lawson Handley, B., Mariani, S., Lambin, X., Sutherland, C., McDevitt, A.D., 2020. Fishing for mammals: Landscape-level monitoring of terrestrial and semi-aquatic communities using eDNA from riverine systems. J. Appl. Ecol. 57, 707–716. https://doi.org/10.1111/1365-2664.13592.
Sato, Y., Kamiishi, C., Tokaji, T., Mori, M., Koizumi, S., Kobayashi, K., Itoh, T., Sonohara, W., Takada, M.B., Urata, T., 2014. Selection of rub trees by brown bears (*Ursus arctos*) in Hokkaido, Japan. Acta Theriol. 59, 129–137. https://doi.org/10.1007/s13364-013-0143-z.
Schaller, G.B., 1998. Wildlife of the Tibetan steppe. University of Chicago Press.
Scheick, B.K., McCown, J.W., 2014. Geographic distribution of American black bears in North America. Ursus 25, 24–33.
Schnell, I.B., Sollmann, R., Calvignac-Spencer, S., Siddall, M.E., Yu, D.W., Wilting, A., Gilbert, M.T.P., 2015. iDNA from terrestrial haematophagous leeches as a wildlife surveying and monitoring tool - prospects, pitfalls and avenues to be developed. Front. Zool. 12, 24. https://doi.org/10.1186/s12983-015-0115-z.
Schwartz, C.C., Haroldson, M.A., White, G.C., Cherry, S., Keating, K.A., Moody, D., Servheen, C., 2006. Temporal, spatial, and environmental influences on the demographics of grizzly bears in the greater Yellowstone Ecosystem. Wildl. Monogr. 161, 1–68.
Schwartz, C.C., Haroldson, M.A., Cherry, S., Keating, K.A., 2008. Evaluation of rules to distinguish unique female grizzly bears with cubs in Yellowstone. J. Wild. Manag. 72, 543–554.

Schwarz, C.J., Arnason, A.N., 1996. A general methodology for the analysis of capture-recapture experiments in open populations. Biometrics 52, 860–873.
Scotson, L., Fredriksson, G., Augeri, D., Cheah, C., Ngoprasert, D., Wai-Ming, W., 2017. *Helarctos malayanus* (Errata Version Publ. 2018). IUCN Red. List Threat. Species 2017 e.T9760A123798233.
Sellers, R.A., Aumiller, L.D., 1994. Brown bear population characteristics at McNeil River, Alaska. Bears: Biol. Manag. Sel. Pap. Ninth Int. Conf. Bear Res. Manag. 9, 283–293.
Sentilles, J., Vanpe, C., Quenette, P.-Y., 2021. Benefits of incorporating a scat-detecting dog into wildlife monitoring: a case study of Pyrenean brown bear. J. Vertebr. Biol. 69, 20096.
Seydack, A.H., 1984. Application of a photo-recording device in the census of larger rain-forest mammals. S. Afr. J. Wildl. Res. 14, 10–14.
Sharief, A., Joshi, B.D., Kumar, V., Kumar, M., Dutta, R., Sharma, C.M., Thapa, A., Rana, H.S., Mukherjee, T., Singh, A., Thakur, M., Sharma, L.K., Chandra, K., 2020. Identifying Himalayan brown bear (*Ursus arctos isabellinus*) conservation areas in Lahaul Valley, Himachal Pradesh. Glob. Ecol. Conserv. 21, e00900.
Sharma, S., Jhala, Y., Sawarkar, V.B., 2005. Identification of individual tigers (Panthera tigris) from their pugmarks. J. Zool. 267, 9. https://doi.org/10.1017/S0952836905007119.
Sharma, S., Dutta, T., Maldonado, J.E., Wood, T.C., Panwar, H.S., Seidensticker, J., 2013. Selection of microsatellite loci for genetic monitoring of sloth bears. Ursus 24, 164–169.
Sharp, T., Garshelis, D., Steinmetz, R., Dhariya, N., 2016. Differentiating Sloth bears from Asiatic black bears in camera-trap photos. Int. Bear. N. 25, 10–12.
Sharp, T.R., Dhariaya, N.A., Malik, A., Pigeon, K., Rabdi, N., Garshelis, D.L., 2019. Preventing the disappearance of sloth bears and sun bears from northeast India: investigation of a site where three bear species once reportedly co-occurred. Final Rep. Int. Assoc. Bear. Res. Manag.
Shen, Y., Liu, M., Wang, D., Shen, X., Li, S., 2021. Using an interactive mapping approach to identify the distribution range and conservation needs of a large threatened mammal, the Asiatic black bear, in China. Glob. Ecol. Conserv. 31, e01831.
Shih, C.-C., Wu, S.-L., Hwang, M.-H., Lee, L.-L., 2017. Evalutation on the effects of aging factor, sampling and preservation methods on Asiatic black bear *Ursus thibeanus*) noninvasive DNA amplification. Taiwania 62, 363–370.
Skrbinsek, T., Jelencic, M., Waits, L., Kos, I., Trontelj, P., 2010. Highly efficient multiplex PCR of noninvasive DNA does not requrie preamplification. Mol. Ecol. Res 10, 495–501. https://doi.org/10.1111/j.1755-0998.2009.02780.x.
Speirs-Bridge, A., Fidler, F., McBride, M., Flander, L., Cumming, G., Burgman, M., 2010. Reducing overconfidence in the interval judgements of experts. Risk Anal. 305, 12–523.
Srivathsa, A., Puri, M., Kumar, N.S., Jathanna, D., Karanth, K.U., 2018. Substituting space for time: empirical evaluation of spatial replication as a surrogate for temporal replication in occupancy modelling. J. Appl. Ecol. 55, 754–765.
Stander, P.E., Ghau, I.I., Tsisaba, D., Oma, I.I., 1997. Tracking and the interpretation of spoor: a scientifically sound method in ecology. J. Zool. 242, 329–341.
Stander, P.E., 1998. Spoor counts as indices of large carnivore populations: the relationship between spoor frequency, sampling effort and true density. J. Appl. Ecol. 35, 378–385. https://doi.org/10.1046/j.1365-2664.1998.00313.x.
Steinmetz, R., Garshelis, D.L., 2008. Distinguishing Asiatic Black bears and Sun bears by claw marks on climbed trees. J. Wildl. Manag. 72, 814–821.
Steinmetz, R., Garshelis, D.L., 2010. Estimating age of claw marks in Southeast Asia tropical forests as an aid to population monitoring. Ursus 21, 143–153.
Steinmetz, R., Chutipong, W., Seuaturien, N., 2006. Collaborating to conserve large mammals in Southeast Asia. Conserv. Biol. 20, 1391–1401.
Sterndale, R.A., 1884. Natural History of the Mammalia of India and Ceylon. Thacker, Spink, and Co.
Stetz, J.B., Kendall, K.C., Servheen, C., 2010. Evaluation of bear rub surveys to monitor grizzly bear population trends. J. Wildl. Manag. 74, 860–870.
Stetz, J.B., Seitz, T., Sawaya, M.A., 2015. Effects of exposure on genotyping success rates of hair samples from brown and American black bears. J. Fish. Wildl. Manag. 6, 191–198.
Stevens, K., Dehgan, A., Karistetter, M., Rawan, F., Tawhid, M.I., Ostrowski, S., Ali, J.M., Ali, R., 2011. Large mammals surviving conflict in the eastern forests of Afghanistan. Oryx 45, 265–271.
Sun, C.S., Fuller, A.K., Royle, J.A., 2014. Trap configuration and spacing influences parameter estimates in spatial capture-recapture models. PloS One. https://doi.org/10.1371/journal.pone.0088025.
Suryawanshi, K.R., Bhatnagar, Y.V., Mishra, C., 2012. Standardizing the double-observer survey method for estimating ungualte prey of the endangered snow leopard. Oecologia 169, 581–590.
Swaisgood, R.R., Wang, D., Wei, F., 2016, *Ailuropoda melanoleuca*, In IUCN Red List of Threatened Species. ⟨http://www.iucnredlist.org/details/712/0⟩.
Swanson, A., Kosmala, M., Lintott, C., Simpson, R., Smith, A., Packer, C., 2015. Snapshot Serengeti, high-frequency annotated camera trap images of 40 mammalian species in an African savanna. Sci. Data 2, 150026. https://doi.org/10.1038/sdata.2015.26.
Taberlet, P., Griffin, S., Goosens, B., Questiau, S., Manceau, V., Escaravage, N., Waits, L.P., Bouvet, J., 1996. Nucl. Acid. Res 24, 3189–3194.
Tattoni, C., Bragalanti, N., Groff, C., Rovero, F., 2015. Patterns in the use of rub trees by the Eurasian Brown Bear. Hystrix, Italian. J. Mammal. 26, 118–124.
Taylor, A.P., Allen, M.L., Gunther, M.S., 2015. Black bear marking behaviour at rub trees during the breeding season in northern California. Behaviour 152, 1097–1111.
Tee, T.L., Lai, W.L., Wei, T.K.J., Shern, O.Z., van Manen, F.T., Sharp, S.P., Wong, S.T., Chew, J., Ratnayeke, S., 2020. An evaluation of noninvasive sampling techniques for Malayan sun bears. Ursus 31, e16. https://doi.org/10.2192/URSUS-S-20-00004.1.
Teintipsiri, T., Sripian, P., Ngoprasert, D., 2015. Asiatic black bear identification based on chest marks photo classification. The 10th Asian Forum on Graphic Science, Japan Society for Graphic Science,, Bangkok. Thailand.
Thatte, P., Patel, K., Ramakreishnan, U., 2018. Rapid species identification of sloth bears from non-invasive samples: a PC-based assay. Ursus 29, 67–70. https://doi.org/10.2192/URSUS-D-17-00024.2.
Thatte, P., Chandramouli, A., Tyagi, A., Patel, K., Baro, P., Chhattani, H., Ramakrishnan, U., 2020. Human footprint differentially impacts genetic connectivity of four wide-ranging mammals in a fragmented landscape. Divers. Distrib. 26, 299–314.
Theobald, D.M., Kennedy, C., Chen, B., Oakleaf, S., Baruch-Mordo, J., Kiesecker, J., 2020. Earth transformed: detailed mapping of global human modification from 1990-2017. Earth Syst. Sci. Data 12, 1953–1972.
Tilker, A., Abrams, J.F., Mohamed, A., Nguyen, A., Wong, S.T., Sollman, R., Neidballa, J., Bhagwat, T., Graya, T.N.E., Rawson, M., Guegan, F., Kissing, J., Wegmann, M., Wilting, A., 2019. Habitat degradtaion and indiscriminate hunting differentially impact faunal communities in the Southeast Asian tropical hotspot. Commun. Biol. 2, 396.
Tilker, A., Abrams, J.F., Nguyen, A.N., Hörig, L., Axtner, J., Louvrier, J., Rawson, B.M., Nguyen, H.A.Q., Guegan, F., Nguyen, T.V., Le, M., Sollmann, R., Wilting, A., 2020. Identifying conservation priorities in a defaunated tropical biodiversity hotspot. Divers. Distrib. 26, 426–440. https://doi.org/10.1111/ddi.13029.
Tomasini, S., 2018. Unpacking the Red list: use (and misuse?) of expertise, knowledge, and power. Conserv. Soc. 16, 505–517.
Torretta, E., Mosini, A., Piana, M., Tirozzi, P., Serafini, M., Puopolo, F., Saino, N., Balestrieri, A., 2017. Time partitioning in mesocarnivore communities from different habitats of NW Italy: insights into martens' competitive abilities. Behaviour 154, 241–266.
Tosoni, E., Boitani, L., Mastrantonia, G., Latina, R., Ciucci, P., 2017. Counts of unique females with cubs in the Apennine brown bear population. Ursus 28, 1–14. https://doi.org/10.2192/URSU-D-16-00022.1.
Tumendemberel, O., Proctor, M.F., Reynolds, H.V., Boulanger, J., Luvsamjamba, A., Tserenbataa, T., Batmunkh, M., Craighead, D., Yanjin, N., Paetkau, D., 2016. Gobi bear abundance and inter-oasis movements, Gobi Desert, Mongolia. Ursus 26, 129–142.
Tumendemberel, O., Tebbenkamp, J., Zedrosser, A., Proctor, M.F., Bloomberg, E., Morin, D., Rosell, F., Reynolds, H., Adams, J.R., Waits, L.P., 2021. Long-term genetic monitoring reveals the demographic status on the critically endangered red Gobi bear population. Ecosphere 12, e03696.
Turvey, S.T., Trung, C.T., Quyet, V.D., Nhu, H.V., Thoai, D.V., Tuan, V.C.A., Hoa, D.T., Kacha, T., Sysomphone, S., Wallate, K., Hai, C.T.T., 2015. Interview-based sighting histories can inform regional conservation prioritization for highly threatened cryptic species. J. Appl. Ecol. 52, 422–433.
Ushio, M., Fukuda, H., Inoue, T., Makoto, K., Kishida, O., Sato, K., Murata, K., Nikaido, M., Sado, T., Sato, Y., Takeshita, M., Iwasaki, W., Yamanaka, H., Kondoh, M., Miya, M., 2017. Environmental DNA enables detection of terrestrial mammals from forest pond water. Mol. Ecol. Res 17, e63–e75. https://doi.org/10.1111/1755-0998.12690.

Vaeokhaw, S., Ngopraset, D., Swatdipong, A., Gale, G.A., Klinsawam, T., Vichitsoonthonkul, W., 2020. Effects of a highway on the genetic diversity on Asiatic black bears. Ursus 31, e3.
Van Manen, F.T., McCollister, M.F., Nicholson, J.M., Thompson, L.M., Kindall, J.L., Jones, M.D., 2012. Short-term impacts of a 40lane highway on American black bears in eastern North Carolina. Wildl. Monogr. 181, 1–35.
Venter, O., Sanderson, E.W., Magrach, A., Allan, J., Beher, J., Jones, K.R., Possingham, H.P., Laurance, W.F., Fekete, B.M., Levy, M.A., Watson, J.E.M., 2016. Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. Nat. Commun. 7, 12558.
Waits, L.P., Luikart, G., Taberlet, P., 2001. Estimating the probability of identity among genotypes in natural populations: cautions and guidelines. Mol. Ecol. 10, 249–256.
Walsh, P.W., Reynolds, J., Collins, G., Russel, B., Winfree, M., Denton, J., 2010. Application of a doubles-observer aerial line-transect method to estimate brown bear population density in southwestern Alaska. J. Fish. Widl. Manag 1, 47–58.
Wang, D., Li, S., Jin, T., Shao, L., 2012. How important is meat in the diet of giant pandas, the most herbivorous bear. Int. Bear. N. 21, 7–9.
Waseem, M., Mahmood, T., Hussain, A., Hamid, A., Akrim, F., Andleeb, S., Fatima, H., 2020. Ecology and human conflict of Asiatic black bears (*Ursus thibetanus laniger*) in Mansehra District, Pakistan,. Pak. J. Zool. 52, 1443–1451.
Wasser, S.K., Davenport, B., Ramage, E.R., Hunt, K.E., Parker, M., Clarke, C., Stenhouse, G., 2004. Scat detection dogs in wildlife research and management: application to grizzly and black bears in the Yellowhead Ecosystem, Alberta, Canada. Can. J. Zool. 82, 475–492. https://doi.org/10.1139/z04-020.
Wheat, R.E., Allen, J.M., Miller, S.L., WIlmers, C.C., Levi, T., 2016. Environmental DNA from residual saliva for efficient noninvasive genetic monitoring of brown bears (*Ursus arctos*). PlosOne 11, 0165259. https://doi.org/10.1371/journal.pone.0165259.
Whittington, J., Hebblewhite, M., Chandler, R.B., 2018. Generalized spatial mark–resight models with an application to grizzly bears. J. Appl. Ecol. 55, 157–168.
Williams, B.K., Nichols, J.D., Conroy, M.J., 2002. Analysis and management of animal populations: modeling, estimation, and decision making. Academic Press,, San Diego, California, USA.
Wong, S.T., 2002. The ecology on Malaysian sun bears (*Helarctos malayanus*) in the lowland tropical rainforest of Sabah Malaysian Borneo. Graduate Student Theses, Dissertations & Professional Papers 6404. ⟨https://scholarworks.umt.edu/etd/6404⟩.
Wong, S.T., Servheen, C., Ambu, L., 2002. Food habits on Malayan sun bears in lowland tropical forests of Borneo. Ursus 13, 127–136.
Woods, J.G., Paetkau, D., Lewis, D., McLellan, B.N., Proctor, M., Strobeck, C., 1999. Genetic tagging free-ranging black and brown bears. Wildl. Soc. Bull. 27, 616–627.
Wu, H., Zhang, S.N., Wei, F.W., 2010. Twelve novel polymorphic microsatellite loci developed from the Asiatic black bears (*Ursus thibetanus*). Conserv. Genet. 11, 1215–1217.
Yang, J., Zhang, Z., Shen, F., Yang, X., Zhang, L., Chen, L., Zhang, W., Zhu, Q., Hou, R., 2011. Microsatellite variability reveals high genetic diversity and low genetic differentiation in a critical giant panda population. Curr. Zool. 57, 717–724.
Yavuz, M., Vatandaslar, C., Ozyanik, M., Keles, G.A., 2017. Determination of the optimal observation points for brown bear (*Ursus arctos*) inventory using GIS in Savsat, Turkey. Int. J. Ecosyst. Ecol. Sci. 7, 57–62.
Zhan, X., Li, M., Zhang, Z., Goossens, B., Chen, Y., Wang, H., Bruford, M.W., Wei, F., 2006. Molecular censusing doubles giant panda population estimate in a key nature reserve. Curr. Biol. 16, R451–R452.
Zhan, X., Zheng, X., Bruford, M.W., Wei, F., Toa, Y., 2010. A new method for quantifying genotyping errors for noninvasive genetic studies. Conserv. Genet. 11, 1567–1571.
Zhang, J., Li, Y., Wang, Z., Ouyang, Qiao, M., Zhang, H., 2017. Comparison of investigation methods for population of wild giant panda. J. Appl. Environ. Biol. (Chin.) 23, 142–147. https://doi.org/10.3724/SPJ.1145.2017.0101.
Zhu, Y., Liu, H.-Y., Yang, H.-Q., Li, Y.-D., Zhang, H.-M., 2017. Factors affecting genotyping success in giant panda fecal samples. PeerJ 5, e3358.