Approaches for assessing illegal hunting of brown bears and other large carnivores in Sweden

Richard Bischof

Department of Ecology and Natural Resource Management

Norwegian University of Life Sciences

P.O. Box 5003, 1430 Ås, Norway

Report 2015:5

from the Scandinavian Brown Bear Research Project

to the Swedish Environmental Protection Agency

www.bearproject.info

Skandinaviska Björnprojektet

Ås, March 2015

Background and motivation

Illegal hunting of wildlife is a global phenomenon with substantial impacts on biodiversity and wildlife management (Gavin et al. 2010). Large carnivores are especially prone to be targeted, mainly as part of unsanctioned attempts at predator control. The objective of this report is to provide Swedish wildlife management authorities with ideas regarding the assessment of the extent of illegal hunting of bears and other large carnivores. There is particular interest in assessments at a national or range-wide scale (i.e. risk mapping; see for example Marquez et al. 2013), while specifically including areas without intensive individual-based monitoring via telemetry. In writing this report, I am taking into consideration both existing sources of information (data) and information that could be collected in the future. In addition, I am drawing on a cursory review of the literature on quantifying the extent and impacts of illegal hunting, as well as on my own experiences in wildlife forensics and law enforcement with a state wildlife management agency in the USA. This document is not to be taken as a protocol for assessing illegal hunting of large carnivores or a comprehensive review of existing research on the subject. Rather, it is a compilation of reflections, presented with the intent to facilitate further discussion and exploration. Sweden has 4 species classified as large carnivore (brown bear, grey wolf, Eurasian lynx, wolverine), and topics discussed here may apply to some or all of these. However, the document was written primarily with brown bears in mind.

Illegal hunting (poaching): any activity that directly results in the illegal removal of wildlife from the population (including shooting, trapping, poisoning)

Non-invasive genetic sampling (NGS): collection of hair, feathers, scat, or urine and subsequent extraction of DNA for genetic analysis

Poacher: person participating in illegal hunting

Telemetry: tracking of individual animals through space and time using VHF or GPS tracking devices (e.g. collars or implants)

As a direct consequence of its clandestine nature, unbiased estimates of the extent and impacts of illegal hunting are exceedingly difficult to obtain. Law enforcement operations, targeted studies, and opportunistic discovery typically only reveal a fraction of illegal activity actually taking place. The study of wildlife crime is primarily characterized by a paucity of information, with direct consequences for decision making targeted at its control and mitigation. Research on illegal hunting amounts to a forensic investigation, without the direct goal of criminal persecution. Forensics in this context entails the search for evidence that 1) indicates that a crime has taken place and 2) links a suspect (people as a whole, not individuals) with the scene of the crime. Although many stakeholders are impacted by illegal hunting, the two main entities directly involved are wildlife (“victims”) and poachers (“perpetrators”). These entities offer different perspectives from which to gather evidence, and the following discussion is structured accordingly.

The wildlife perspective

Whether correctly identified as the cause or not, illegal hunting results in the removal of individual animals. Because individual survival is one of the main constituents of population dynamics, illegal hunting is manifested also as a change at the population level. There are various approaches for monitoring both individual life histories and the dynamics of wild populations, and inherent in the choice of method is the trade-off between intensity and extent. Intense monitoring studies that involve physical-mark recapture and GPS telemetry can yield detailed and precise observations on study subjects, but are usually limited in their spatial scope and number of individuals included. Conversely, approaches that can be implemented at the scale of landscapes and populations (e.g. non-invasive genetic sampling, NGS), often yield only a limited number of observations (sample size) per individual. The trade-off between intensity and extent has implications also for investigations into illegal hunting: intense individual-based monitoring offers a greater probability that the illegal kill of a tracked individual is detected; whereas studies with a wider scope, but less intensive monitoring of individuals, are liable to include more animals that are exposed to illegal hunting, but are less likely to detect their death or confirm its cause.

Telemetry Swedish authorities are interested in possible approaches for assessing illegal hunting in areas not covered by telemetry studies of the targeted species. Telemetry is nonetheless included in this discussion, as it yields data that could be useful for assessments beyond the boundaries of a given study region.

During telemetry studies, illegal hunting can sometimes be directly identified as the cause of an individual's death. These observations can then be used to construct indices of effort- and population-size corrected temporal or spatial trends in the rate of detected illegal deaths. For example, long-term VHF and GPS telemetry of brown bears by the Scandinavian Brown Bear Research Project (SBBRP) in northern and central Sweden could be used to estimate cause specific hazard ratios between these regions for mortality attributable to illegal hunting. This however, assumes that detectability of illegal kills of monitored bears is not significantly different between the two regions or, alternatively, that differential detectability can be estimated and accounted for during analysis.

Animals monitored via telemetry generally have tracking devices that are readily detected by poachers who can then take evasive actions to avoid being implicated (Goodrich et al. 2008, Liberg et al. 2011). Such actions could entail killing only individuals that show no external signs of being monitored (e.g. absence of ear tags or telemetry collars) or removing/disabling tracking devices after making an illegal kill. As a result of the latter, illegally killed monitored animals may simply disappear from a study, which prompted Liberg et al. (2011) to coin the term "cryptic poaching". Use of tracking devices that remain undetected prior to an illegal kill, and that can be clandestinely monitored afterwards, could help increase detection of poaching. Alternatively, physiological monitoring devices could be used to alert researchers to death or injury of the study animal in time before the tracking device can be disabled. For example, several brown bears monitored by the SBBRP have implanted heart-rate monitors that communicate with the animal's GPS collar (Friebe et al. 2014). These devices could be designed to trigger immediate data dumps (e.g. via GSM) when certain physiological thresholds are exceeded, thereby increasing the chance that illegal kills are detected.

The spatial extent of telemetry studies of large carnivores in Sweden is insufficient to construct range-wide maps of illegal hunting risk. However intensive individual-based monitoring projects can 1) serve as case studies to better understand the mechanics of illegal hunting risk, 2) yield data to complement information from other sources and parameterize models targeting other areas, and 3) provide a platform for testing models of illegal hunting and validating their predictions. Furthermore, clandestine telemetry could be implemented in suspected hot-spots of illegal activity in the future.

<u>Dead recoveries:</u> The Swedish Veterinary Institute compiles and administers an extensive national database of nearly all confirmed deaths of brown bears (Bischof et al. 2008, Bischof et al. 2009) and other large carnivores. Records of deaths originate both from targeted investigations, mandatory registration, and opportunistic discoveries. Most records contain information about the individual (gender, year of birth) and its death (cause, location, date). Genotype information from dead animals is included in the genetic database and records of dead individuals are thereby linked with other observations, such as those obtained during monitoring studies. Neither systematic inventory nor opportunistic discovery lead to detection of all deaths. Used in isolation, dead recovery data therefore cannot give an unbiased picture of illegal hunting. However, as will be discussed in the next sections, these data could be combined with other sources of information.

<u>Non-invasive genetic sampling</u> Non-invasive genetic sampling of brown bear, wolf, and wolverine in Sweden reaches areas that are not covered by telemetry studies, and the spatial scale of NGS may be conducive for constructing risk maps of illegal hunting. However, illegal deaths are not directly detectable within the typical NGS sampling scheme. Inferences about poaching may therefore require the inclusion of additional sources of data, such as dead recoveries. Alternatively (or additionally) assumptions have to be made about the nature of disappearances.

Although imperfect detection is a major impediment to quantitative assessment of illegal hunting, it is not a unique constraint. Most studies of ecological phenomena suffer from detection probabilities that are less than 1. Hierarchical analytical methods, specifically capture-recapture (CR) models, have been a mainstay of wildlife research for half a century, and can estimate and thereby account for detection probability of individuals or events (Williams et al. 2002, Kéry & Schaub 2012).

Hierarchical models offer an intuitive way to think about the link between a real system and our perception of it. Figure 1 shows the possible pathways individuals can take in a simplified system with illegal hunting and the associated perception of an observer. Thick solid lines for boundaries and arrows indicate true states and transitions between them, respectively. Dashed lines and boxes with thin gray outlines indicate the observation process and apparent states. For simplicity, we can distinguish between 4 main causes of mortality: 1) natural: all deaths not directly caused by humans; 2) accidental (human-caused): mainly collisions with motor vehicles and trains, some research-related; 3) legal: legal hunting and sanctioned removal for protection of life and property, and 4) illegal hunting. One assumes that, by definition, all true legal hunting deaths and almost all human-caused accidental deaths are detected and correctly designated as such. The same is not the case for deaths caused by natural events or illegal hunting. Even if they are discovered, there is a probability that the cause of such deaths is not determined or misidentified. As a consequence, aside from correctly identified illegal hunting deaths in the "state identified" category, illegal and natural deaths may also be hidden/unconfirmed in the other three categories of designations: "apparent disappearance", "unidentified", and "misidentified".

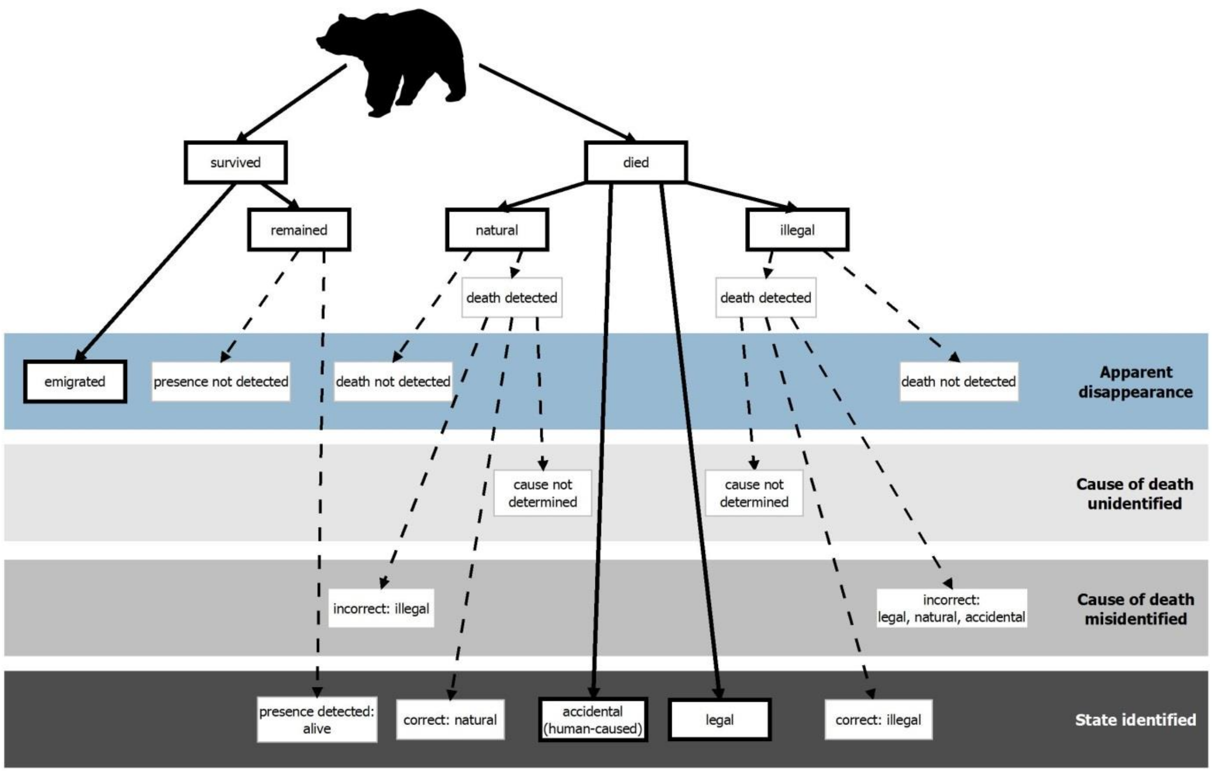

Figure 1. Illustration of a hierarchical population model for a large carnivore, with true states (boxes with bold outlines), transitions (solid arrows) and observation process (boxes with grey outlines and dashed arrows). See text for more information.

From the perspective of management authorities and researchers, animals killed by illegal hunting are most likely to just disappear from the population. Several pathways lead to the category "apparent disappearance": individuals that left the study area permanently (emigrated), individuals that remained alive in the study area, but that monitoring failed to detect, and individuals that died undetected (natural mortality or illegal hunting). Consequently, apparent disappearance cannot be taken as illegal hunting, and without additional information the transition probability from alive to dead due to illegal hunting is not identifiable.

Given so many unknowns and uncertainties, how can illegal hunting be quantified from large-scale monitoring data such as NGS? One option is to look for irregularities within the pathways that lead to the various forms of apparent states and disappearances of bears and other large carnivores. Such irregularities may for example include:

- Spatial and temporal outliers in estimated apparent mortality/emigration or effort-corrected rate of disappearance for which other explanations are lacking. E.g. areas with few hunter-reported deaths, but dynamics suggesting low local survival.
- Unusually high apparent mortality/emigration/disappearance of adult animals, which tend to have high survival rates and exhibit philopatry, at least in large mammals.
- Unusually high apparent mortality/emigration of a specific demographic group in a given region or at a certain time. E.g. adult male brown bears are the first to emerge from hibernation and are thus particularly vulnerable to tracking and poaching during the period of snow cover (Swenson et al. 2001, Manchi & Swenson 2005).

Combining multiple sources of information can help expose irregularities. For populations monitored via non-invasive genetic sampling, spatial and temporal inconsistencies between NGS relocations and hunter-reported kill locations and dates may provide indication of possible rule violations, e.g. when illegal kills are concealed as legal kills or accidental deaths. Similarly, even if dead-recovered individuals cannot be matched to a genotype in the NGS monitoring data, genetic similarly or dissimilarity at the subpopulation level may help elucidate potential illegal hunting (Millions & Swanson 2006).

Variations of traditional capture-recapture models have already been used to make inferences about illegal hunting (Liberg et al. 2011). Multi-state CR (MCR), spatially-explicit CR (SECR) or a combination thereof may be particularly suitable for estimating (or inferring) illegal mortality. MCR can accommodate multiple mortality sources as separate state transitions, including transitions to unobserved states (Kéry & Schaub 2012). SECR models establish a link between abundance and space by estimating individual centers of activity (unobserved) from the spatial pattern of detections (Efford & Fewster 2013, Royle et al. 2013; Fig. 1). SECR models could for example be used to detected "holes" in abundance or local source-sink dynamics.

Although the spatial-scale of brown bear NGS data in Sweden is appropriate for producing range-wide risk maps, the sampling schedule poses limitations. Sampling shifts annually from one region to another and there are approximately 5-year gaps between consecutive surveys of the same region. Annual surveys that cover all of a species' national range, such as those conducted for brown bears in Norway, are better suited for use in hierarchical population models if parameters such as survival are to be estimated. Large carnivores, especially bears, are long-lived species, with high adult survival. It is therefore conceivable that even data from monitoring schemes with less frequent sampling can be used in such models, once a sufficient number of repeated surveys has been achieved. If the current sampling scheme proves to be insufficient to capture dynamics with the required precision, increased sampling frequency and targeted searches could be implemented in areas of interest.

Population models that include illegal mortality as a (partially) unobserved transition could integrate different sources of information (such NGS data, telemetry data, dead recoveries, and possibly independent population estimates), thereby compensating for the inherent uncertainty associated with unobservable events and large stochasticity (Fig. 2). The utility of integrating multiple sources of information has already been shown for wolves in Sweden, where Liberg et al. (2011) combined telemetry, snow tracking, scat-based NGS to quantify an additional source of mortality attributed to cryptic, i.e. undetected, poaching.

As an alternative to multi-season models that estimate cause-specific transition probabilities, single-season models could be used to estimate spatially-referenced population size, which could then be linked with independent estimates or indices of illegal hunting, derived for example from effort-controlled law enforcement records and dead recoveries. This in turn could yield an index of the (relative) per-capita risk of mortality due to poaching.

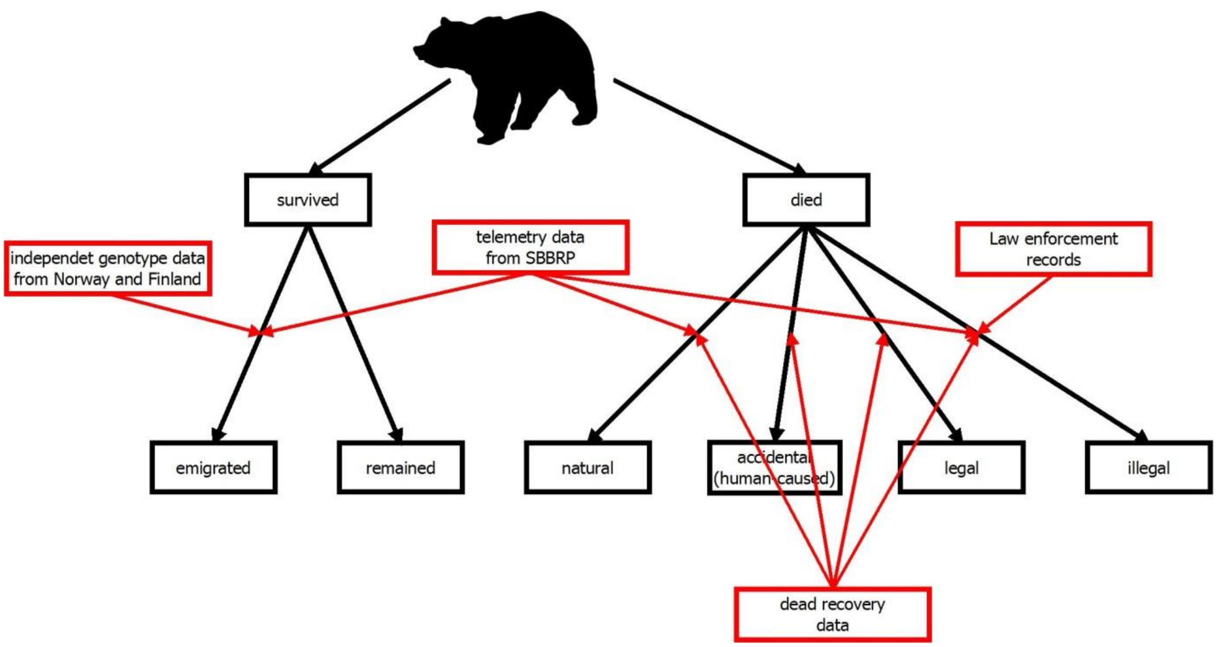

Figure 2. Additional data sources (red boxes) can potentially be integrated with NGS data to make transition parameter estimates identifiable and/or improve their precision.

<u>Large carnivore observations</u> Regional or national records of large-carnivore observations (mainly reported by moose hunters) may present another option in the search for spatial, temporal or demographic trends indicative of a local sink. However, even with some measure to control for effort (e.g. hunter-field-days) such data are likely too coarse to yield more than speculative indication even in severe cases of intensive localized poaching.

The poacher perspective

The scope and scale of illegal activity can also be assessed with a focus on the perpetrators. Here, illegal hunting is manifested as an action and its aftermath (e.g. physical evidence and witnesses) but is also reflected in attitudes and decision making. The emphasis on human dimension and criminal activity implies a different set of research tools from those outlined in the previous section, but the resulting information from both perspectives can be integrated to provide a clearer picture.

Law enforcement seizure and arrest records

Law enforcement seizure and arrest records are not a complete inventory of all illegal activity taking place, but can serve to make spatial or temporal comparisons of the extent of illegal activity and participation therein (Hilborn et al. 2006). If relevant national local law enforcement records in Sweden are made available for wildlife research purposes, a comprehensive analysis could identify patterns in risk across space and time. Due to imperfect detection, such comparisons require correction for variation in effort (e.g. quantified intensity of patrolling and other enforcement operations) to control for its confounding effect on the observed rate of violations (Hilborn et al. 2006, Gavin et al. 2010). Establishment of spatial patterns and quantification of the extent of illegal hunting of large carnivores would benefit from linking information about individual detection histories and population dynamics with law enforcement data. For example, suggestive spatial, temporal, and demographic patterns in apparent disappearances would present stronger evidence if they are correlated with trends in effort-corrected law enforcement records of seizures and arrests. In addition, genotyping existing and future physical evidence collected by law enforcement (hair, skin, claws, teeth, etc.) could help improve detectability of poaching by correctly categorizing additional illegal kills at a later time even if these initially went undetected during monitoring.

Adopting law enforcement methods for targeted studies

Clandestine activity often requires clandestine efforts for detection and mitigation. For example, wildlife decoys have been used to assess participation in illegal activity, especially for ungulates in North America (Dooley & Combs 1995). The use of such tools could be a potential option for quantifying the risk of illegal action against some large carnivore species in Sweden, but may require legislative changes. The systematic and wide-spread use of decoys would be facilitated by the comparatively dense road network through most of Sweden. Depending on legal parameters, targeted research could also employ other law enforcement methods, for example sting operations, to attain effort-corrected estimates of illegal activity. Even when certain methods cannot legally be used for sweeping law enforcement purposes (e.g. due to issues such as entrapment and invasion of privacy), use for research purposes may be warranted if it precludes identification and persecution of participating individuals.

Questionnaires/surveys

Biases are inherent in surveys on sensitive behavior such as illegal hunting. Such biases include social-desirability bias (dishonest answers to project a socially favorable image) and non-response bias (participation in the survey is correlated with participation in sensitive behavior). Although participants in unsanctioned wildlife use are secretive about their activities, innovative survey methods can elucidate information about the forms of violation and the extent of participation (St. John et al. 2010). Sensitive surveys could target potential violators directly, by including a random element that increases the respondents' sense of privacy and deniability (randomized response technique; Warner 1965). Alternatively, surveys can target violators indirectly, by asking questions about the number of acquaintances that have done violations (nominative technique; St. John et al. 2010). The use of such surveys is still relatively new in the context of unsanctioned wildlife use, but could potentially augment or validate other sources of information about the spatial and temporal configuration of illegal activity. Existing spatially-explicit surveys on attitudes towards and tolerance of illegal hunting in Scandinavia (Gangaas et al. 2013) could also serve to validate model- or index-derived risk maps.

Conclusions

Imperfect detection due to the cryptic nature of illegal hunting poses a considerable challenge for investigations into the extent and impacts of poaching of large carnivores and other wildlife. It is therefore not surprising that the literature exploring the impacts of illegal hunting on wildlife populations is biased towards modelling studies, as opposed to empirical work (Kenney et al. 1995, Yiming et al. 2003, Byers & Noonburg 2007, Chapron et al. 2008; see also Keane et al. 2008).

There is a marked need for quantitative information to guide decision making and management actions. Research on illegal hunting should be approached akin to a forensic/criminal investigation, with the aim to detect both direct evidence and indirect signs of potential illegal activity. Direct evidence, i.e. confirmed illegal kills, are liable to comprise only a small portion of all illegal activity, but may be useful as additional data sources and as case studies to facilitate understanding of the mechanics involved. Spatial, temporal and demographic irregularities in apparent disappearances in large-scale monitoring studies may contain information for detecting hot-spots of illegal activity. Whether this is done through effort-corrected indices or true parameter estimates using hierarchical population models, the results will have to be taken as suggestive, rather than proof. However, the strength of evidence and reliability of parameter estimates can be improved by combining multiple sources of information. In addition, suggestive patterns that identify potential high-risk areas can then be used to guide targeted investigations to confirm and quantify illegal activity.

Law enforcement records involving wildlife-related violations and experiences in various jurisdictions could play a crucial role in understanding the mechanics of illegal hunting of large carnivores in Sweden and for supplementing monitoring data. In addition, suggestive spatial, temporal, and demographic patterns in apparent disappearances would represent stronger evidence if supported with trends in effort-corrected law enforcement records of seizures and arrests. Thus, a comprehensive attempt at quantifying illegal hunting should entail cooperation between wildlife managers, law enforcement agencies, and researchers.

Illegal hunting is a human-caused phenomenon, driven by human decision making and actions. Methods developed for sensitive human-dimensions research in other fields (e.g. psychology, criminology and health) may be considered also for investigating poaching. As a whole, considering multiple angels, disciplines and their tools could help compensate for the inherent difficulties associated with studying the impacts of a cryptic activity.

There is a growing trend in ecological data analysis toward linking multiple sources of information, particularly in hierarchical population models (Schaub et al. 2007, Schaub & Abadi 2011). An integrative approach can help make parameters identifiable and detect patterns indicative of illegal hunting, thereby help compensate for the high uncertainty inherent in research targeting cryptic activity (e.g. see Liberg et al. 2011).

Although an assessment of spatial patterns in illegal hunting in Sweden should be data-based, modeling has to be an essential component of the analytical process. Research questions and availability of data will guide the selection of analytical methods and types of models employed. An analysis that makes comprehensive use of the varied assemblage of data could employ a Bayesian approach to parameter estimation, due to the ease with which multiple-sources of information are integrated and the flexibility it offers when building models (Kéry 2011, Kéry & Schaub 2012).

As a general approach one could envision a system where information available at a national level, such as NGS data, dead recoveries records, survey results, and law enforcement records are used to identify potential hotspots of illegal harvest. Focused investigation could then target such areas to 1) verify that illegal activity is indeed to blame for the large-scale patterns, 2) quantify the extent and impact locally, and 3) explore the human dimension and mechanics of the activity (motivation, participation, execution, etc.).

Specific recommendations for assessing illegal hunting of brown bears in Sweden

1. Compile maps of available information: spatial configuration of NGS searches and detections, telemetry study areas, dead recovery locations, carnivore observation report locations, independent indicators of monitoring effort, and law enforcement activity/presence. Use the map to identify geographic gaps in information and to select spatial and temporal subsets of data for further investigation.
2. Compile, cross-reference, and run quality control on all existing confirmed records of illegal mortality in dead-recovery data (SVA), telemetry studies (SBBRP), the genetic database (ROVDATA), and law enforcement records (police).
3. Establish whether physical evidence exists (pelts, hair, teeth, claws, tissue, etc.) from suspected and confirmed cases (old and recent) of large carnivore poaching from which genotypes could be, but have not yet been obtained. If so, attempt DNA extraction and genotyping, and incorporate positive results into the dead-recovery data and the genetic data base.
4. Investigate options to quantify search effort across space and time for non-invasive genetic sampling
5. Investigate options to quantify search effort with respect to law enforcement activities that do or could lead to detection of illegal hunting of large carnivores. Evaluate the feasibility of using effort-corrected law enforcement records as an index for spatial and temporal comparisons in illegal hunting pressure.
6. Build a spatially-explicit capture-recapture model to derive a brown bear density map from NGS data and dead recoveries. Look for discontinuities on the density surface that suggest unexplained holes in abundance. Search for apparent source-sink dynamics using spatially-explicit models and a combination of NGS data, telemetry data and dead-recoveries. I.e. are there areas that individuals are more likely to disappear into than elsewhere?
7. Evaluate the potential of using NGS data for constructing and fitting population dynamic models that allow for spatial and temporal comparisons in unexplained mortality/disappearances. Integrate additional sources of information from genotyped dead recoveries, telemetry studies, and law enforcement records.
8. Compare the predicted risk maps with spatially-explicit trends in effort-corrected indices of abundance based on annual observation reports.
9. Once a range-wide risk map for illegal hunting has been derived from existing data, attempt targeted investigations (e.g. surveys, experiments, clandestine investigations) both in potential hot-spots and in control areas to validate the approach used for constructing the map and to obtain detailed quantitative information.

References

Bischof R., Fujita R., Zedrosser A., Söderberg A., Swenson J.E. (2008) Hunting patterns, the ban on baiting, and harvest demographics of brown bears in Sweden. *Journal of Wildlife Management* **72**, 79-88.

Bischof R., Swenson J.E., Yoccoz N.G., Mysterud A., Gimenez O. (2009) The magnitude and selectivity of natural and multiple anthropogenic mortality causes in hunted brown bears. *Journal of Animal Ecology* **78**, 656-665.

Byers J.E., Noonburg E.G. (2007) Poaching, enforcement, and the efficacy of marine reserves. *Ecological Applications* **17**, 1851-1856.

Chapron G., Miquelle D.G., Lambert A., Goodrich J.M., Legendre S., Clobert J. (2008) The impact on tigers of poaching versus prey depletion. *Journal of Applied Ecology* **45**, 1667-1674.

Dooley J.A., Combs D.L. (1995) Profile of road hunters in Tennessee observed during the use of decoy deer. *Proceedings of the Forty-Ninth Annual Conference - Southeastern Association of Fish and Wildlife Agencies*, 702-711.

Efford M.G., Fewster R.M. (2013) Estimating population size by spatially explicit capture–recapture. *Oikos* **122**, 918-928.

Friebe A., Evans A.L., Arnemo J.M. *et al.* (2014) Factors Affecting Date of Implantation, Parturition, and Den Entry Estimated from Activity and Body Temperature in Free-Ranging Brown Bears. *Plos One* **9**.

Gangaas K.E., Kaltenborn B.P., Andreassen H.P. (2013) Geo-Spatial Aspects of Acceptance of Illegal Hunting of Large Carnivores in Scandinavia. *Plos One* **8**.

Gavin M.C., Solomon J.N., Blank S.G. (2010) Measuring and Monitoring Illegal Use of Natural Resources. *Conservation Biology* **24**, 89-100.

Goodrich J.M., Kerley L.L., Smirnov E.N. *et al.* (2008) Survival rates and causes of mortality of Amur tigers on and near the Sikhote-Alin Biosphere Zapovednik. *Journal of Zoology* **276**, 323-329.

Hilborn R., Arcese P., Borner M. *et al.* (2006) Effective enforcement in a conservation area. *Science* **314**, 1266-1266.

Keane A., Jones J.P.G., Edwards-Jones G., Milner-Gulland E.J. (2008) The sleeping policeman: understanding issues of enforcement and compliance in conservation. *Animal Conservation* **11**, 75-82.

Kenney J.S., Smith J.L.D., Starfield A.M., McDougal C.W. (1995) The Long-Term Effects of Tiger Poaching on Population Viability. *Conservation Biology* **9**, 1127-1133.

Kéry M. (2011) *Introduction to WinBUGS for ecologists: a Bayesian approach to regres sion, ANOVA, mixed models and related analyses*. Elsevier, Amsterdam.

Kéry M., Schaub M. (2012) *Bayesian population analysis using WinBUGS: a hierarchical perspective*. Academic Press, Waltham, MA.

Liberg O., Chapron G., Wabakken P., Pedersen H.C., Hobbs N.T., Sand H.k. (2011) Shoot, shovel and shut up: cryptic poaching slows restoration of a large carnivore in Europe. *Proceedings of the Royal Society B: Biological Sciences*.

Manchi S., Swenson J.E. (2005) Denning behaviour of Scandinavian brown bears *Ursus arctos*. *Wildlife Biology* **11**, 123-132.

Marquez C., Vargas J.M., Villafuerte R., Fa J.E. (2013) Risk mapping of illegal poisoning of avian and mammalian predators. *Journal of Wildlife Management* **77**, 75-83.

Millions D.G., Swanson B.J. (2006) An application of Manel's model: Detecting bobcat poaching in Michigan. *Wildlife Society Bulletin* **34**, 150-155.

Royle J.A., Chandler R.B., Sollmann R., Gardner B. (2013) *Spatial capture-recapture*. Elsevier/Academic Press, Amsterdam.

Schaub M., Abadi F. (2011) Integrated population models: a novel analysis framework for deeper insights into population dynamics. *J Ornithol* **152**, 227-237.

Schaub M., Gimenez O., Sierro A., Arlettaz R. (2007) Use of integrated modeling to enhance estimates of population dynamics obtained from limited data. *Conservation Biology* **21**, 945-955.

St. John F.A.V., Edwards-Jones G., Gibbons J.M., Jones J.P.G. (2010) Testing novel methods for assessing rule breaking in conservation. *Biological Conservation* **143**, 1025-1030.

Swenson J.E., Sandegren F., Brunberg S., Segerstrom P. (2001) Factors associated with loss of brown bear cubs in Sweden. *Ursus* **12**, 69-80.

Warner S.L. (1965) Randomized-response - a survey technique for eliminating evasive answer bias. *Journal of the American Statistical Association* **60**, 63-69.

Williams B.K., Nichols J.D., Conroy M.J. (2002) *Analysis and management of animal populations*. Academic Press, San Diego, California, USA.

Yiming L., Zhongwei G., Qisen Y., Yushan W., Niemelä J. (2003) The implications of poaching for giant panda conservation. *Biological Conservation* **111**, 125-136.