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PRACTITIONER'S PERSPECTIVE

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Towards grizzly bear population recovery in a modern landscape

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1 | INTRODUCTION

There seems to be a dichotomy in societal responses to scientific news stories regarding grizzly bears (*Ursus arctos*) lately. On the one hand, there appears to be strong positive support of research highlighting conservation challenges faced by the bears, including studies of the impacts of road density, human settlement, railway, and human recreation (e.g., Lamb et al., 2018; Murray, Fassina, Hopkins, Whittington, & St. Clair, 2017). On the other hand, there has been scepticism and even outright denial as to the quality and value of scientifically acquired knowledge relating to "unpopular" conservation issues. This includes science favouring the delisting of grizzly bears as an endangered species in Yellowstone National Park, USA, and, more recently, research not confirming the need to halt to the controversial grizzly bear trophy hunt in British Columbia (BC), Canada.

What seems to be overlooked, however, is that both the popular and unpopular conservation research relating to grizzly bears are often being produced by the same groups of scientists, or at least widely supported by biologists generally. One might think the seemingly well received and socially accepted research in the first category would alleviate public distrust of unpopular scientific findings in the second category. However, this does not seem to be the case. There may be several reasons for this. For one, people might tend to support research that supports their own opinions or agendas ("motivated reasoning" *sensu* Kunda, 1990), in this case related to grizzly bears. Secondly, such opinions towards grizzly bears and their conservation are often passionate. Yet another possibility, and one common to science generally, is that the actual science behind the news story (and not the simplified and often misinterpreted media message) is complex. Opinions and agendas are further amplified, and the science possibly further distorted, via proliferation through social media.

Consider the recent ban on grizzly bear trophy hunting in BC. With an estimated 15 000 grizzly bears in BC, past levels of allowable hunting, which averaged 297 bears per annum (Government of British Columbia, 2017), were considered biologically sustainable (Boyce, Derocher, & Garshelis, 2016). This was contentious as the scientific rigour of previous sustainable harvest quotas has been an area of debate (Jones, 2014). Yet, ultimately the scientifically-derived assertion that a grizzly bear trophy hunt could happen without affecting the population's sustainability was irrelevant to subsequent governmental public policy. Social and political opposition to trophy hunting were the deciding factors. It is important to note, while still acknowledging

FIGURE 1 Grizzly bear management areas (BMAs) in the province of Alberta, Canada

the importance of critically evaluating scientific research, that it was not necessary to disprove or distrust the science supporting a sustainable harvest of grizzly bears in BC for the hunt to be called off, as it was a political decision. No matter that the loss of a certain number of grizzly bears might be sustainable from a population perspective, society has deemed it unacceptable to lose any grizzlies to trophy hunting. The science simply said that a hunt *could* happen sustainably, not that it *should* happen.

This outcome, however, does not obviate the need for rigorous scientific research into grizzly bears. Far from it, the outcome further underscores its necessity by highlighting the conservation value and societal importance of the species, where the best available scientific evidence needs to be considered to make the most informed management decisions. A successful approach to modern grizzly bear management requires a synthesis and integration of information across a spectrum of modalities, from remote sensing to molecular biology. The province of Alberta, Canada (Figure 1), provides an exemplar test case for implementing an interdisciplinary and collaborative approach to monitoring grizzly bear populations in a dynamic and increasingly industrialized landscape used by multiple stakeholder groups.

2 | TOWARDS POPULATION RECOVERY IN ALBERTA, CANADA

In contrast to neighbouring BC, the province of Alberta declared a moratorium on all grizzly bear hunting in 2006. The bears were eventually listed as a provincially Threatened species in 2010 due to their relatively small population size (estimated at *c.* 700 by Festa-Bianchet, 2010), high levels of human-caused mortality, and declining habitat conditions. Since the moratorium, evidence suggests that grizzly subpopulations may be recovering in some provincial bear management areas (BMAs). For instance grizzlies in the actively managed BMA adjacent to Jasper National Park have shown a rate of increase (*c.* 7%) higher than commonly seen among interior North American grizzly bear subpopulations—estimates were 36 (CI 28.6–45.3) bears in 2004 vs. 71 (CI 53.9–94.2) in 2014 (Stenhouse et al., 2015)—whereas the subpopulation in the BMA adjacent to the Montana, USA, and BC borders has remained stable or increased (Morehouse & Boyce, 2016). The reasons for these trends are unclear, likely involving a complexity of factors. For instance, there has been a substantial input of translocated bears (due to human-wildlife conflict) from source areas within the province into areas where grizzly bear numbers were previously declining (Milligan, Brown, Hobson, Frame, & Stenhouse, 2018). While in southern Alberta, connectivity with larger source subpopulations in BC and Montana likely plays a role.

It is clear that managing this charismatic socially and ecologically important apex predator in Alberta presents several challenges. While considerable progress has been made towards better understanding the interactive factors at play, much remains to be elucidated. For one, managing the interactions between bears and roads (and perhaps the people that use them) remains among the highest priorities for grizzly bear management in western Canada. There is a well-established relationship between human-caused grizzly bear mortality and road density: areas of higher road density result in greater grizzly bear deaths due to increased human contact (Boulanger & Stenhouse, 2014), and reducing road density can lead to population increases (Lamb et al., 2018). There is evidence that major transportation routes and the accompanying infrastructure are fragmenting populations (Proctor et al., 2012), and the effects of barriers to movement and habitat connectivity on the genetic structure of grizzlies requires further investigation. Furthermore, the responses of grizzlies to anthropogenic habitat alterations, such as oil and gas exploration (Sorenson, Stenhouse, Bourbonnais, & Nelson, 2015), mining (Cristescu, Stenhouse, Symbaluk, Nielsen, & Boyce, 2016), forestry (Phoebus, Segelbacher, & Stenhouse, 2017), agriculture (Northrup, Stenhouse, & Boyce, 2012), and human recreation (Ladle, Steenweg, Shepherd, & Boyce, 2018) need to be better understood. Given their large home ranges, wide provincial distribution, remote and hard to access habitats, and limited operational resources, monitoring the provincial grizzly bear population also presents significant logistical challenges.

One thing is certain: the recovery and monitoring efforts required to manage, achieve, and sustain a viable and resilient grizzly bear population in Alberta are complex. Yet, the situation in Alberta speaks to global challenges related to wildlife management more broadly: there is a tendency for societies to "want it all" on the same piece of land, where efforts are made to retain and in some cases recover certain wildlife populations while simultaneously altering their habitat through various anthropogenic activities. The impacts of these activities are further compounded by large-scale processes, such as wildfire, forest disease outbreaks, and climate change. Yet, there is no guide to managing the complexity of such ecosystems in an ever-changing landscape.

In Alberta, the approach has been to investigate the challenges facing grizzly bears across broad and interactive thematic scales (i.e., the environment, populations, and individuals), where research is broken into manageable units focusing on the most critical areas as a priority. The challenge thus becomes how best to scale-up data and results from BMAs to inform provincial-scale evaluation of species status. Importantly, data are collected across a variety of scales which are then integrated and analysed to provide the information required to manage the species, and the anthropogenic activities that impinge upon them, based on societal and governmental priorities (Figure 2).

3 | MULTI-SCALAR AND MULTI-DISCIPLINARY DATA COLLECTION TOWARDS UNDERSTANDING THE "BEAR" NECESSITIES

At the broadest scale, the novel application of remote sensing data is revolutionizing the practice of wildlife management. In Alberta, grizzly bear monitoring is moving towards tracking individuals, food, and habitat resources at a range of spatial and temporal scales (Table 1). For one, elucidating the movement patterns of individual bears from tracking-collar data provides important information relating to habitat preferences, denning, distribution, human-wildlife conflict, and mortalities. Remote sensing technologies are being harnessed to assess environmental and climatic factors affecting grizzly bear habitat, including plant phenology, food, and nutritional resources. For example, spring den emergence is a critical period for bears leaving hibernation, and the relationships between spring snow conditions (snow depth, cover, and melt) and landscape greening require further understanding (Pigeon, Stenhouse, & Côté, 2016). Especially relevant to grizzly bear management is the application of remotely sensed data for the up-to-date and large-scale mapping of the extent, type, and timing of both anthropogenic and natural habitat disturbances (Bourbonnais et al., 2017). Importantly, to study their effects environmental and landscape factors derived from satellites can be linked to both populations and individuals through molecular techniques.

3.1 | Population

Assessing population performance is a critical aspect of wildlife conservation. The measurement of DNA in hair collected from grizzly bears using barbed wire hair snags is proving an effective and non-invasive way to monitor Alberta's grizzly bear populations (Rovang, Nielsen, & Stenhouse, 2015). These noninvasive DNA capture techniques are also being used to assess the effects of highways at the genetic level—grizzly movement is often inhibited by large-scale highways and associated infrastructure and has resulted in genetic isolation within both Alberta and BC (Proctor et al., 2012). By comparing patterns in population density between recent 2004 and 2014 DNA hair snag surveys with landscape factors such as road density, industrial and anthropogenic activity, and landscape-scale food and nutritional supply, the dynamics of both top-down (i.e., mortality) and bottom-up (i.e., nutritional resources) factors on the provincial bear population can be better understood to support management and policy decisions. Understanding landscape nutritional dynamics and the subsequent population-level effects helps inform provincial recovery targets, monitor regional populations, and understand the effects of changing landscape conditions. Before setting provincial recovery targets, scientists need to understand how many bears the environment can support now, and into the future.

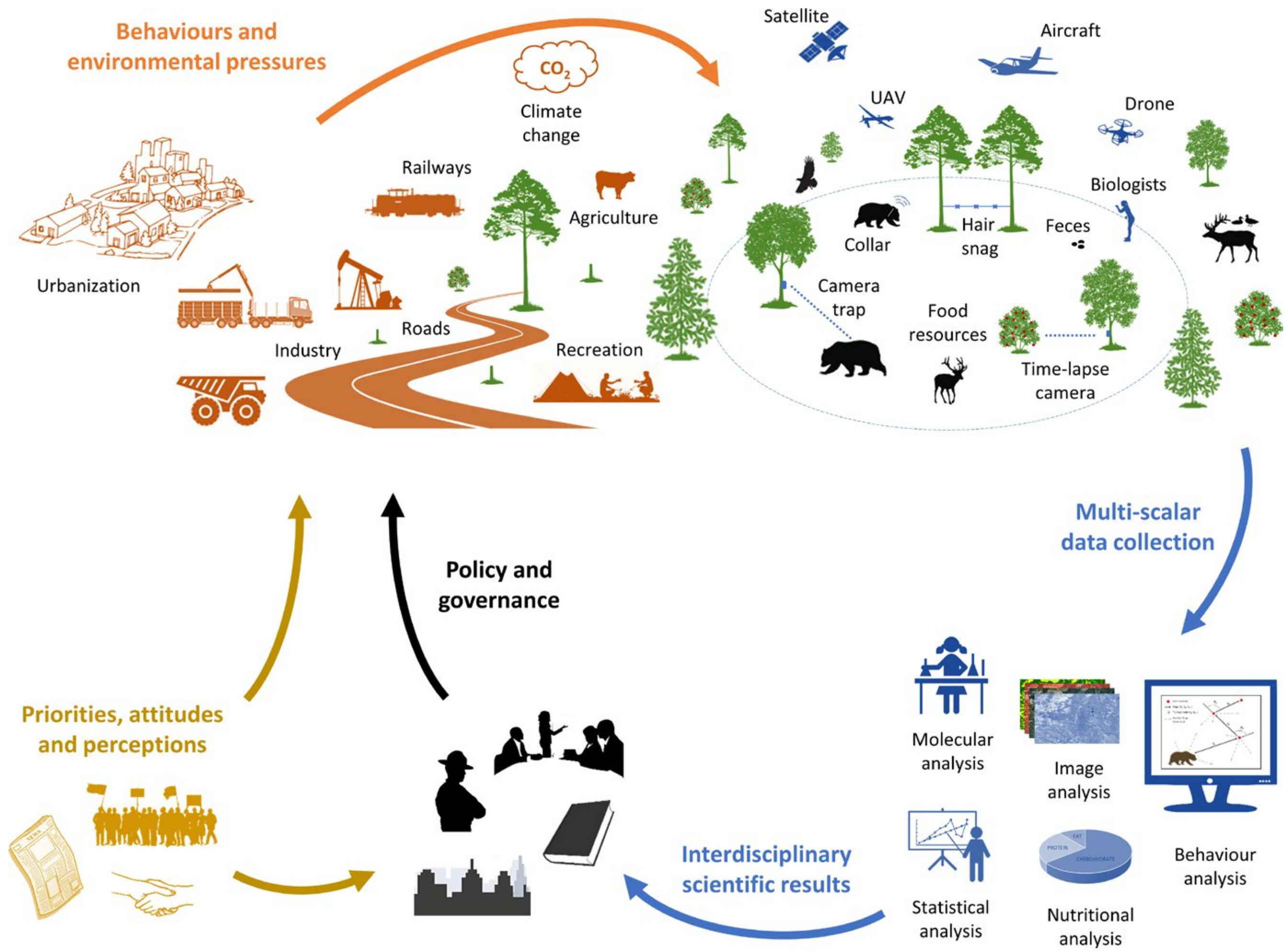

FIGURE 2 Representation of the multidimensionality of recovering the grizzly bear population in Alberta, Canada. Multi-scalar and interdisciplinary data collection, from remote sensing to molecular biology, is being undertaken by biologists to better understand bear behaviour, population dynamics, natural resources, and the impacts of anthropogenic stressors on the provincial population, including the effects of industrial activity (e.g., forestry, mining, and oil and gas). Data are analysed and reported to provide recommendations for policy and management towards recovery of the provincial population

TABLE 1 Some remote sensing applications used for grizzly bear management in Alberta, Canada

Remote sensing modality	Description
Global positioning system (GPS) radio collars	Identify bear movements and habitat preferences
Near-scale remote sensing (time-lapse cameras, motion-detecting camera traps, apps)	Monitor phenology of bear foods Monitor snow dynamics in relation to food availability and denning behaviour Links to citizen science
Unmanned aerial vehicles (UAVs)	Monitor landscape structure (timely, fine scale)
Light Detection and Ranging (LIDAR)	3D landscape representation
Satellite imagery (MODIS, Landsat, RapidEye)	Monitor disturbance and habitat productivity from space Free and open access (MODIS, Landsat) Commercial high-res (RapidEye)

3.2 | Food

Bottom-up resource dynamics are critical aspects of grizzly bear ecology (Nielsen, McDermid, Stenhouse, & Boyce, 2010), and thus understanding the relationships between food and nutritional resource dynamics (Coogan, Raubenheimer, Stenhouse, Coops, & Nielsen, 2018) are critical for species recovery and management. This is especially important given that grizzlies have a limited foraging period to acquire the nutritional and energetic resources necessary to survive hibernation, and for females to produce offspring. The timing of food availability is a critical aspect of grizzly bear foraging behaviour, as bears select plant food resources during preferred developmental stages (e.g., roots) or when they become available (e.g., fruit). Additionally, the timing and availability of spring and autumn foods may also relate to the level of human-bear interactions and possible conflicts with humans and anthropogenic food sources (Coogan & Raubenheimer, 2016; Cristescu, Stenhouse, Goskie, & Boyce, 2016). For example, understanding grizzlies' nutritional resources in space and time is required to link to effective road access management. Grizzly bears have been known to forage on roadsides or railways with abundant food resources which raises their risk of human-caused mortality.

3.3 | Nutrition

Fortunately, understanding the nutritional and metabolic relationships between grizzlies and their environment has been improved by incorporating modern knowledge of grizzly bear foraging behaviour and physiology. New research has demonstrated the complex multidimensionality of grizzly bear nutrition, where the nutrients in foods have been shown to exert a powerful influence on their food selection, body mass dynamics, and physiology (e.g., Erlenbach, Rode, Raubenheimer, & Robbins, 2014). Importantly, this information on individual-level foraging behaviour and physiology is being scaled-up to help explain population-density effects in Alberta ecosystems (Nielsen, Larsen, Stenhouse, & Coogan, 2017), while remote sensing technology has been used to monitor the relationships between phenology and nutrition of important bear foods (Nijland et al., 2013).

3.4 | Health

At the individual level, the concept of wildlife health is an integral aspect of managing grizzly bear populations. In the emerging field of "conservation medicine", modern technologies used in human biomedical sciences for health assessment and disease diagnosis are being applied as tools to understand the health of wildlife species at risk. Researchers studying Alberta's bear population are contributing novel physiological methods of assessing grizzly bear health, including the first antibody-based protein microarray developed for free-ranging wildlife that simultaneously determines the expression of over 30 proteins associated with physiological stress isolated from small skin biopsies (Carlson et al., 2016). Work is ongoing in this area using technological advances in mass spectrometry-based proteomics to determine expression of multiple proteins associated with energetics, reproduction, and stress.

3.5 | Stress

In assessing grizzly bear health, the measurement of stress is particularly important because it provides critical insight into how the animal perceives its environment, which may differ considerably from what humans adjudge. Related to nutrition, these molecular techniques are being harnessed to understand how bears respond to nutritional stress, perhaps due to inhabiting sub-par habitat with less-preferred or nutritionally poor foods. This may be critical for female grizzlies with cubs-of-the-year, which may often inhabit poorer quality habitats to avoid conflict with other bears including possible cub mortality. Related to road and anthropogenic disturbance, these stress-associated proteins are being analysed in relation to indices of anthropogenic disturbance developed from remotes sensing technologies.

Hair samples collected using noninvasive snags are also being used in Alberta to quantify concentrations of steroid hormones that accumulate within the hair shaft during the period of hair growth from June to October. These hormones—cortisol, a major "stress hormone", and testosterone, progesterone, and estradiol, the primary reproductive hormones—can now be measured in small hair samples collected noninvasively as markers of long-term stress, age class, and possibly reproductive status (Cattet et al., 2018).

3.6 | Conservation

Beyond bears, grizzly bear researchers in Alberta recognize that not all species of conservation concern receive substantial funding or public interest (Troudet, Grandcolas, Blin, Vignes-Lebbe, & Legendre, 2017), and that grizzly bears in fact live alongside community assemblages composed of numerous species' populations. Given their large spatial habitat requirements, research is being undertaken to understand how conserving grizzly bear habitat might serve as an umbrella for conserving other species and their habitats. In this way, conservation of a single charismatic species may potentially benefit other plant and animal species of provincial conservation concern.

3.7 | International challenges

The challenges of coexisting with grizzly bears, which are synonymous with brown bears outside of North America, in current and future landscapes is a global problem given the circumpolar distribution of the species, and requires region-specific approaches. Europe, for example, has experienced stable or increasing populations of large carnivores, including brown bear, "coexisting" in human-dominated landscapes largely outside of protected areas (Chapron et al., 2014). Reasons given for the successful coexistence of brown bear and humans in Europe has been attributed to favourable public support, legislation, and a variety of management practices. As bear populations in Europe have expanded, new management and societal challenges have also emerged which require new approaches.

4 | CONCLUSIONS

The complex, interactive, and multidimensional factors acting upon grizzly bears in Alberta necessitates an interdisciplinary and multiscalar scientific approach to their population recovery and management.

The data and subsequent insight acquired from such an approach will better inform decision makers, and may ultimately contribute towards improving public faith in the scientific processes informing decision making. Importantly, however, to have a societal and political impact it is imperative that scientists broadly communicate their research in a way that non-specialists can understand, while simultaneously establishing the rigorous state-of-the-art science underpinning grizzly bear research. Improving public understanding of research related to the ecology, management, and conservation of the bears may go a long way towards fostering the social tolerance necessary for co-existing with a healthy grizzly bear population in Alberta, which is a lesson learned from the European successes. Furthermore, such an approach may assuage the public's lack of faith in science communication dissonant with their own personal beliefs. Great science, and public understanding and acceptance of it, is necessary for large carnivore conservation, especially if societal values and ethics ultimately shape management policy.

Given the recent situation in BC, the question arises as to whether population recovery in Alberta will lead to an end of the hunting moratorium in that province? This is a question that we, of course, cannot answer. Certainly, however, we need the aforementioned science to help direct actions that most efficiently and effectively increase the population size, to determine when then population has recovered, and to manage that population post-recovery, before the possibility of a sustainable grizzly bear hunt could even be evaluated. Eventually, if population recovery is successful, a grizzly bear trophy hunt in Alberta will be up to society and government to decide. But we have to get there first, and that requires directed monitoring and applied research.

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AUTHORS' CONTRIBUTIONS

S.C.P.C. conceived the project and led the writing of the manuscript; S.C.P.C., N.C.C., D.M.J., M.R.L.C., G.B.S. and S.E.N. contributed to writing the manuscript. S.C.P.C. and S.P.K. created figures. All authors contributed critically to the drafts and gave final approval for publication.

DATA ACCESSIBILITY

Data have not been archived because this article does not contain data.

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BIOSKETCH

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