Scaling Up Camera Trap Surveys to Inform Regional Wildlife Conservation




Images: Cole Burton

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Online

Columbia Mountains Institute of Applied Ecology

This document is available as a free PDF download from the website of the Columbia Mountains Institute, at www.cmiae.org in the "Past Events" section. Look for the write-up for this forum here.

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We are appreciative of the fabulous work done by our conference organizing committee and others who contributed expertise as the event developed. The members of the organizing committee were:

- **Cole Burton**, University of British Columbia (UBC), Wildlife Coexistence Lab (WildCo Lab)
- **Chris Beirne**, UBC, WildCo Lab
- **Emily Chow**, BC Ministry of Forests, Lands, Natural Resources and Rural Development
- **Kim Dawe**, Quest University
- **Jason Fisher**, University of Victoria
- **Alys Granados**, UBC, WildCo Lab, WildCAM Network
- **Doris Hausleitner**, Selkirk College, CMI
- **Virgil Hawkes**, LGL Limited
- **Mike Miller**, LGL Limited, CMI
- **Cat Sun,** UBC, WildCo Lab
- **Hailey Ross**, CMI

We ***thank*** our conference volunteers, Alexia Constantinou, Joanna Burgar, Emma Griggs, Ian Adams, Sydney Goward, Rebecca Smith, and Meg Langley.

To *all* of the speakers and the people who presented posters, we are grateful for your willingness to share your knowledge with us, and for the support of your agencies in allocating time for you to participate in this event. Thank you also to Chris Beirne for donating so much of your time to develop and present part II of your workshop: Tips and Tricks for the Exploration and Analysis of Camera Trap Data.

To everyone who followed the development and eventually participated in what was originally meant to be an in-person event in Kimberley-BC to the online pandemic adaptation that took place – thank you. This event was a long-time in the making and it would not have survived the pandemic had it not been for your enthusiasm and willingness to adapt.

Thank you to our hired facilitation team:

- Nicole Trigg, Netwaves Communications
- Will Murray, Will Murray Company

About the Columbia Mountains Institute of Applied Ecology
www.cmiae.org

The Columbia Mountains Institute of Applied Ecology (CMI) is a non-profit society based in Revelstoke, British Columbia. CMI is known for hosting balanced, science-driven events that bring together managers, researchers, educators, and natural resource practitioners from across southeastern British Columbia. CMI's website includes conference summaries from all of our events, and other resources.

Conference description

The exponential growth in the use of camera traps (aka remote cameras, trail cams) is revolutionizing wildlife monitoring. Improvements and cost-reductions in camera trap technology, advances in statistical and computing methods for analysis, and a growing awareness of the need to monitor wildlife across large spatial and temporal scales, are all leading to increasing use of this powerful tool. Hundreds of thousands of cameras are being deployed to survey wildlife around the world, including many thousands deployed in western Canada by academic researchers, government and industry practitioners, and citizen scientists. This growth in sampling has the potential to transform our understanding of the ecology of terrestrial vertebrate wildlife, and inform their conservation and management at regional scales. However, the dizzying pace of growth in camera trap methodology can temper this potential, creating confusion or disjunction in implementation. The emergence of global and regional camera-trap networks is aiming to improve standardization and coordination among surveys, but the success of these networks will depend on effective communication and collaboration among researchers and practitioners.

This conference addressed key questions in the development and application of camera trap methods. It showcased established and emerging case studies, and was a forum for sharing lessons on fundamental topics such as sampling design, data management and analysis, and multi-project collaboration. This conference provided a virtual gathering space for scientists, managers, students, and citizen scientists to network and learn about current thinking on the science and application of camera trapping for wildlife ecology and management. And finally, it posed the question of what questions attendees had, or barriers they faced, with respect to integrating camera trapping efforts into a regional camera network? (Discussion results included in this document.)

This was CMI's first online conference and featured three half-days of presentations from world leaders to new student researchers, poster presentations, group discussions, a practical workshop and networking opportunities on the Slack channel. The event was engaging, informative *and fun*!

Registration for the event closed at just over 200 people and an average of 160 people remained online for the live-delivery of the conference. There was strong representation from individuals across southeaster BC, Alberta and the Yukon in addition to numerous registrations from around the world including the United States, Brazil, and Israel. All delegates received access to conference recordings for 3 months.

Summaries of presentations

The summaries of presentations in this document were provided by the speakers. Apart from small edits to create consistency in layout and style, the text appears as submitted by the speakers.

The information presented in this document has not been peer reviewed.

1. *How a new technology platform can put camera trap data to work for conservation*

Plenary Speaker: **Jorge Ahumada**, Senior Wildlife conservation scientist & Executive Director – Wildlife Insights. Moore Centre for Science, Conservation International, Arlington, VA, USA.
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Many conservation organizations and governments need to make recommendations (or decisions) about how to manage natural areas with very little or outdated information of how species living in those areas are changing over time. The fundamental questions "Which species live here?" and "How are their populations changing over time?" remains unanswered for many places and populations on the planet. Conservationists use proxies of species presence, such as habitat extent to measure conservation outcomes, a very raw and unreliable indicator of species status. The current ecosystem of species indicators at the global level (Living Planet Index, Red List Index, etc.) are inadequate to answer these questions and can be biased taxonomically, are a reflection of the past, depend on presence-only data, and rely too heavily on expert opinion. How do we get to a data-driven observation system for species? I argue that we can learn significantly from studying the evolution of established global observation systems such as the climate one. I compare the 300-year history of the modern climate global observation system (CGOS), with our current species observation system. An initial examination shows that unlike the CGOS, our current species monitoring systems lacks national level species monitoring networks, has no dedicated funding mechanism to create and maintain these networks, and does not have an international body coordinating activities, standards and funding (the equivalent of the World Meteorological Organization in GCOS). What is the role of camera trapping in filling these gaps? Camera trap data has several advantages to provide the basis of many species observing systems including easy to standardize surveys, presence/absence data, spatial and temporal replication, verifiable observations and affordable technology. But until recently, camera trap data have been difficult to

process, manage, identify, and analyze. The data remains in silos and raw, and most non-technical personnel are unable to analyze or understand the data in ways that are useful to conservation. In response to these issues, several organizations created Wildlife Insights (WI), a platform to speed the processing, management, and analysis of camera trap data. Since then, we have recognized that WI not only solves the logistical issues of data management and analysis, but also provides a template for national government to easily create, deploy and manage wildlife observing networks. We showed three case studies with two national governments and one state government in the US that are experimenting with WI as they explore building their own national observing species networks. We believe that is an important step in the scaling and implementation of global species observing systems in the globe.

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2. *WildTrax, a tool to standardize and maximize the utility of environmental sensor monitoring data*

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In the past five years, wildlife monitoring in western Canada has fundamentally changed. Environmental sensors such as remote cameras are rapidly replacing conventional human survey techniques. Remote cameras are used to capture images of mid- to large-size mammals including wolves, ungulates, and many furbearers. Such sensors allow for continuous or near continuous data collection over extended periods of time, resulting in the accumulation of "big data"—a key benefit of their use.

Despite the increasing reliability and accessibility of these environmental sensors, there are several practical challenges to their use in collecting data. One major challenge is the standardization of data and metadata across data collectors. A lack of standardization limits data integration and stands in the way of addressing large-scale monitoring and research questions. Further, the time required for human taggers to process these images can be resource intensive. While automated recognizers and processors have been developed and applied to improve tagging rates and minimize processing time, these may also suffer from a lack of standardization. To harness the full potential of environmental sensors, an integrated and collaborative approach to data collection, standardization, storage, and processing is needed.

WildTrax is a modular web-based platform designed for users to store, manage, process, standardize, and discover remote camera and autonomous recording unit (ARU) sensor data. It integrates the latest developments in image processing and automated

recognition, ensures minimum metadata standards are maintained and provides a centralized system for sharing these very large datasets to facilitate environmental decision-making.

Currently, WildTrax supports three sensor types: ARUs, remote cameras and avian point counts. ARU and camera data are composed of species detections tagged from acoustic recordings and images, respectively. In contrast, point count data are standardized species detections from a variety of human-observed distance-based sampling from the Boreal Avian Modelling database. Since its operational inception in 2019, WildTrax has seen an accumulation of ~35 million images and ~1.8 million species detections from the camera and ARU sensors, respectively.

WildTrax operates under a role-based user system, whereby users can log in and see organizations, projects, tasks, and data they own or to which they have been granted access. Roles are currently defined at the organization level for management; project level for data sharing; and task level for processing. This policy-neutral access-control mechanism defines roles and privileges, making it simple to perform user assignments or share and discover data. It was designed primarily to foster and promote licensing and sharing of data through organizations and projects in support of open data standards.

The data structure allows for an organization to manage its location, visit, and equipment metadata. Location coordinates can be buffered or hidden, depending on the sensitivity of the data or area being surveyed. Visits are when a human has gone to a location to conduct a survey (i.e., point count) or to deploy/retrieve an ARU or camera. Equipment deployed/retrieved during a visit can be tracked and managed in the system to provide a live inventory of where an organization's sensors are located on the landscape.

An organization can create "projects" in WildTrax, which are defined as aggregations of media to answer specific questions. ARU project features and functions include batch uploading of audio recordings, user assignment, and processing methods. Camera project features include batch uploading of image sets, auto-taggers, user assignment, and species verification. Image sets and acoustic recordings are presented as tasks within a project to be processed by assigned taggers and transcribers.

WildTrax offers unique processing interfaces for each sensor type. The ARU interface involves creating boxes for spectral signatures on a spectrogram. Each box is defined as the frequency range and time duration of an animal vocalization. The camera processing interface allows users to tag images, either individually or in bulk, with attributes such as species, age, and sex, and verify species tags. The point count interface is a static table that houses species detections from the human-observed counts. Quality control checks

and processes are in place throughout the processing interface to ensure data is of high quality.

To support open data, administrators have the option to publish their data, making it available via “Data Discover” and “Data Download” functions. Complete projects can be published and locked for editing by the administrator. There are four options for publishing:

- Private - the project data is only available to project members.
- Map only - the project data will be accessible through Data Discover but the media and report are not accessible to users who are not project members,
- Map + Report - the project data become available to all WildTrax users through Data Downloads and Data Discover, however, the media is not accessible. or
- Public - all of the project data become available to any WildTrax user as well as the details of the project in Data Downloads and Data Discover.

The selected option determines who will be able to access that project and its data via the project dashboard, Data Discover or Data Download for analysis and application.

WildTrax is a living entity, whose features and functions are continually evolving and improving to support and meet user needs and expectations. We would like to thank our sponsors ECCC, University of Alberta, Alberta Environment and Parks, InnoTech Alberta, JOSM, COSIA, and NSERC who have contributed their vision and development support, and our partners, who have helped with data collection projects and in creating the foundation for WildTrax.

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3. *Automated image recognition for wildlife camera traps: making it work for you*

Presenter: **Saul Greenberg**, Professor Emeritus, University of Calgary and Greenberg Consulting Inc.
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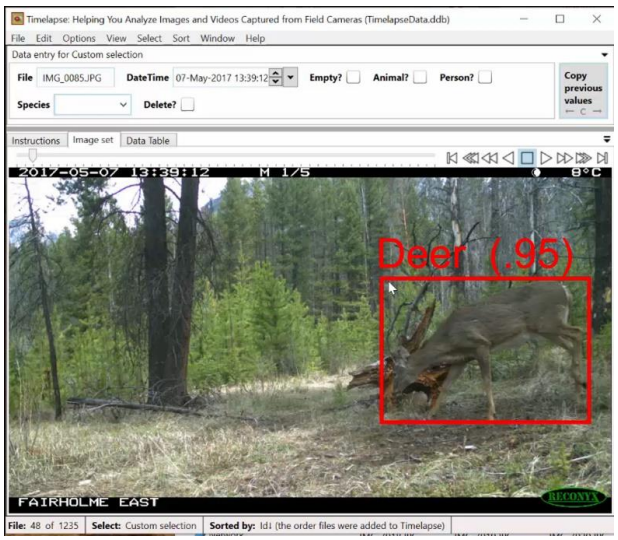

You may have heard about applying automated image recognition to wildlife camera trap images. The basic idea is that an image recognizer will automatically analyze your images to locate and classify the wildlife species captured within each image. When recognition succeeds, it correctly detects and identifies whether animals are in an image, along with a classification of each detected animal. Various academic papers report what appears to be excellent recognition performance, some in the 90%+ correctness range in detecting wildlife and identifying the correct species. This may make you believe that you should now apply an image recognition system to automatically classify the (possibly) millions of camera trap images you have collected, as the time and cost savings can be enormous. Yet before you do, you should be aware of the nuances of applying recognition to your images. This includes understanding why recognition on your own images may be less than the reported performance, knowing where recognition will likely succeed or fail, and how to adjust your workflow to include a 'human in the loop' to make best use of recognition predictions. The presentation discusses these points, where it illustrates a workflow using the freely available Timelapse image analyser for camera traps, which in turn incorporates recognition results produced by the Microsoft Megadetector.

A full paper describing the contents of the talk is available as:

Greenberg, S. (2020) *Automated Image Recognition for Wildlife Camera Traps: Making it Work for You*. Technical report, Prism University of Calgary's Digital Repository, University of Calgary, Calgary, Alberta, Canada. August 21.

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4. *Models and monitoring: using camera trap data to assess long-term trends in wildlife populations*

Presenter: **Wendel Challenger**, LGL Limited Environmental Research Associates
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Camera trap (CT) technology provides promising tools for monitoring of wildlife populations, however data analyses for long-term studies presents many challenges. For unmarked populations, the occupancy framework is often employed due to the ability to account for imperfect detection. The framework estimates the portion of sites in the sampling frame that are occupied by the species of interest, a surrogate measure for abundance, after correcting for imperfect detection. Repeat observations within the closure period, a period of time where the occupancy state is assumed to be static, allows the detection process to be disentangled from occupancy. The closure period may be static over a study period, or dynamic where the periods of closure are interspersed with periods where the occupancy state is allowed to evolve over time. Violations of the closure assumption can result in biased parameter estimates, but typically these types of violations receive little attention and may be especially problematic for long-term monitoring programs. Shorter closure period durations are less likely to result in a closure violation but may be undesirable for long-term monitoring applications due to the large number of state changes that need to be modelled over the study period. For example, seasonal, random environmental changes, and long-term trends can make shorter closure period formulations especially problematic as these factors may not be known *a priori* when determining which transitions will be affected. We present a hierarchical Bayesian formulation designed to address many of these issues. The formulation uses a fine temporal time step (i.e., monthly) over a long assessment period (i.e., 10 years). Occupancy was assumed to be static within each month but could change between months. Hierarchical structuring was then used to capture natural seasonality and to allow for deviations from this natural cycle on differing temporal scales to account for long-term changes, environmental stochasticity, and one-off random events which can be common in long-term longitudinal studies. Fine-scale estimates were then averaged to coarser time scales (e.g., yearly) to monitor long term changes in the study area. As a demonstration of the approach the model was fit to a 10-year continuous time series of wildlife camera trap data collected as part of a monitoring program in the Athabasca Oils Sands Region.

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5. *Use of 3G motion camera to monitor an active Flammulated Owl nest near a mineral exploration drilling site*

Presenter: **Ian Adams (Presenter)**, Larix Ecological Consulting
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Flammulated Owl (*Psiloscops flameolus*) is a species at risk in the dry interior forests of southern British Columbia. In the East Kootenay region, it is known from a number of locations mainly on the west slope of the Rocky Mountains on the east side of the Rocky Mountain Trench. Many reports and management plans cite the species as being highly sensitive to noise disturbance. However, no thresholds for "how much is too much" are available. An exploration mineral drilling program in 2017 targeted a location near the base of Lakit Mountain, east of Kimberley, BC, known to be Flammulated Owl breeding habitat. An initial survey on June 3, 2017, found up to 11 individuals in the Lakit area, including an active nest approximately 400m from the proposed drill site. The drilling program was adjusted from 24/7 to 12 hours a day, from 07:00-19:00h, the rig was enclosed and fitted with a muffler to help reduce noise. At the same time, we deployed two motion-detection cameras, including one 3G-enabled, at the active owl nest to monitor for disturbance related to the drilling. Photos were transmitted immediately to a cell phone and if abnormal behaviour was noted, drilling would immediately cease. We collected >22,000 images between 16 June and 1 August. Drilling began on June 20 and ran through 10 July. No abnormal behaviour was observed by the owls, who continued to emerge nightly between 22:00 and 22:30. Young first emerged from the nest 16 July and fledged soon after. One owl returned to the nest 30 July. We concluded that the nest was not disturbed by the nearby drilling activity based on photographic evidence of consistent behaviour at the nest. The use of 3G-enabled motion cameras allowed us to remotely monitor owl behaviour in a non-intrusive manner.

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6. *A new viewpoint: investigating the use of arboreal camera traps in Madagascar to assess lemur occupancy*

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Camera traps have long been used to monitor wildlife populations and are a growing trend in the field of conservation. While camera traps have been effectively implemented to study terrestrial species, they have not widely been used to study arboreal species of interest. Specifically, in Madagascar, whole communities of lemurs have not yet been studied at canopy heights in natural forest. The goal of our research was to set up an array of arboreal camera traps in forest fragments of southeastern Madagascar in order to assess the occupancy levels of several lemur species in the area. The study took place in Kianjavato, Madagascar over a span of four months (May-September 2019). Cameras were deployed across five forest fragments in a 700-meter grid formation. There was a total of 30 camera trapping points. Arboreal cameras were placed 6-14 meters (mean =

10 meters) high in trees using a single-rope climbing system. Cameras ran for a continuous 30-day trapping period. Single-season, single-species occupancy modeling was completed in the software PRESENCE. Occupancy (ψ) was calculated for five lemur species: the red-fronted brown lemur (*Eulemur rufifrons*; $\psi = 0.54 \pm$ SD 0.03), Jolly's mouse lemur (*Microcebus jollyae*; $\psi = 0.14 \pm 0.17$), the greater dwarf lemur (*Cheirogaleus major*; $\psi = 0.42 \pm 0.30$), the red-bellied lemur (*Eulemur rubriventer*; $\psi = 0.24 \pm 0.03$), and the black-and-white ruffed lemur (*Varecia variegata*; $\psi = 0.24 \pm 0.08$). Tree diameter, elevation, distance to village, and canopy connectivity were important predictors of occupancy. Arboreal cameras detected all nine study site lemur species, while ground cameras detected only one species of lemur. This research shows the promise of arboreal camera trapping and how data stemming from this technique can increase the knowledge surrounding arboreal wildlife that has the potential to aid in their protection.

Published paper:

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Chen, D. M., Narváez-Torres, P. R., Tiafinjaka, O., Farris, Z. J., Rasoloharijaona, S., Louis, E. E., & Johnson, S. E. (2021). Lemur paparazzi: Arboreal camera trapping and occupancy modeling as conservation tools for monitoring threatened lemur species. *American Journal of Primatology*, e23270. http://doi.org/10.1002/ajp.23270

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7. *Are arboreal camera traps better than line-transects for documenting lemur diversity?*

Presenter: **Pamela Narváez-Torres**, University of Calgary
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Line-transect surveys have been widely used to study arboreal primates' abundance and diversity (Buckland et al., 2010; Peres, 1999). However, this method can be very time-consuming, labour intensive, and have poor detection precision for some taxa (Moore et al., 2020; Silveira et al., 2003). On the other hand, camera traps have been widely used in ecological studies of terrestrial mammals. Although arboreal cameras are still relatively new, they can be a handy tool for the study of canopy primates (e.g., Bowler et al., 2017; Gregory et al., 2014; Whitworth et al., 2016). This study compares the effectiveness of arboreal camera traps with line transects to document lemur species in Southeast Madagascar.

We collected data in five forest fragments across the Kianjavato-Vatovavy forest fragments in Southeast Madagascar – a hotspot of threatened biodiversity that has undergone massive forest degradation. Nine species of lemurs inhabit this area, and all of them are threatened with extinction. We conducted lemur surveys on 37 line transects between July and December 2016, and we walked each transect up to 22 times, covering 212 km in total. The transect surveys were conducted during the day (7:00h - 14:00h) and night (18:30h - 22:30h), and up to five transects were walked each day (e.g., three during the day and two at night). Due to how labour-intensive line transects are, each shift was conducted by a different team. We used arboreal camera traps to survey 30

points within the Kianjavato-Vatovavy forests fragments between May and August 2019. We installed the camera traps at heights between 6 m and 16m using a Single Rope System or SRS tree climbing technique. The cameras were positioned within a grid 0.7 km apart, and each camera operated for at least 30 days (1058 camera trapping nights).

With the line-transect surveys, we recorded seven of the nine lemur species present at this site; of these seven species, we recorded 270 individuals during 111 sightings. On the other hand, with the camera traps, we detected the nine species of lemurs (Fig. 1). However, in 130 events, we only recorded 152 individuals. To compare the effectiveness of these methods, we used species accumulation curves (Fig. 2). For line-transects, the species accumulation curve reached an asymptote when seven species were detected after 313 walks. With the arboreal camera traps, the asymptote was reached at nine species after 1052 trapping nights.

In conclusion, the camera traps recorded a higher number of lemur species in less time than the line transects. Additionally, the camera traps were better at recording nocturnal and rare species. However, the higher number of individuals detected in the line-transect surveys suggests that more information on group dynamics can be determined from this sampling methodology. Despite the high initial costs of camera-trapping, this is an excellent method for documenting and monitoring the diversity of arboreal mammals, thus an excellent tool for conservation.

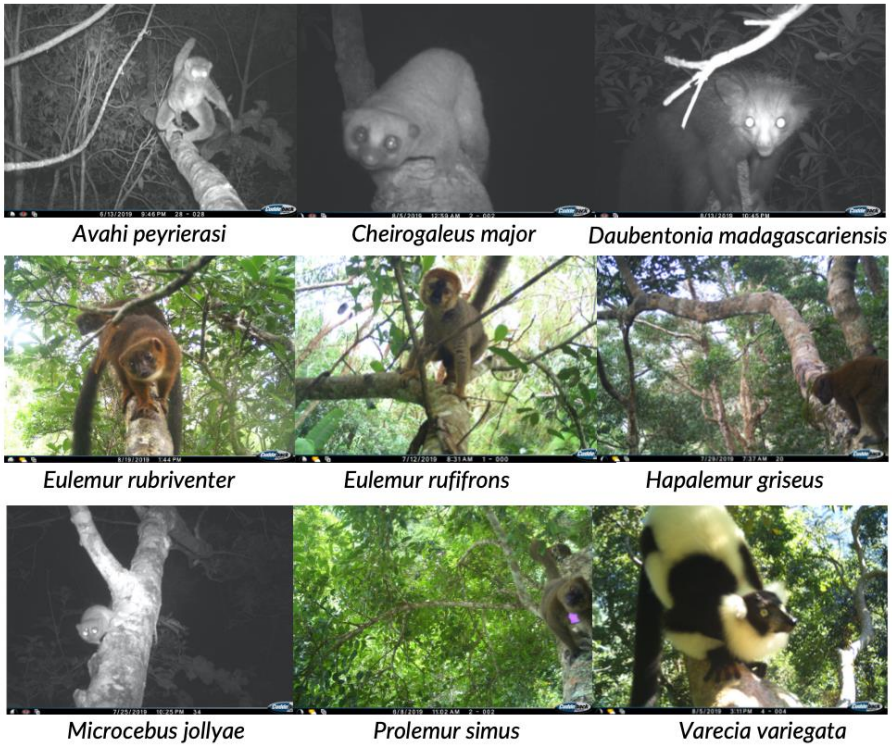

FIGURE 1. Lemur species present in the Kianjavato forest fragments and captured by the arboreal camera traps.

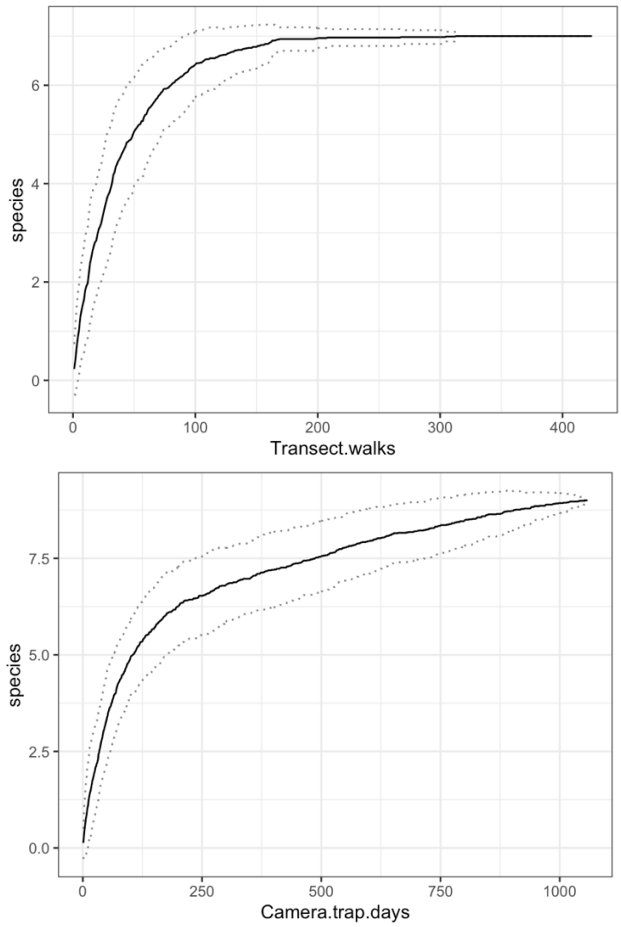

FIGURE 2. Species accumulation curves (black lines) with the upper and lower 95% confidence limits (dotted lines).

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8. *Using remote cameras to assess spatial patterns of mammalian habitat use in the Elk Valley*

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Abstract

Remote cameras are increasingly used by wildlife professionals and industry practitioners to passively monitor wildlife because they are relatively inexpensive to deploy and maintain for the amount of multi-species data generated. Remote cameras are commonly used to generate demographic estimates (i.e., population density, abundance, and trends), species richness, and temporal interactions among elusive and wide-ranging mammals. Another common application is to link wildlife to their habitat using occupancy models. Occupancy models are generally used to assess habitat associations between wildlife and their environment by assigning a binary category (i.e., detection/non-detection), then linking this with environmental covariates. But this modelling approach may not be appropriate for answering questions where amount of use (i.e., number of detections) at each camera location is important. We sought to answer questions about the potential effects of anthropogenic habitat disturbance on several wildlife species in British Columbia's Elk Valley, focusing on bighorn sheep (*Ovis canadensis*), Canada lynx (*Lynx canadensis),* elk (*Cervus elaphus*), grizzly bear (*Ursus arctos*), and moose (*Alces alces*). We deployed 116 remote cameras between June 2017 and August 2020 using stratified random sampling, placing cameras at least 1 km from each other to reduce spatial dependence. Using these data to answer our questions depended not only on determining whether species were detected at a given camera location, but also accounting for the number of detections. We discuss the merits of different statistical approaches to answering questions about wildlife habitat relationships when the number of detections is important, and provide examples using our Elk Valley remote camera data.

Introduction

Commercial coal mining and forest harvesting have been present in the Elk Valley, British Columbia (BC) for over a century, and the human population in the Elk Valley

has also increased substantially over this period. Human recreation, such as hunting, mountain biking, hiking, skiing, and off highway vehicle (OHV) use, are common in many parts of the Elk Valley. First Nations, outdoor enthusiasts, and regulators have identified cumulative effects to large mammal movements and habitat use as an area of concern in the Elk Valley, especially in relation to expanding mining and forestry developments and increased recreational use.

There are information gaps about the degree to which anthropogenic developments and activities may be influencing the habitat use and movements of large mammals in the Elk Valley. To fill information gaps, we developed a wildlife monitoring program using remote cameras as the data collection tool. Remote cameras are increasingly being used to answer a wide variety of ecological questions about population size and trend, animal abundance and distribution, habitat selection and use, and temporal trends in wildlife community composition (Burton et al. 2015, Steenweg et al. 2017). Networks of remote cameras can collect data about how wildlife use landscapes year-round, over large areas, and for many different species simultaneously. Data can also be collected at relatively low cost compared to other methods capable of answering similar questions.

We selected five target species, bighorn sheep (*Ovis canadensis*), Canada lynx (*Lynx canadensis*), elk (*Cervus elaphus*), grizzly bear (*Ursus arctos*), and moose (*Alces alces*), because of their ecological and conservation importance in the Elk Valley and because pilot data indicated that we could obtain statistically robust sample sizes of detections for these species. We identified several key questions to understand the general ecology of large mammals (e.g., seasonal patterns of use) and how anthropogenic disturbances and activities in the Elk Valley affect these target mammal species:

- How does large mammal photograph rate in the Elk Valley vary by season?
- Does the average rate of use of monitoring features by large mammals differ significantly between anthropogenic linear features (e.g., exploration roads, OHV trails, seismic lines) and naturally-occurring linear features (e.g., game trails)?
- How does rate of human activity, distance to anthropogenic linear features, distance to active mining, and amount of reclaimed mine areas influence large mammal habitat use?
- How do photograph rates of an ungulate species (i.e., bighorn sheep) vary in relation to photograph rates of predators?

Materials and Methods

Camera Deployment

We deployed 116 Reconyx Hyperfire Professional Infrared remote cameras (models PC800, PC900, or HP2X) between June 2017 and August 2020. We used a stratified random sampling design to select deployment locations for cameras. First, we created a sampling matrix of 1.77 km^2 circular plots (i.e., a point with 750-m radius) for our study area (Fig 1). We selected circular plots at random and assigned targeted deployment locations within selected circular plots. We assigned a monitoring feature (i.e., 'anthropogenic linear feature' or 'game trail') to selected circular plots. Once in the field, we deployed cameras at target monitoring features, 20−50 m from targeted deployment locations, and considered safety, accessibility, and viability for long-term monitoring when choosing deployment locations. All cameras were deployed > 1 km from each other.

Where available, we mounted cameras on suitable trees. When suitable trees were unavailable, we mounted cameras to posts driven into the ground. We mounted cameras 1−1.5 m from the ground and angled cameras towards monitoring features. We affixed cameras to trees or posts using Reconyx security enclosures and locks to deter theft and/or tampering. We equipped all cameras with 12 Energizer lithium AA batteries and 16 or 32 GB memory cards. We programmed cameras to capture motion-triggered photographs 24h/day, and to take two photographs with a one-second delay when triggered by motion (i.e., 'motion' photographs). We also programmed cameras to take a daily timed photograph at 13:00 (i.e., 'timed' photographs), which we used to confirm that the camera was functional and did not have a compromised field of view. We assigned each deployment location a unique identifier. We visited cameras at least annually to replace SD cards, replace batteries, trim vegetation, and replace stolen or damaged cameras (if necessary).

Photograph Interpretation

We downloaded photographs from SD cards after each visit to cameras. We reviewed motion and timed photographs using the Timelapse2 image analyzer (Greenberg and Godin 2015). For motion photographs, we identified all wildlife and/or humans captured in each image. When wildlife was detected, we determined the species, where possible. We categorized human use into one of six activities (i.e., mine truck, car/truck, OHV vehicle, equestrian, biker, and/or hiker). If multiple human activities were detected in the same photograph, we counted the largest visible unit (i.e., mine truck > car/truck > off-highway vehicle > equestrian > biker > hiker).

For both wildlife and humans, we counted individuals appearing for the first time as 'new' individuals. If the same individual was captured in subsequent photographs, we counted them as 'same' individuals. If an individual left the field of view for > 5 minutes and returned, the individual was counted as a 'new' individual, even if we could determine that it was same individual. To determine whether an individual was 'new' or 'same', we paid close attention to physical attributes such as horns/antlers, colouring, size, and the physical activity and location of the individual. If there was discrepancy as to whether an individual should be counted as 'new' or 'same', we classified the individual as 'new'.

We calculated the number of active monitoring days for each deployment location and season. We defined summer as April 16−November 14 inclusive and winter as November 15−April 15 inclusive. For cameras that collected timed images, we calculated active days based on the total number of unique dates with a daily image with an uncompromised field of view. For cameras that did not collect timed images (e.g., cameras with programming errors), we calculated active days based on the number of days between the first and last motion image. We summed the total number of new individuals per species, deployment location, and season then divided this by the number of active days per deployment location and season to obtain a photograph rate per species. We calculated human use rates in the same manner.

Statistical Analyses

We assessed how photograph rate for target species varied by season by comparing summer and winter photograph rates using balanced two-tailed t-tests (alpha = 0.05). We considered only cameras that were active for both seasons in this analysis. We assessed use of monitoring features by comparing photograph rates at anthropogenic linear features (henceforth called 'linear features') and game trails using unbalanced two-tailed t-tests (alpha = 0.05). We applied unbalanced t-tests because the number of deployment locations on linear features and game trails were unequal. Prior to conducting t-tests, we examined data to test for normality of residuals and equal variance between the groups being compared.

To understand how rates of human activity, distance to anthropogenic linear feature, distance to active mining, and amount of reclaimed mine areas influenced habitat use by target species, we investigated occupancy models and generalized linear models (GLMs). Occupancy models are generally used to assess habitat associations between wildlife and their environment by assigning a binary category (i.e., detection/non-detection), then linking this with spatial and/or environmental covariates (Burton et al. 2015). However,

this modelling approach may not be appropriate for answering questions where amount of use (i.e., number of detections) at each camera location is important, as was the case for our study.

Thus, we developed generalized linear models (GLMs) to understand how the rate of human activity, distance to anthropogenic linear feature, distance to active mining, and amount of reclaimed mine areas influenced habitat use by target species. We developed continuous raster surfaces using multiple data sources (i.e., a disturbance layer and reclamation and seeding layer, both provided by Teck Coal Limited [Teck]). We fit an *a priori* disturbance model to data for each target species and season, except for grizzly bears during winter. We fit the disturbance model using a hurdle GLM by implementing the *pscl* package (Jackman 2020) in *R*. We included an offset term for the logarithm of active days to account for unequal active days among cameras. We selected a top model per species and season using Akaike's Information Criterion corrected for small sample size (i.e., the top model had ΔAICc <2.0; Burnham and Anderson 2002).

To assess how photograph rates of bighorn sheep varied in relation to photograph rates of predators, we compared paired bar graphs. Paired bar graphs compared relative photograph rate of predators (i.e., cougars and wolves) and sheep at each deployment location. We summed the total number of new detections of cougars and wolves per deployment location and season, then divided by the active days per season. We scaled both the photograph of predators and sheep between 0 and 1 to facilitate comparison. We ordered deployment locations along the x-axis based on the relative photograph rate of predators so that the highest relative predator photograph rate (i.e., equal to 1) was the furthest left and cameras without predator detections were furthest right (i.e., equal to 0).

Results

Cameras (n = 116) in our study area were active for 114,084 days between June 2017 and October 2020. During this period, we obtained the following counts of new individuals: 9,807 bighorn sheep, 49,097 elk, 474 grizzly bear, 319 lynx, and 1,366 moose. We identified significant differences in seasonal photograph rates for elk, lynx, and moose (Fig 2, Table 1). In all monitoring years, elk had significantly higher photograph rates in summer than in winter (Fig 2, Table 1). In 2019, lynx had significantly higher photograph rates in winter than in summer, and the opposite trend was true in 2020 (Fig 2, Table 1). Moose photograph rates were higher in summer than in winter for all years except 2020 (Fig 2, Table 1).

Except for summer 2019, bighorn sheep photograph rate did not differ between game trails and linear features (Fig 3, Table 2, Table 3). Elk photograph rate did not differ

significantly between game trails and linear features in summer or winter (Fig 3, Table 2, Table 3). Grizzly bear photograph rate was significantly higher on linear features than on game trails in summers of 2018 and 2019 (Fig 3, Table 2, Table 3). Lynx photograph rate in summer was significantly higher on linear features than on game trails in 2020 (Fig 3, Table 2) and this same pattern was observed in winters 2018 and 2019 (Fig 3, Table 3). Average moose photograph rate was significantly higher on linear features than game trails in winter 2017 (Fig 3, Table 2, Table 3).

Models converged for all species in all seasons, except for bighorn sheep in winter. In summer, we identified the strongest responses to disturbance for bighorn sheep (counts increase at cameras closer to active mining) and lynx (counts decrease with increased amount of reclaimed areas; Fig 4). In both seasons, all target species showed a small positive association with rate of human use (Fig 4). The direction of species response to distance to linear disturbance varied across species in summer (Fig 4). Response to disturbance was generally weaker in winter than in summer, across target species (Fig 4). In general, these results indicate that elk and bighorn sheep occur more frequently near and on mines; grizzly bears have similar detection rates on and off of mines; and lynx and moose are not commonly detected on mines, though they may occur in the vicinity of mining operations (Fig 4).

During both summer and winter, cameras with the highest relative photograph rate of predators (i.e., cougars and wolves) had no or few detections of bighorn sheep, and cameras with the highest relative photograph rate of bighorn sheep had no detections of predators (Fig 5, 6). In general, bighorn sheep were detected at cameras with little or no predator use, and this trend was consistent across all monitoring years (Fig 5, 6). Although we present results only for bighorn sheep, these results indicate that visualizing photograph rates can be a useful tool for understanding spatial use of sites by ungulates and their predators.

Discussion

We detected higher photograph rates for elk and moose in the summer than in the winter, which is likely due to seasonal changes in movement rates (i.e., elk and moose move shorter distances and less frequently in the winter due to weather and/or snow). Elk and moose also concentrate in different areas of the Elk Valley during the winter than they do in summer, which could explain why cameras had lower overall photograph rates in the winter. We did not observe strong seasonal patterns in lynx photograph rate, which supports that lynx are equally able to move across the landscape during summer and winter. Photograph rates for bighorn sheep did not differ by season. Deep snow impedes movement and foraging by bighorn sheep (Demarchi et al. 2000, Poole 2013), which

should result in lower photograph rates in winter than summer. However, if cameras were biased to monitor locations that bighorn sheep frequently use in the winter, then differences in photograph rate by season may not be obvious.

We observed variation in the way large mammal species used linear features and game trails. Generally, photograph rates of bighorn sheep, elk and moose did not differ by monitoring feature, across years. Conversely, predators (i.e., grizzly bear and lynx) had significantly higher photograph rates on linear features than game trails, which is consistent with other carnivore studies (Dickie et al. 2016). Anthropogenic linear features may facilitate large mammal movement in the Elk Valley or, at a minimum, they do not appear to disrupt movement for predators.

Target species responded differently to disturbances in the Elk Valley. Bighorn sheep used areas closer to active mining year-round and were commonly found on operational mines. Although bighorn sheep were commonly detected on mines, the total amount of reclaimed area in the vicinity of a camera was not a strong driver of bighorn sheep use. Bighorn sheep have specific habitat requirements (i.e., forage near escape terrain such as highwalls and footwalls), which could explain why reclamation within the vicinity of the cameras, in general, did not strongly predict bighorn sheep use. Instead, reclamation near escape terrain is more likely to be a strong driver of bighorn sheep use. Elk used areas closer to mining operations and were detected more commonly in areas with a greater amount of reclaimed habitat in the vicinity of a camera in all seasons. Grizzly bears did not show strong responses (positive or negative) to mining or reclamation. However, higher grizzly bear photographic rates were obtained at cameras deployed on linear features and at cameras with higher human use. Lynx were detected closer to active mining in summer, but not in winter. Active mines and associated reclamation areas were avoided by lynx. Moose tended to use areas further away from active mining in both summer and winter and tended to avoid reclaimed areas. Avoidance of active mines and associated reclamation areas by lynx and moose may have been due to the early seral structural stage in these areas.

Use of habitats by bighorn sheep was negatively correlated to the rate of use by predators (i.e., cougars and wolves). Bighorn sheep and predators demonstrated little overlap during both summer and winter. Cougars use forest edges to hunt prey while remaining undetected (Laundre and Hernandez 2003) and wolves use travel corridors, such as ravines and riparian areas (Kauffman et al. 2007), to hunt prey. Ungulates may avoid areas such as these where predation risk is higher. It is possible that mine sites and the high levels of human use associated with them provide some refuge from predation. As more data are collected, predator-prey relationships could be explored with GLMs.

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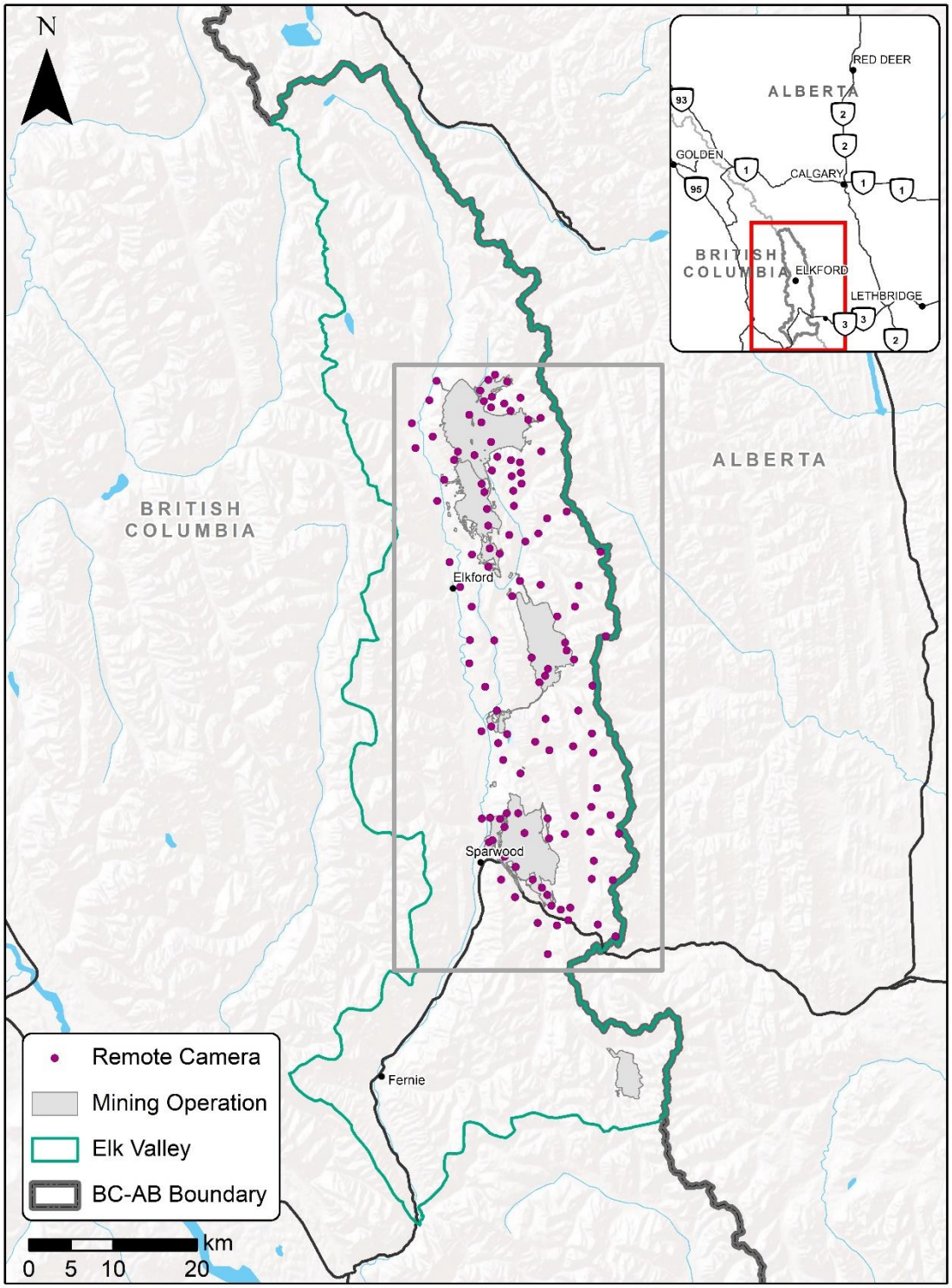

Figure 1: The study area (grey box), located in the Elk Valley, British Columbia (outlined in teal). Deployment locations for remote cameras used in our study are identified as magenta points.

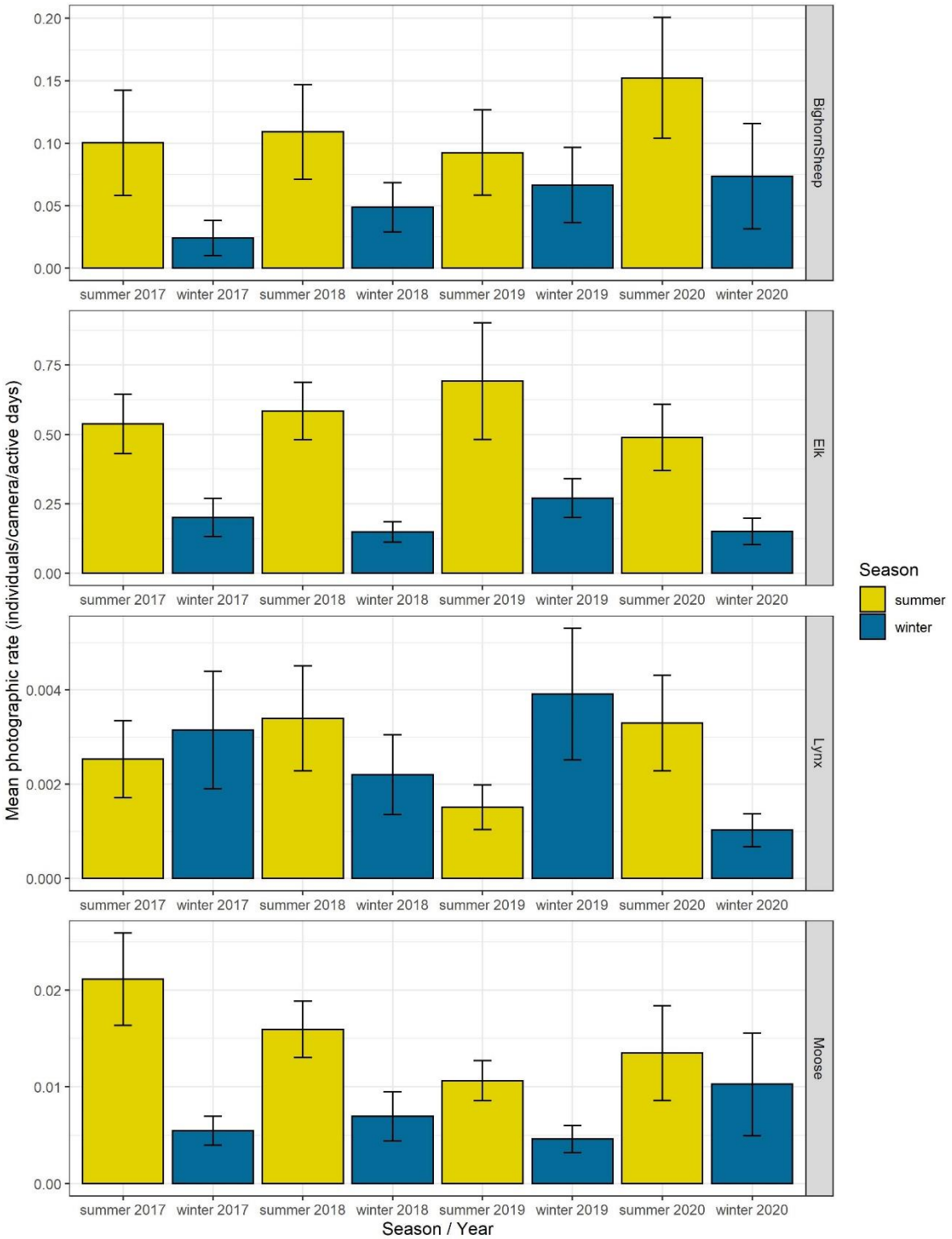

Figure 2: Mean photograph rate of bighorn sheep, elk, lynx, and moose compared between summer and winter. Error bars represent standard error.

Table 1: Results of paired two-tailed t-tests used to compare photograph rate of target species between summer and winter.

Target Species	Photograph Rate (Mean ± SE)			t-value	df	p-value
	Year	Summer	Winter			
Bighorn sheep	2017	0.10 ± 0.04	0.02 ± 0.01	1.56	101	0.12
	2018	0.11 ± 0.04	0.05 ± 0.02	1.59	116	0.11
	2019	0.09 ± 0.03	0.07 ± 0.03	0.71	111	0.48
	2020	0.15 ± 0.05	0.07 ± 0.04	1.42	98	0.16
Elk	**2017**	**0.54 ± 0.11**	**0.20 ± 0.07**	**3.09**	**101**	**<0.01**
	2018	**0.58 ± 0.10**	**0.15 ± 0.04**	**5.09**	**116**	**<0.01**
	2019	**0.69 ± 0.21**	**0.27 ± 0.07**	**2.03**	**111**	**0.05**
	2020	**0.49 ± 0.12**	**0.15 ± 0.05**	**3.09**	**98**	**<0.01**
Canada lynx	2017	0.003 ± 0.001	0.003 ± 0.001	-0.55	101	0.58
	2018	0.003 ± 0.001	0.002 ± 0.001	0.94	116	0.35
	2019	**0.001 ± 0.0004**	**0.004 ± 0.001**	**-2.14**	**111**	**0.04**
	2020	**0.003 ± 0.001**	**0.001 ± 0.0003**	**2.25**	**98**	**0.03**
Moose	**2017**	**0.02 ± 0.004**	**0.005 ± 0.001**	**3.28**	**101**	**<0.01**
	2018	**0.02 ± 0.003**	**0.007 ± 0.003**	**3.37**	**116**	**<0.01**
	2019	**0.01 ± 0.002**	**0.005 ± 0.001**	**3.46**	**111**	**<0.01**
	2020	0.01 ± 0.005	0.01 ± 0.005	-0.41	98	0.68

Notes: SE = standard error; df = degrees of freedom. Bolded rows indicate years with statistically significant differences.

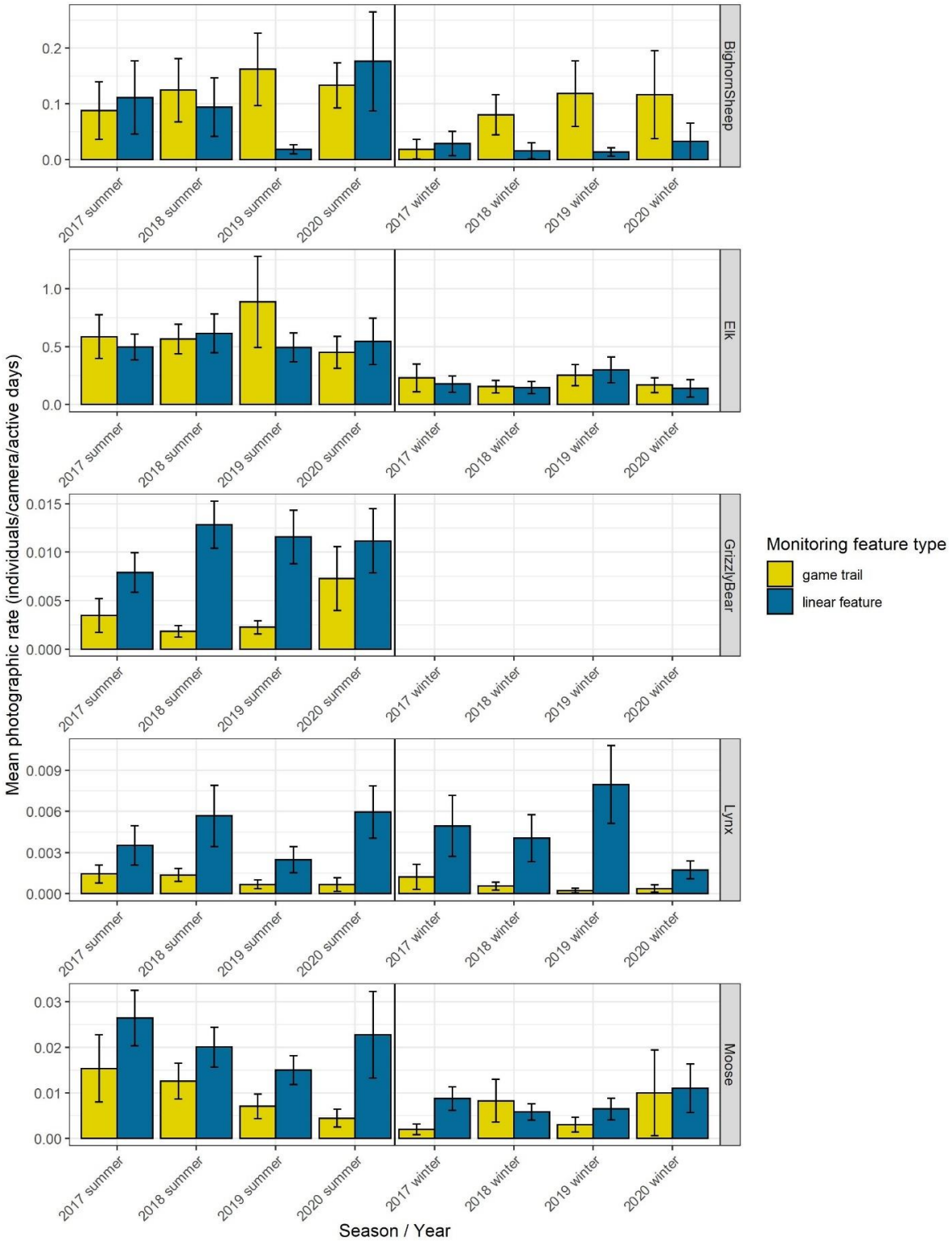

Figure 3: Mean photograph rate of bighorn sheep, elk, grizzly bear, lynx, and moose compared between game trails and linear features. Error bars represent standard error.

Table 2: Results of two-tailed t-tests used to compare photograph rate of target species at game trails and linear features during summer.

Target Species	Summer Photograph Rate (Mean ± SE)			t-value	df	p-value
	Year	Game trail	Linear feature			
Bighorn sheep	2017	0.09 ± 0.05	0.11 ± 0.07	-0.28	101	0.78
	2018	0.12 ± 0.06	0.09 ± 0.05	0.39	113	0.70
	2019	**0.16 ± 0.06**	**0.02 ± 0.01**	**2.10**	**109**	**0.04**
	2020	0.13 ± 0.04	0.18 ± 0.09	-0.44	71	0.66
Elk	2017	0.58 ± 0.19	0.49 ± 0.11	0.41	82	0.68
	2018	0.56 ± 0.13	0.61 ± 0.17	-0.23	113	0.81
	2019	0.89 ± 0.39	0.49 ± 0.12	0.95	68	0.34
	2020	0.45 ± 0.14	0.55 ± 0.20	-0.40	89	0.69
Grizzly bear	2017	0.003 ± 0.002	0.008 ± 0.002	-1.64	105	0.10
	2018	**0.002 ± 0.0006**	**0.01 ±0.002**	**-4.39**	**61**	**<0.01**
	2019	**0.002 ± 0.0007**	**0.01 ± 0.003**	**-3.27**	**58**	**<0.01**
	2020	0.007 ± 0.003	0.01 ± 0.003	-0.83	100	0.41
Canada lynx	2017	0.001 ± 0.0006	0.004 ± 0.001	-1.32	75	0.19
	2018	0.001 ± 0.0005	0.006 ± 0.002	-1.89	59	0.06
	2019	0.0007 ± 0.0003	0.002 ± 0.0009	-1.82	63	0.07
	2020	**0.0007 ± 0.0005**	**0.006 ± 0.002**	**-2.69**	**58**	**<0.01**
Moose	2017	0.02 ± 0.007	0.03 ± 0.006	-1.16	105	0.25
	2018	0.01 ± 0.004	0.02 ± 0.004	-1.27	113	0.21
	2019	0.007 ± 0.003	0.01 ± 0.003	-1.92	109	0.06
	2020	0.004 ± 0.002	0.02 ± 0.009	-1.89	55	0.06

Notes: SE = standard error; df = degrees of freedom. Bolded rows indicate years with statistically significant differences.

Table 3: Results of two-tailed t-tests used to compare photograph rate of target species at game trails and linear features during winter. We did not test winter photograph rates at monitoring features for grizzly bears during winter due to hibernation.

Target Species	Winter Photograph Rate (Mean ± SE)			t-value	df	p-value
	Year	Game trail	Linear feature			
Bighorn sheep	2017	0.02 ± 0.02	0.03 ± 0.02	-0.36	106	0.72
	2018	0.08 ± 0.04	0.02 ± 0.01	1.66	77	0.10
	2019	0.12 ± 0.06	0.01 ± 0.01	1.76	58	0.08
	2020	0.12 ± 0.08	0.03 ± 0.03	0.98	65	0.33
Elk	2017	0.23 ± 0.12	0.18 ± 0.07	0.38	82	0.71
	2018	0.15 ± 0.05	0.14 ± 0.05	0.12	114	0.91
	2019	0.25 ± 0.09	0.30 ± 0.11	-0.32	109	0.75
	2020	0.17 ± 0.06	0.14 ± 0.07	0.29	97	0.77
Canada lynx	2017	0.001 ± 0.0009	0.004 ± 0.002	-1.54	72	0.13
	2018	**0.0005 ± 0.0003**	**0.004 ± 0.002**	**-2.00**	**57**	**0.05**
	2019	**0.0002 ± 0.0002**	**0.008 ± 0.003**	**-2.72**	**53**	**0.01**
	2020	0.0004 ± 0.0003	0.002 ± 0.0007	-1.92	63	0.06
Moose	**2017**	**0.002 ± 0.001**	**0.009 ± 0.003**	**-2.39**	**75**	**0.02**
	2018	0.008 ± 0.005	0.006 ± 0.002	0.49	75	0.63
	2019	0.003 ± 0.002	0.006 ± 0.002	-1.19	94	0.24
	2020	0.01 ± 0.009	0.01 ± 0.005	-0.09	77	0.93

Notes: SE = standard error; df = degrees of freedom. Bolded rows indicate years with statistically significant differences.

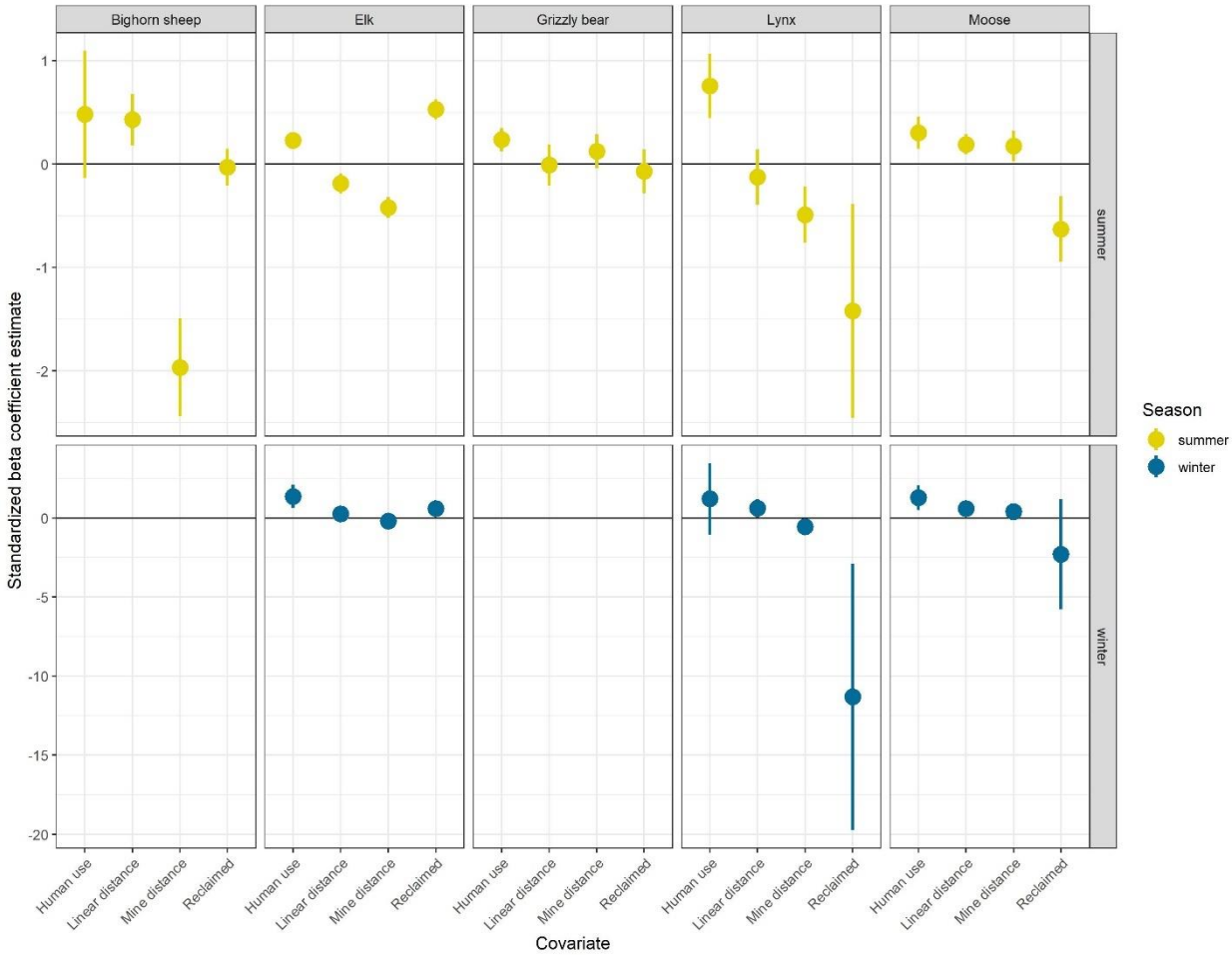

Figure 4: Standardized beta coefficient estimates from the disturbance generalized linear model (GLM) applied to bighorn sheep, elk, grizzly bear, lynx, and moose for summer and winter. Error bars represent standard error. The winter bighorn sheep model did not converge and we did not fit a winter model for grizzly bear due to hibernation during winter.

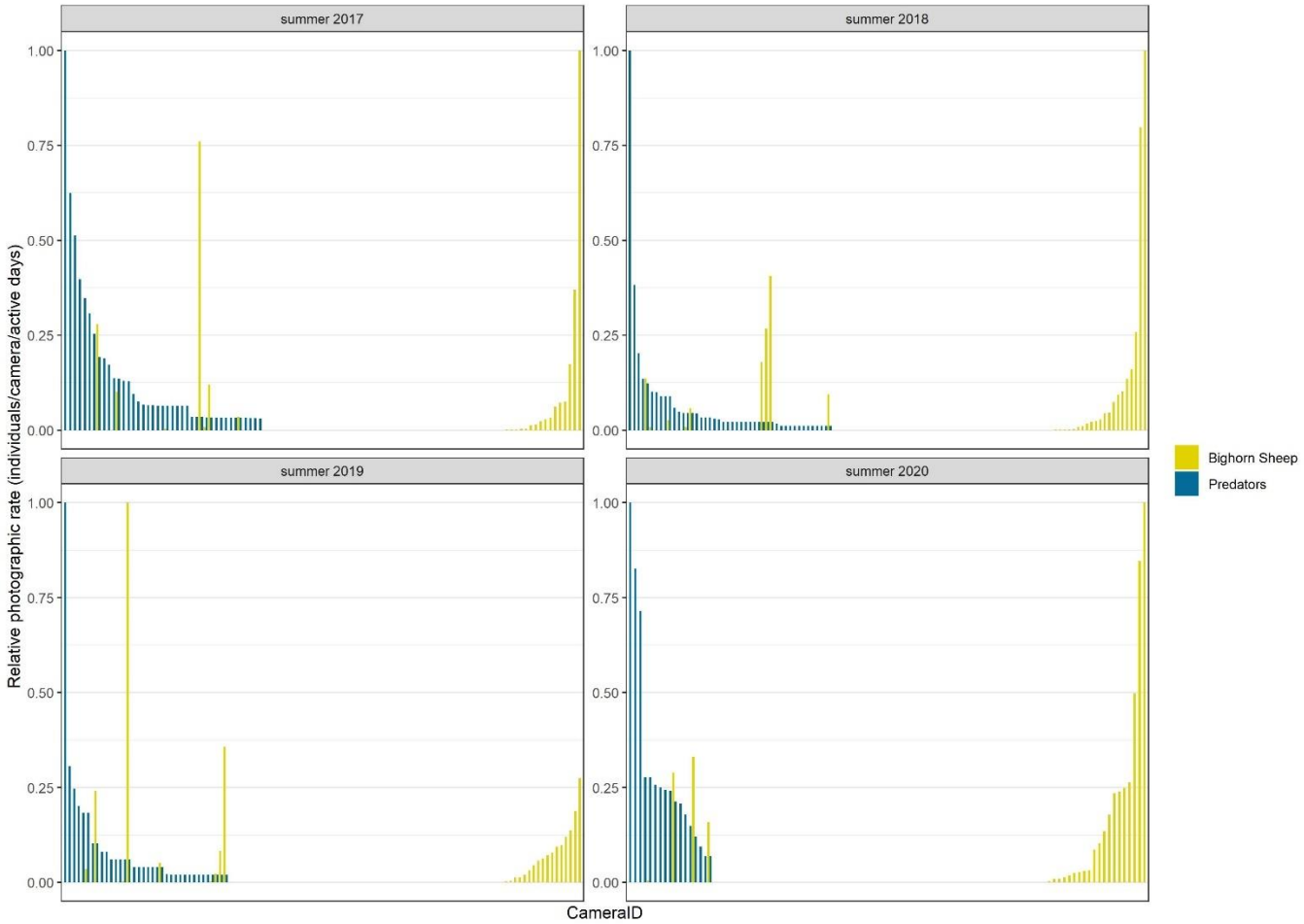

Figure 5: Relative summer photograph rate of bighorn sheep and their predators (i.e., cougars and wolves) for remote cameras in the study area.

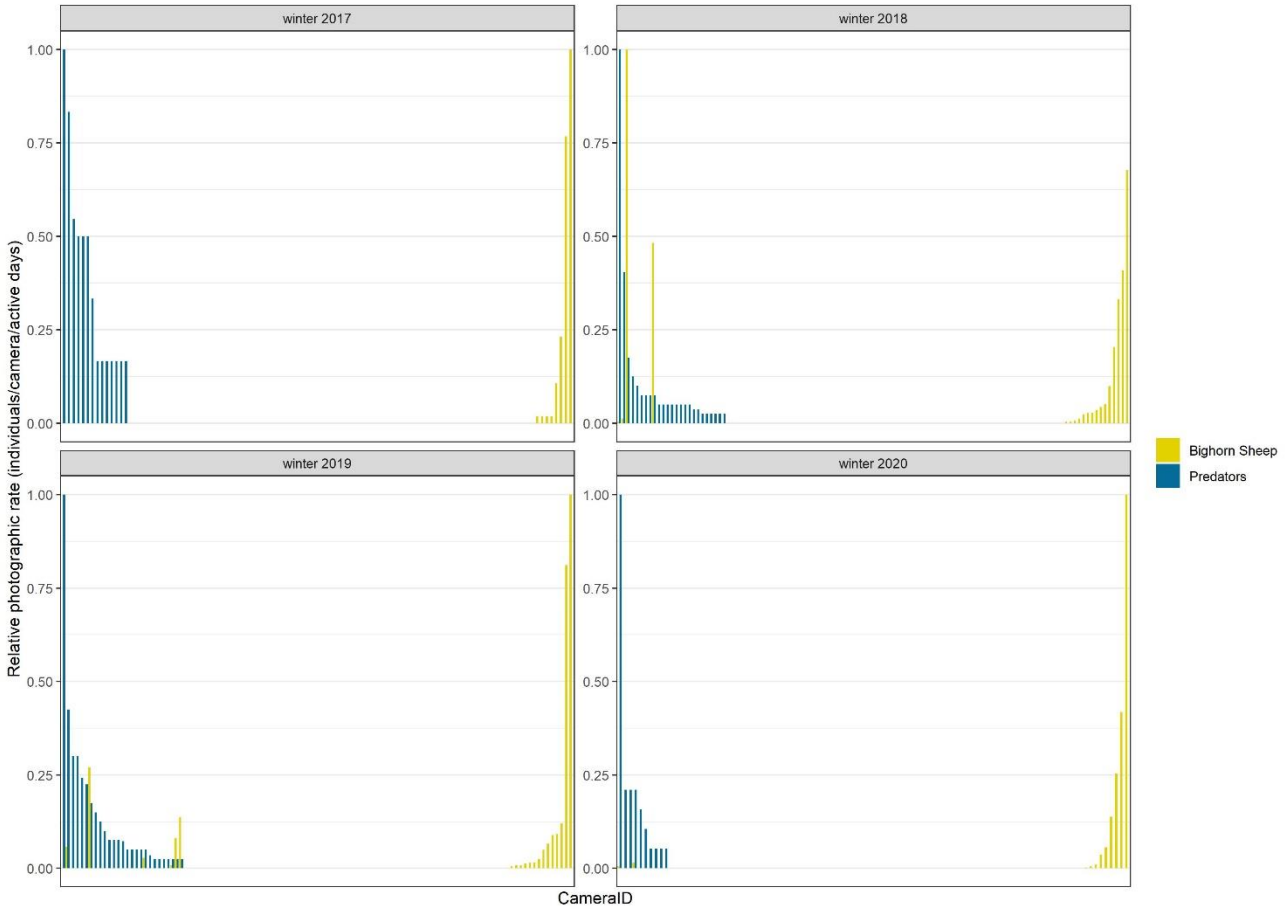

Figure 6: Relative winter photograph rate of bighorn sheep and their predators (i.e., cougars and wolves) for remote cameras in the study area.

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9. *Mammal responses to a gradient of forest harvesting treatments across interior BC*

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Forest harvesting is part of the economic backbone of BC and Canada, but the widespread use of clearcutting and the resulting homogenized landscape can be problematic for mammal species that depend on forest cover and structural diversity found in uneven-aged stands. Forest harvesting has evolved practices towards a "natural disturbance emulation paradigm", which aims to have harvested areas look like and create a similar set of conditions as would be present after a natural disturbance. However, the leftover organic materials and scales can be quite different between natural disturbances and clearcut forest harvesting. Partial harvest methods have been suggested and used to mitigate the effects of clearcut harvesting on biodiversity and to combine ecological and economic goals in managed landscapes while maintaining structural and functional diversity. Since winter 2018, we have been operating camera traps in the east Kootenays, the Cariboo and the Nechako regions in a gradient of forest harvesting treatments: clearcuts, seed tree retention, 30% and 60% partial harvests and uncut control forest. We expect that partial harvesting treatments create conditions that allow usage by species that are forest-dependents or prefer closed canopy forest can use these harvest plots, as well as more generalist species that can thrive in open-canopy areas. By using

non-invasive camera traps on small scale harvests, we are able to evaluate the frequency of usage of these harvesting techniques by all species, as well as their behaviour. We used generalized linear mixed effect models to determine usage of each of these treatments by all species. In British Columbia, forest industry influences are combining with environmental and climate change, creating compounding effects on wildlife habitats. Our results will improve understanding of wildlife responses to alternative forest harvest strategies across a climate gradient.

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10. *Evaluating the effectiveness of fence modifications to create permeable fences for pronghorn*

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Phase II Study:
Evaluating Responses by Sympatric Ungulates to Fence Modifications Across the Northern Great Plains

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Across North America, incentive programs have assisted landholders with the construction of fences, often considered *"*wildlife friendly,*"* to assist in grazing management, which has resulted in a proliferation of fencing on the landscape. Many suggested *"*wildlife-friendly*"* fence modifications have not been evaluated for their effectiveness on the targeted species or evaluated to assess consequences for nontarget species. We evaluated the effects of 2 modifications aimed to increase fence visibility (sage-grouse [SAGR] reflectors and white polyvinyl chloride [PVC]) on the fence-crossing behavior of 3 sympatric ungulates in the Northern Great Plains. We used trail cameras from 2016 to 2018 to capture images of pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), and white-tailed deer (*O. virginianus*) at sites before and after fence sections were modified and compared crossing success by the 3 ungulates

with that achieved at unchanged control sites. We used generalized linear modeling and a time-to-event approach to test the effect of fence modifications on ungulate crossing behavior. Our results showed that both SAGR reflectors and white PVC pipe did not impede fence-crossing behaviors for either pronghorn or deer, nor was there a time lag in use of sites observed after modifications were deployed. Though we did not alter the height of the bottom wire, there was enough variability in bottom wire height between sites that our results indicate a greater probability of successful crossing by all 3 ungulates as bottom wire height increased. We recommend implementation of both SAGR reflectors and white PVC pipe because our results demonstrate no substantial unintended consequences on the crossing behavior of pronghorn and deer.

Citation

Jones, P.F., Jakes, A.F., MacDonald, A.M., Hanlon, J.A., Eacker, D.R., Martin, B.H. and Hebblewhite, M. (2020), Evaluating Responses by Sympatric Ungulates to Fence Modifications Across the Northern Great Plains. Wildl. Soc. Bull., 44: 130-141. https://doi.org/10.1002/wsb.1067

Phase I Study
Evaluating Responses by Pronghorn to Fence Modifications Across the Northern Great Plains

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Pronghorn (*Antilocapra americana*) is an endemic North American ungulate susceptible to negative effects of fences, especially given the vast amount of barbed-wire fencing currently on the landscape. Despite multiple nongovernmental organizations, and state and provincial wildlife agencies publishing guidelines for creating wildlife-friendly fencing, there are no published studies that evaluate and compare evidence of the effectiveness of endorsed practices. We analyzed pronghorn crossing success in Alberta, Canada, and Montana, USA, between 2012 and 2016 in response to fence-modification treatments to understand 1) differences between bottom wire height at selected versus available fence sites, 2) the change in crossing rates before and after fence modification treatments, 3) the effect of a suite of fence, environmental, and demographic characteristics on group crossing success, and 4) the time lag until pronghorn became habituated to different fence modifications after initiation of treatments. Use of either smooth wire or clips with a bottom wire height of approximately 46 cm were most effective at allowing passage by pronghorn, while the commonly proposed goat-bar was ineffective and created a negative behavioral response by pronghorn. Though smooth wire and clips were effective at allowing passage, we observed a time lag as pronghorn switched use from their strong fidelity at known-crossing sites to using modified sites. Pronghorn-group crossing success was greatest during summer, for all-male groups, and increased with larger group sizes. We advocate not using goat-bars as modifications to fences, and instead, recommend using smooth wire and clips at a minimum bottom-wire height of 46 cm to allow movement by pronghorn. Our study provides guidance for wildlife-friendly fencing techniques to wildlife managers and private landholders as a means to improve permeability for pronghorn and additionally, can be used as a model to evaluate fence modifications for pronghorn and other target species that may be sensitive to fence interactions.

Reference

Jones, P.F., Jakes, A.F., Eacker, D.R., Seward, B.C., Hebblewhite, M. and Martin, B.H. (2018), Evaluating responses by pronghorn to fence modifications across the Northern Great Plains. Wildl. Soc. Bull., 42: 225-236. https://doi.org/10.1002/wsb.869

Slide show

View project photos shared at the conference here. Submitted by Paul F. Jones[1] *Alberta Conservation Association* (includes photos submitted by Roland Kays as well).

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11. *Effects of anthropogenic disturbance and wolf population reduction on caribou predators and competitors in west-central Alberta*

Presenter: **Caroline Seip** Government of Alberta/University of British Columbia
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Co-Authors:
Robin Steenweg, Canadian Wildlife Service/Environment and Climate Change Canada

Cole Burton, University of British Columbia

Dave Hervieux, Government of Alberta

Woodland caribou are a threatened species in Alberta and across Canada. The Little Smoky caribou population in west-central Alberta is at risk due to anthropogenic disturbances, such as forest harvest and linear features, which facilitate increased predation on caribou. To aid caribou recovery the Government of Alberta is working to conserve areas of existing caribou habitat, recover habitat on linear features, and annually reduce wolf abundance. These management actions are beneficial for caribou, but potential effects on other wildlife have rarely been tested. To better understand any effects, we conducted multispecies surveys using remote cameras within and around the Little Smoky caribou range.

We hypothesized that changes in wolf detection rate would be the predominant factor influencing other wildlife, because they are the top predator on the landscape. We predicted decreased wolf detection rate in areas of high wolf removal efforts would result in higher detections of coyotes and lynx, through decreased competition, and higher detections of moose, elk, and deer, through decreased predation.

As expected, wolf detections were negatively affected by wolf removals. Unexpectedly, mesopredator detections were positively associated, and ungulate detections unaffected, by wolf activity. These species were instead more strongly associated with habitat disturbances (clearcuts, linear features), and mesopredators were also associated with prey availability. Our results suggest that despite the direct effect of wolf removals on wolves, wolf population management did not have a cascading effect on other wildlife in this system. Rather, bottom-up factors were the most important drivers affecting wildlife in west-central Alberta.

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12. Scaling up insights from camera trapping in western Canada with the WildCAM network

Presenter: **Cole Burton**, University of British Columbia
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Camera trap surveys have come a long way from early efforts with film cameras to apply mark-recapture methods to large patterned cats like tigers and leopards. Modern surveys use data on a wide range of terrestrial vertebrates to make inferences about abundance, habitat use, animal behaviour, and community attributes like species diversity. The growing number of camera surveys around the world presents an exciting opportunity for improved wildlife monitoring, yet many surveys remain disjointed and focused only on local inferences. The WildCAM network (Wildlife Cameras for Adaptive Management, https://wildcams.ca) was initiated in 2018 to bring together camera trap practitioners and projects in western Canada and facilitate more effective inferences and applications at regional scales. The network is growing and now includes more than 150 members running 60 projects with over 6000 camera traps.

In this presentation, I discussed how some members of the network are pooling together standardized camera trap survey results to improve understanding of the impacts of recreational activities on wildlife. Recreational demands are growing rapidly in British Columbia and elsewhere, putting pressure on park ecosystems and the dual mandate of park managers to provide recreational opportunities while protecting biodiversity. Camera traps provide a useful tool for monitoring interactions between people and wildlife in parks. UBC's WildCo lab, together with collaborators, has deployed more than 200 camera traps in 5 parks in southwestern BC, to examine whether hiking and other forms of recreation are displacing wildlife. Emerging results show variable responses to recreation across species and parks. For example, we found evidence that mountain biking displaced species, including grizzly bears, in space and/or time in South Chilcotin Mountains Provincial Park. In contrast, mountain goats in Cathedral park were associated with hikers in space, but may be partitioning time by avoiding trails during periods of highest human use.

The drastic changes in human activity driven by the COVID-19 pandemic have provided a unique opportunity to learn more about wildlife responses to recreation. In Golden Ears park near Vancouver, cougars showed increased use of park trails during the COVID-19 closure. Preliminary results from Joffre Lakes Provincial Park suggest that more species are being detected on cameras during the park's extended closure than are being detected in a nearby portion of Garibaldi park, which re-opened to recreation.

Research is ongoing to complete these studies and synthesize their results, as well as those from other surveys in the WildCAM network, to scale up our inferences on human-wildlife interactions in western Canada. By promoting standardized camera trap methods, data sharing, and collaboration, WildCAM and other related efforts are helping to move us toward more effective regional-scale monitoring of terrestrial vertebrate wildlife during this time of rapid environmental changes.

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13. *Estimating causal impacts of human recreation on grizzly bear detections in South Chilcotin Mountains*

Presenter: **Robin Naidoo**, Lead Scientist for Wildlife Conservation at WWF-US & University of British Columbia
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Previous research[1] from the South Chilcotin Mountains, using data from May - October 2018 that was generated by a grid of ~ 60 camera traps, found that while environmental factors shaped the broad-scale patterns of weekly site-use of most species, negative associations between recreation (specifically mountain biking) and weekly trail-use were documented for two species, moose (*Alces alces*) and grizzly bears (*Ursus arctos*). Given these results arose from one summer's worth of data and considered a suite of species that required consistency of modelling approach, many questions that arose from that analysis require more detailed, species-specific investigation.

This talk summarized the results from new analyses that allow a more detailed examination of the association between human trail-use and the detection of grizzly bears at 60+ camera stations over 3 summers (2018, 2019, and 2020) in and around the South Chilcotin Mountains provincial park. Statistical and econometric techniques were used to attempt to estimate the causal impacts of human recreation on grizzly bear detections. Detection peaks of grizzly bears and mountain bikers occurred at different times of the year (Fig. 1). Grizzly bear detections consistently peaked, across all 3 years, in early June, with a subsequent decline in the number of detections through the rest of the year, while mountain biker detections increased and maintained peak numbers from late July through early September. The key question is whether this relationship is causal or not, i.e., do mountain bikers cause grizzly bears to avoid using trails at camera stations and result in lower detections of bears during the high mountain bike season?

Since an experimental design (the gold standard for causal inference) is clearly impossible in this context, the next-best approach is to use statistical tools from the quasi-experimental program evaluation literature that aim to replicate, for non-experimental, observational studies, the conditions that would have resulted from a randomized controlled trial or experiment. In particular, I use here a technique called statistical matching, which aims to ensure that stations and times that did detect mountain bikers were equal, in all other observable and relevant ways to grizzly bears, to stations and times that did not detect mountain bikers. In this sense I aim to essentially eliminate all relevant observable differences between the group of stations with versus without mountain bikers, such that the only remaining factor that differs, and that therefore could result in a difference in grizzly bear detections, is the presence of mountain bikers.

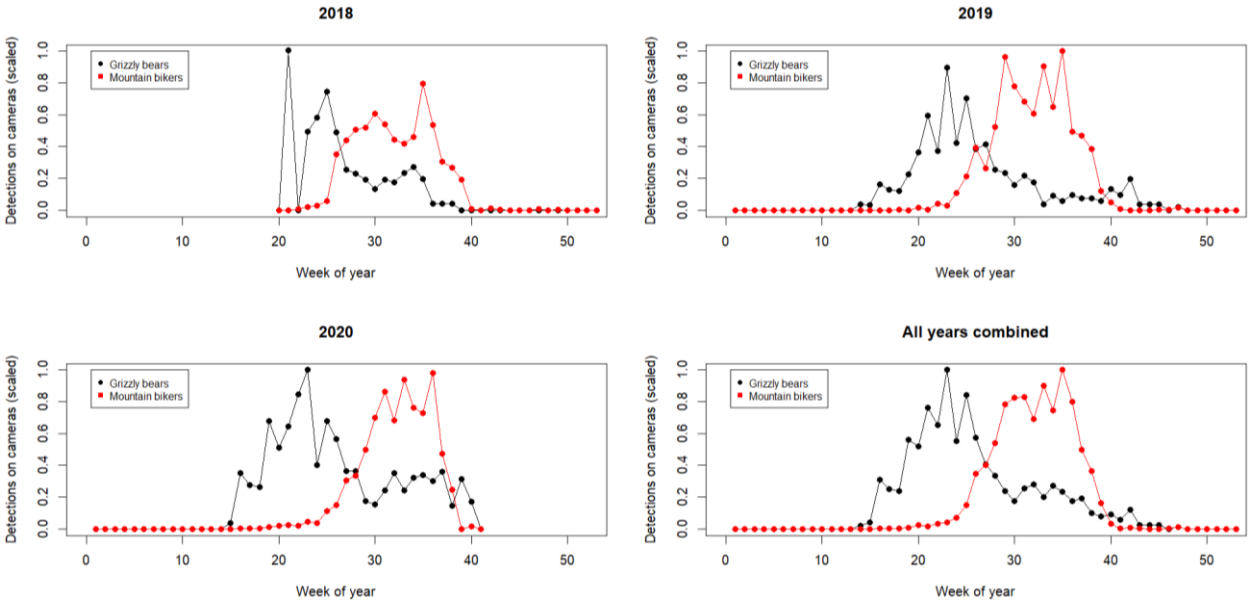

Fig. 1. *Temporal trends (by week) in the detection of grizzly bears and mountain bikers in and around the South Chilcotin Mountains provincial park, British Columbia. Detections are scaled to highlight differences in temporal trend; absolute values of detections for mountain bikers are many times higher than for grizzly bears*.

The results suggest that there was causal statistical evidence that declines in grizzly bear detections from the early season to the high season were stronger at high mountain bike sites within the South Chilcotin Mountains camera trap grid in the summer of 2019, but not in 2018 and 2020. Furthermore, analysis of same-day and next-day impacts of camera sites with >2 mountain bikers showed that within the high mountain biking season, grizzly bears were less likely to be detected, by a similar factor as above, at camera trap stations where 2 or more mountain bikers had been present the day before in the summer of 2020 but there was no effect in 2018 or 2019. These variable results across years suggest more detailed investigation is necessary to better understand why some years and time scales show causal impacts of mountain bikers on grizzly bears, while others do not. In particular, future work should seek to rule out alternative explanations (i.e., seasonal shifts in use, unobserved confounding variables) using a combination of additional causal analyses, additional camera deployments, and tracking data from GPS-collared grizzly bears.

Acknowledgments

I thank Professor Cole Burton and members of his Wildlife Coexistence lab at the University of British Columbia for critical inputs on the project. The work has been generously supported by BC Parks via their Living Laboratory and Park Enhancement Fund programs. We also thank Craig Baillie, Lori Homstol, Melanie Percy, and Colby Olsen of BC Parks for valuable contributions over the last 4 years of the project. The

work inside the South Chilcotin Mountains provincial park was conducted via permission granted by a Letter of Authorization from Craig Baillie. We thank Tyax Adventures, Habitat Conservation Trust Fund, Lillooet Field Naturalists Society, and WWF for funding support.

[1] Naidoo, R. & Burton, A. C. Relative effects of recreational activities on a temperate terrestrial wildlife assemblage. *Conserv. Sci. Pract.* **2**, e271 (2020).

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14. *Urban wildlife monitoring: Calgary Captured challenges Calgarians to better understand their wild neighbours*

Presenter: **Nicole Kahal**, Miistakis Institute
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Co-Author:
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Calgary Captured is a multi-year wildlife monitoring program that aims to better understand urban wildlife, and to challenge the notion that wildlife only exists outside the city. The program is gathering information on medium to large mammal species that live and move through Calgary – such as deer, coyote, fox, bobcat, cougar, and black bear –to inform management and development decisions that benefit wildlife and resilient urban ecosystems. As 70 camera traps are operating year-round, camera and data management are immense undertakings. Cameras are installed using a one kilometer grid approach, to capture species presence in 13 City parks, one provincial park, and two wildlife corridors. Monitoring wildlife corridors will help to validate Calgary's ecological network, while gaining insight into how wildlife move around the built environment. A partnership with City of Calgary, Miistakis Institute, Alberta Environment and Parks, Friends of Fish Creek Provincial Park Society, and Glenmore/Weaselhead Park Preservation Society, the program brings a collaborative approach to research and public engagement.

Calgary Captured Program

Calgary Captured was developed with three goals:

1. Improve understanding of wildlife occurrence in the City of Calgary.
2. Improve understanding of how wildlife responds to development and their use of wildlife corridors in Calgary.
3. Engage Calgarians in wildlife monitoring through citizen science.

1. Improve understanding of wildlife occurrence in the City of Calgary

Calgary Captured is helping to fill a data gap on urban wildlife. In absence of the right information, development decisions cannot consider the needs of wildlife, and effective management of biodiversity is difficult.

For example, Calgary's Ring Road – a 6 to 8 lane highway that completes a circle around the city – is finishing up construction on the SW portion, and was approved with little to no consideration for wildlife movement. There was no systematically collected,

defensible information on the wildlife that live and move around Calgary that may have helped to inform decisions.
A summary of year one results (technical report and citizen science updates) for Calgary Captured can be found at the following links:

- https://www.rockies.ca/files/reports/Calgary%20Captured_Reporting_May2017-2018.pdf
- https://www.rockies.ca/files/reports/MIR_CalgaryCaptured_Year1Results_NOV2020_2Pager_print.pdf
- https://www.rockies.ca/files/reports/MIR_CalgaryCaptured_Year1Results_NOV2020_MapPage_print.pdf

2. Improve understanding of how wildlife responds to development and their use of wildlife corridors in Calgary

The City of Calgary recently developed an ecological network, which is now in their municipal development plan. This is a big step toward ensuring that connectivity is sustained in the city. We are monitoring corridors mapped in the city's ecological network to help validate the network, and provide additional information to support their commitment to maintaining the network.
The two corridors we are monitoring have adjacent land either slated for development or future development proposed that may affect wildlife movement, and the camera data can help us determine if there's a difference in wildlife detection before, during and post construction.

3. Engage Calgarians in wildlife monitoring through citizen science

We launched Calgary Captured with the intention to build citizen awareness that nature does not just lie outside of a city, and that biodiversity is important for our wellbeing, here in a city where we live. This is necessary to gain citizen support for municipal investment in biodiversity and effective management.

To engage Calgarians the remote camera images are classified on Zooniverse, an open-source citizen science on-line platform where 4,746 participants (60% from Calgary) have contributed to classifying wildlife.
Working with our partners we developed communication materials to promote wildlife coexistence in Calgary through an I'm a Calgarian Campaign (Figure 2).

To view the I'm a Calgarian Campaign please visit:
https://www.rockies.ca/imacalgarian/

Figure 1: Example from the I'm a Calgarian Campaign focused on bob at co-existence

Lessons Learned

Calgary Captured engages public through partner networks and programming, as well as through Zooniverse, where over three thousand citizen scientists have helped classify species found in images. The well-known global Zooniverse platform is key to reaching a large audience and ensuring images are classified, however, the process is slow. We currently have a time lag of over 1.5 years between images taken and a cleaned dataset. We account for quality control by requiring each image to be classified eight times. However, this still leaves thousands of images flagged for review – often, when not obvious if it's white-tailed or mule deer. The recent addition of a machine-learning model to auto-tag images of humans (protecting privacy) and empty images has greatly improved efficiency and reduced the amount of images, and therefore time, needed to classify on Zooniverse.

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15. *Impacts of outdoor recreation on deer space-use and behaviour in a Scottish upland landscape*

***Presenter*: Solène Marion,** University of St Andrews, Scotland, UK & The James Hutton Institute, Scotland, UK
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Understanding wildlife-livestock interactions is of importance for biodiversity conservation and livestock management. However, interactions between wildlife and livestock are often complex and changes to such interactions can have cascading effects on lower trophic levels. Anthropogenic activities, such as outdoor recreation, have the potential to change these complex interactions between wildlife and livestock, with further consequences for landscape management. This study presents a novel investigation of the three-way interaction amongst wildlife, livestock, and outdoor recreationists. We investigate how hiking activity affects spatio-temporal co-occurrence between domestic sheep (*Ovis aries*) and red deer (*Cervus elaphus*). Both species are heavily managed and monitored due to their grazing impacts, especially in the Scottish Highlands, where they compete for resources. We used camera traps to capture the spatio-temporal distribution of red deer and sheep at varying distances from a popular hiking trail. We used generalized linear models to investigate the spatial distribution of sheep and deer. We then calculated coefficients of temporal overlap between the two species for each camera trap location and used a generalized linear mixed-model to investigate which factors influence the spatio-temporal succession between deer and sheep. We do not find that sheep and red deer spatially avoid each other, but we did find that sheep temporally avoid red deer, while red deer do not appear to temporally avoid sheep. The coefficient of temporal overlap varied with distance from the hiking trail, with stronger temporal co-occurrence at greater distances from the hiking trail. Red deer were more likely to be detected further from the path during the day, which increased the

temporal overlap with sheep in these areas. This suggests that hiking pressure influences spatio-temporal interactions between sheep and deer, leading to greater temporal overlap in areas further from the hiking path due to red deer spatial avoidance of hikers.

*This work is currently under peer review, we will provide a URL when the paper gets accepted via an edit to this document as posted on our event webpage.

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16. *Integrating monitoring tools to plan for human-wildlife coexistence near Canmore, Alberta*

Presenter: **Stephan Boraks**, 2151068 Alberta Ltd.
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Land-use planners must consider competing priorities when managing land development proposals. This is especially true in the mountainous Bow Valley which has topographic constraints and is a critical east-west movement corridor for wildlife through the Rocky Mountains. Any decisions on development in these important natural areas should be made with the best available science and data.

A decision-making tool was developed that integrated wildlife cameras, wildlife snow tracking, and a trail assessment study to better inform decisions by identifying ecological and social variables in a 19km² area near Canmore, Alberta. The survey area is shown in Figure 1 as the red, cross-hatched area. The survey area is a constriction point in a wildlife movement corridor that connects federally protected areas to the north-west and provincially protected areas to the south-east. The survey area is also a hotspot for a variety of recreational activities including hiking, trail running, snowshoeing, rock climbing, mountain biking, camping and equestrian use. The study area is bound by a steep ridge to the north and human development to the south-west.

FIGURE 1. *Study area on the east side of Cougar Creek near Canmore, Alberta is indicated by red cross-hatching. Constriction point indicated by the word DAM in yellow font.*

Data on wildlife presence and movement patterns collected by Alberta Parks in the area around this constriction point has been analyzed and is presented here. Wildlife presence has been tracked at ten non-random locations using wildlife camera traps which have a total of 356 months of recorded data. These cameras were deployed to both track large mammal occupancy data and to examine the differences in the relative

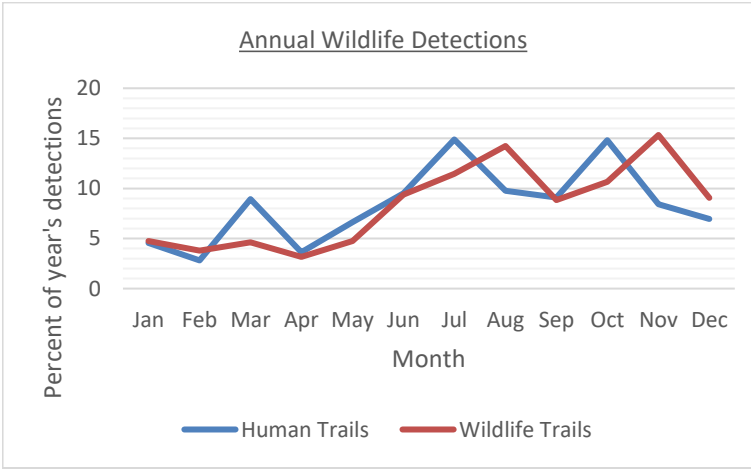

FIGURE 2. *Average monthly detections of wildlife made by wildlife cameras on trails with high human use (Human Trails) and trails with low human use (Wildlife Trails)*

wildlife abundance on trails with either high or low human presence.

The cameras tested two hypotheses: that trails with high human abundance have significantly lower wildlife abundance than trails with low human abundance, and that high human presence causes a temporal shift in wildlife abundance on trails. It was found that cameras placed on trails with significantly higher human abundance saw no significant difference in wildlife abundance. Additionally, there was no significant temporal shift in the detections of wildlife between trails with high and low human abundance. Figure 2 demonstrates this in terms of monthly detections and Figure 3 demonstrates this in terms daily detections. These findings indicate that within this study area there has not been a significant adaptive-avoidance response from wildlife to high levels of human abundance.

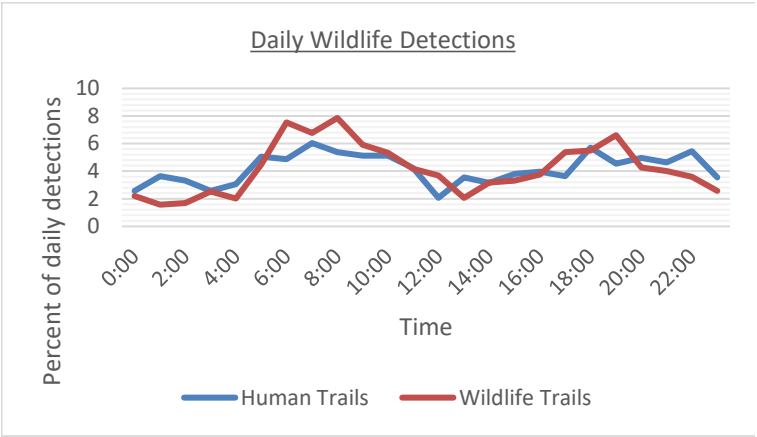

FIGURE 3. *Average daily detections of wildlife made by wildlife cameras on trails with high human use (Human Trails) and trails with low human use (Wildlife Trails)*

Human presence is highly dispersed in the study area and the zone of human influence can should be considered as spanning from valley bottom to the top of the ridge. While there is a long history of human presence in the area, data from the wildlife cameras indicates that human abundance in the study area has increased substantially in the past five years. The pervasive presence and long history of humans may explain the lack of adaptive-avoidance response from wildlife in the study area. Furthermore, wildlife response may not yet have occurred considering that the rapid increase in human abundance is still relatively recent.

In the winter of 2020/21 the construction of an earthen dam began in the constriction point. Beside the dam, a spill way will be built with a 30m high sheer rock face that may be an obstacle for predator movement. Alberta Parks has been monitoring predator movement through the constriction by conducting winter tracking transects for the past twenty years. When predator presence is detected on the transects, the predator is backtracked creating a GPS log of the predator's movement. Figure 4 indicates that the spillway is being built in the

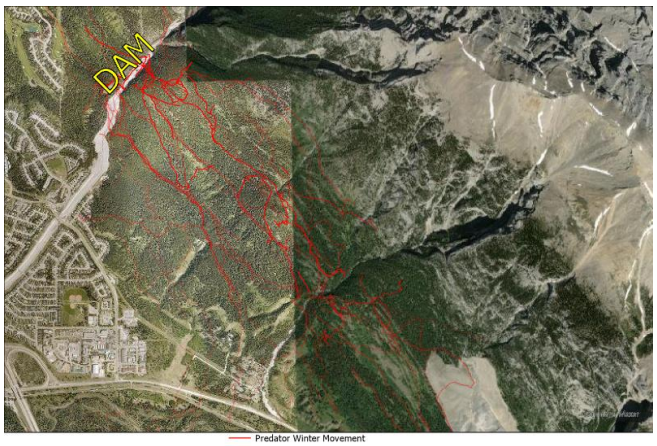

FIGURE 4. *Predator movement in winter between 2000-2019 on the east side of Cougar Creek*

primary area predators have historically moved through. Continued winter tracking in the area will demonstrate any changes in predator movement due to the spillway.

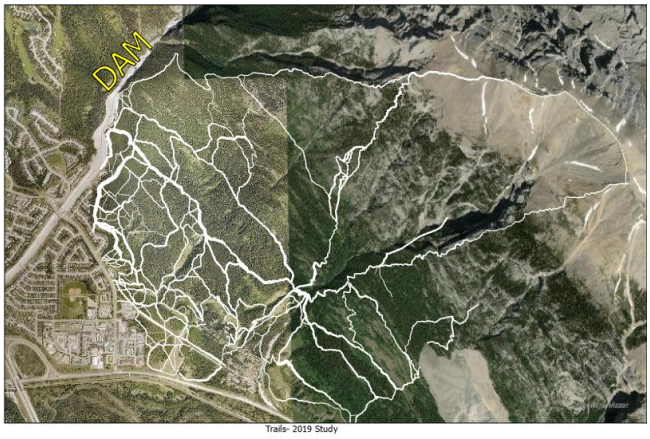

FIGURE 5. *Trails actively used in 2019 within the study area east of cougar creek.*

While data on the current and historic presence of wildlife in the area is important for maximizing human-wildlife coexistence, it is essential that land planners also understand current human presence and use patterns. In the spring of 2019 56km of trails within the survey area were mapped, the trail volume was measured at survey points, and the presence of user types were identified. Figure 5 is a representation of trails actively used in 2019 which has been scaled to volume of each trail. The trail network was also visualized such that the types of trail users on each trail can be identified. Using trail volume as a correlate of the frequency of trail use, the relative importance of trails to the trail network was identified. The trail-use model was then calibrated, and the findings were expanded using data from six wildlife cameras that have been operating for up to five years. The calibration of the model and the equation that resulted is shown in Figure 6. Land planners can use the georeferenced database to select individual trails and determine the total number of monthly users. This information can be used to estimate the potential effects of trail closures on users and how those closures may affect the trail network more broadly. The poor correlation seen in Figure 6 is likely due to a low n value, trail substrate variability and non-human causes of increases in trail volume. Controlling some of these covariates and integrating data from low-cost monitoring equipment such as trail counters already deployed in the survey area may increase confidence in this model.

After the study was completed in 2020, land-use planners have been able to use this tool to prioritize trails and areas for conservation and to minimize human disturbance in a critical east-west wildlife movement corridor. Additionally, it provided a means to measure the impact of trail closures on specific human user groups and it functioned as a visual aid during community consultation. By integrating monitoring data collected by Alberta Parks over the past twenty years and a study of the current human use in the area, land planners in the Canmore area have a valuable set of tools with which to make informed decisions to maximize human-wildlife coexistence.

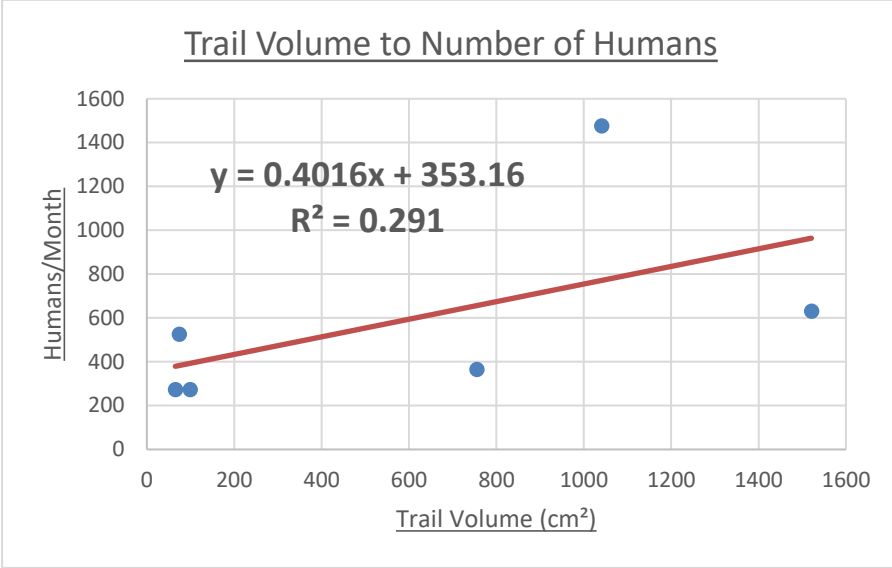

FIGURE 6. *An equation which represents the relationship between trail volume and the average number of users detected monthly at six wildlife camera traps.*

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17. *Monitoring states and countries with camera traps: strategies, study design, and discoveries*

Plenary Speaker: **Roland Kays**, North Carolina State University, North Carolina Museum of Natural Resources
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The earth is changing fast. Some wildlife species are adjusting to these changes, some are not. We need up to date data on wildlife populations, every year, to track these changes and know which populations need the most protection, and which are doing ok. Camera traps have the potential to deliver this data, but we need to find ways to scale up our data collection. This includes field work, data processing, data management, and efficient data analyses. In this talk I focus on the field work, how we can get more cameras on the ground, and also do it in a consistent way that allows us to compare across studies. While there are a thousand ways to set a camera trap, we need to develop some standards for monitoring. I advocate for a general medium-large terrestrial mammal set using cameras with a fast trigger, no bait, IR flash, and set low (50cm) and parallel to the ground. I suggest we should also explore other standards for small mammals, arboreal animals, and very snowy areas. When it comes to deciding where to put these cameras I advocate for a randomized, gridded, or stratified random design – the overall goal is to get a representative sample. Based our earlier sub-setting analysis of existing data we have a general recommendation of 2-5 weeks per array, with 40-60 camera locations, done in a way that accounts for seasonal changes for any comparisons. In my talk I provide examples of how we have used this approach with citizen scientists to sample over 4000 locations in North Carolina in the Candid Critters project, and in a massive scientific collaboration to sample 1530 locations across all 50 states in the Snapshot USA project. I think both of these approaches have potential for helping to get more cameras on the ground, in standardized ways, to provide long term monitoring of wildlife populations.

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18. *Estimating animal density from camera trap data through large-scale regional monitoring*

Presenter: **Marcus Becker,** Alberta Biodiversity Monitoring Institute (ABMI), University of Alberta
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Estimating animal density or abundance is an essential goal of many wildlife monitoring programs. Camera traps allow for simultaneous data collection on multiple species, and recent advances in modelling approaches for unmarked animal species has increased the utility of camera traps for wildlife management. Here, we describe the implementation of a large-scale camera based multi-species monitoring program using a novel method called time in front of the camera (TIFC) to estimate animal abundances without the need for marking or individual identification. We show how to estimate parameters and test key assumptions of the TIFC model from motion-activated images collected by still photography camera traps. We compare moose density estimates from aerial surveys and TIFC, including incorporating correction factors for known TIFC assumption violations. The resulting corrected TIFC density estimates are comparable to aerial density estimates. Despite the challenges of assumption violations and high measurement error, cameras and the TIFC method can provide useful alternative or complementary animal abundance estimates for multi-species monitoring.

Using cameras to estimate density with the TIFC model

Density is the number of individuals per unit area, and ecologists often use fixed-area plots ("quadrats") to estimate density. For instance, if a 100m2 quadrat contains a single tree, then the density is 1 tree per 100m2. If the quadrat can be considered a representative sample of a larger area, the density can then be extrapolated to apply to the greater area, e.g., 10,000 trees per km^2 in this example. Similarly, if a camera has a field-of-view of $100m^2$ and there is one animal continually present in the field-of-view, then density is one animal per $100m^2$, or 10,000 animals per km^2 in the broader region that the camera represents. However, unlike trees, animals move. To address this, we can calculate the number of animals in the field of view as the average number of animals over time, including all the time when no animal is present. If one animal is present for 1/10,000 of the total camera operation time, the density is 1/10,000 animals per $100m^2$, or 1 animal per km^2. Two animals present for the same duration would give 2 animals per km^2. Thus,

Equation 1

$$D = \frac{\sum(N \cdot T_F)}{A_F \cdot T_O}$$

where N is the number of individuals, T_F is the time in the camera field-of-view, A_F is the area of the field-of-view, and T_O is the total camera operating time. The units are animal-time per area-time, which reduces to animals per area.
For a given density of animals, this simple measure is independent of both home range size and movement rates. If movement rates were twice as fast, then an individual would spend half as much time in the field-of-view, but would pass by a camera twice as often. Similarly, if home ranges were twice as large, an individual would be in a camera's field-of-view half as often, as there are twice as many other places for it to be. To determine density, the important variable is total animal-time in the field-of-view, whether that comes from one long visit by one individual, several shorter visits from one individual, or several shorter visits by different individuals.

Unlike traditional quadrat sampling, cameras have additional complexity because a camera's field-of-view, the area being sampled, is not fixed: the probability of an animal triggering the camera decreases with distance (Rowcliffe et al. 2011). In addition, converting the discrete images taken by a motion-detection camera into total time in field-of-view requires additional analysis, including adjusting for the possibility that an animal leaves the field-of-view between images and returns. In the next sections, we apply distance sampling methods to estimate effective detection distances and, by extension the area surveyed by a camera, which can vary between species, habitat types, and time of year (Buckland et al., 2015; Apps and McNutt, 2018; Hofmeester et al 2019).

We then address the time components of the TIFC model: converting discrete images into time in front of the camera, and calculating the total time a camera is deployed.

Data Collection

We applied TIFC using remote camera data collected throughout the province of Alberta, Canada. We used a systematic-random sampling design, based on a grid pattern of point locations spaced 20km apart plus a random offset up to 5.5km. At each of these 'core' sites, we placed four Reconyx PC9000 Hyperfire cameras at each corner of a square with 600m long sides (ABMI, 2019). We used a scent lure (O'Gorman LDC) at two of the four camera deployments at each core site. Cameras were mounted to either a tree or a stake, with the base of the camera unit 1m from the ground. We placed a 1m tall brightly coloured pole 5m in front of each camera to facilitate effective detection distance analysis (discussed below). The camera was aimed at the base of the 5m pole. For this study, we pooled data collected between 2015 and 2019, which totaled 2,769 cameras across 764 sites. Cameras were deployed into the field between November and March, and retrieved later that year in July or August. The median number of operational days was 161 per camera deployment.

Components of the model

1. Effective area of the camera field-of-view

Effective detection distance (EDD) is the distance from the camera that would give the same number of detections if all animals up to that distance were perfectly detected and none were detected farther away (Buckland, 1987). We used the pole placed 5m from the camera to divide animals in images into two distance bins: < 5m from the camera and > 5m from the camera. Images of animals too close to the pole to classify or animals actively investigating the pole or camera were excluded. To reduce bias, we only used images from unlured cameras to estimate the EDD. From this data,

Equation 2

$$EDD\ (m) = \frac{5}{sqrt(1 - p_{>5m})}$$

where p < 5m is the proportion of images that contain animals between the pole and the camera. The calculation assumes that we detected all animals that occurred within 5m of the camera (tested below in Assumption 3). The area of the camera's field-of-view was then calculated as:

Equation 3

$$Area\ (m^2)\ =\ \frac{(\pi\ *\ EDD^2\ *\ angle)}{360}$$

The angle of view for the Reconyx PC9000 Hyperfire cameras used in this study was assumed to be 42°. We expected EDD and area of the field-of-view to vary by species, habitat type, and season because of the effects of snowpack and leaf phenology, and the thermal environment for infrared sensors (Hofmeester et al., 2019). To address this, we considered eight broad habitat types of Alberta (upland coniferous forest, upland deciduous forest, grassland, shrubland, lowland forest, lowland grass, water, and human footprint) and two seasonal periods ('summer' between April 16 and October 15, and 'winter' being the inverse). We then used a model selection framework to compare models of EDD by habitat types and season for each species or species group.
For moose, the best supported model had an EDD of 6.5m (90% CI: 6.32 to 6.67m) in all vegetation types and both seasons, producing an area of 15.5m (90% CI: 14.64 to 16.3m) for the camera field-of-view. Other species had EDD that varied by vegetation type, typically with longer EDD in more open habitats. The EDD for moose may be underestimated because moose spend considerable time investigating the camera (discussed further in Testing Assumptions section). Although those investigating images were not used in the EDD calculation, investigative behaviour may inflate the number of non-investigative images near the camera.

Using a single pole to create two distance bands was a minimal-effort approach to estimating EDD, but allowed us to collect enough data to compare estimated EDD across habitat types and seasons for multiple species. Directly measuring the distance and angle from the camera at first detection by tracking movement paths through the camera field-of-view provides a more refined EDD estimate, but requires significantly more effort (Rowcliffe et al., 2011). Using additional markers to delineate multiple distances in the field-of-view, as recommended by Hofmeester et al. (2017), would also contribute to a more finely delineated detection distance curve, but was not operationally feasible given our scale of deployment.

2. Time in field-of-view

Motion-activated cameras record animals as a series of discrete time-stamped images. To implement the TIFC approach, practitioners must convert these images into the total time the animal was in the field-of-view. Because we only collected still images, we needed to account for whether an animal left the field-of-view between two sequential images. Examining all images for evidence of the animal leaving or staying between images was too costly given the high volume of images collected. Instead, we examined sequential images from a subset of cameras to develop rules to apply to all images. For this sub-

sample of images, we tagged whether the animal left the field-of-view in one image and returned in the next, or if it stayed in the field-of-view with no evidence of leaving in the interim. We found that for intervals of < 20 seconds between images, the animal had almost always stayed in the field-of-view, while the animal had almost always left the field-of-view in intervals > 120 seconds, regardless of species. For intervals between 20 and 120 seconds, we developed species-specific models of the probability that an animal left the field-of-view. For moose, we examined a sample of 1,212 images. Of these, 30% of intervals of 20 seconds had evidence of the animal leaving the field-of-view and returning, rising to 80% for intervals of 120 seconds.

We use these models of leaving probability in a simple algorithm to convert discrete images into time in field-of-view as follows:

1. Define a "series" as consecutive images of a species with intervals < 120 seconds between any two consecutive images. An image without the species ends the series, as do consecutive images showing an animal leaving and returning to the field-of-view (from the sample of images that were explicitly tagged to develop the probability of leaving models). A series may range from a single image to hundreds of images.
2. Calculate total time in field-of-view for each series as the sum of time of all intervals < 20 seconds, plus the sum of intervals 20–120 seconds multiplied by (1 - probability of leaving) for that species and interval length. For example, if a series consists of three moose images separated by 5, 10, and 30 seconds, and the model for moose indicates there is a 40% chance that it would leave during a gap of 30 seconds, then the cumulative time for that series would be calculated as $5 + 10 + (30 \times (1 - 0.4)) = 33$ seconds.
3. We then account for time the animal is in the field-of-view before the first image and after the last image by adding to each series the time equivalent to the species-specific average number of seconds between consecutive images. For moose, this is 4.54 seconds. This additional time in the field-of-view is also added to series with a single image, which would otherwise have a time in the field-of-view of 0 seconds.
4. When multiple animals are simultaneously in the field-of-view, we use the average number of animals in images in the series as N in equation 1 for that series.

3. Time camera is operating

For most camera deployments, the total operating time is the time from initial set up to final collection. However, some cameras fail before recovery, most often because they run out of memory space or battery power, but sometimes because they are physically

damaged. We program cameras to also take time-lapse images every two hours to determine if or when the camera failed. Cameras may also become displaced, and we consider the camera too displaced to use the images if the 5m pole is no longer in the field-of-view or if the camera is tilted > 30° from horizontal, as these conditions greatly affect the EDD. In addition, we divide the time cameras are operating into two seasonal periods, summer (April 16 to October 15) and winter (October 16 to April 15), to account for changes in species seasonal patterns, habitat use, and detectability. The total numbers of days operating in each season are calculated.

Calculating density

Using equation 1, we calculated the density of a species at each camera. First, we calculated density separately for each of the two seasons, using the estimate of a species' time in the camera field-of-view during the season, the area of the camera field-of-view (based on seasonally-adjusted and habitat-specific EDD), and the camera operating time during that season. Next, we averaged the two seasonal estimates together for a yearly density estimate at each camera. For moose, the distribution of these estimates is extremely right-skewed, with the majority of cameras recording zero density (no detections), low densities at some cameras (one or a few individuals briefly passing by), and high densities at a small number of cameras (one or more individuals spending large amounts of time in front of the camera). Of the 2,769 cameras used in this study, 1,988 did not record any moose detections.

Testing Assumptions: Movement not affected by the camera

The time in the field-of-view estimate is an important component of the TIFC method. Most animal detections last only a few seconds as the animal crosses the camera field-of-view, with a small proportion lasting far longer. However, if animals spend even a few seconds investigating the camera or associated equipment (e.g. the 5m pole) on each visit, the total time in the field-of-view will be substantially inflated and result in a biased density estimate.

We assessed the overall proportion of time in the field-of-view that animals spent investigating the camera or 5m pole, including whether this proportion differed by broad habitat types. We measured investigative behaviours directly based on a subset of randomly selected series for each species. For moose, we selected 274 series, about 10% of the total. We classified each image in each series based on the behaviour of the animal: (1) actively investigating or interacting with the pole or the camera, (2) behaviour associated with investigation, including traveling directly towards the pole or the camera prior to investigating behaviour, and/or lingering around the pole or camera

after investigating, and (3) natural behaviours appearing to be unaffected by the pole or camera. Behaviour 1 was generally unambiguous, but behaviour 2 was more challenging to interpret, and we do not know how much of the time animals spent in behaviour 2 would have been spent in the field-of-view if they had not been attracted to the camera or pole.

Across all habitat types, moose spent 51% of their total time in the field-of-view investigating the camera or pole (behaviour 1; 90% CI: 46-55%). Proportion of time in behaviour 1 was highest in grassy areas and lowest in deciduous forest. If investigating time was additive to time that moose would have otherwise been in the field-of-view, behaviour 1 increased the overall density estimate by a factor of 2.02 (90% CI: 1.84-2.25), ranging from 1.51 to 3.41 across habitat types (with correspondingly wider confidence intervals). Combined, behaviours 1 and 2 represented 67% of total time in field-of-view (90% CI: 62-71%), with proportion of time highest in grass, shrub, and wet habitats, and lowest in deciduous forest, coniferous forest, and human footprint. Overall, including both behaviours 1 and 2 in the density calculations corresponded to a 3.00 times increase in density (90% CI: 2.62-3.47), with a range of 1.89 to 6.92 across habitat types (with correspondingly wider confidence intervals).

Moose density in Wildlife Management Units

Wildlife Management Units (WMUs) are key spatial units for wildlife management and policy in Alberta, such as establishing hunting quotas and determining priority areas for recovery actions. Since 2014, the Alberta provincial government has used distance sampling techniques (Buckland et al., 2015) on aerial ungulate surveys to estimate moose densities in most WMUs (Peters et al., 2014). Distance transect surveys are flown in winter, with observers recording the perpendicular distance from the transect of any observed moose. The distance method assumes that animals are detected with certainty along the transect line and that distances are measured without error (Buckland et al., 2001). To the extent that these assumptions are met, the results of aerial surveys can be considered an unbiased estimate of moose density in each WMU.

We obtained moose density estimates, including confidence intervals, for moose in WMUs from reports available on the Alberta Environment and Parks website (AEP 2021). We used only estimates based on distance sampling techniques and restricted our sample to aerial surveys conducted between 2014 and 2020 in the boreal portion of the province.

To calculate mean moose density for each WMU using the TIFC method, we used camera data from the core sites described previously. The same camera models and set-

up protocol were used at all deployments, including the pole at 5m. We only completed density estimates for WMUs with at least 10 cameras deployed between 2015 and 2019. Confidence intervals were estimated as a zero-inflated log-normal distribution using Monte Carlo simulation of both the presence/absence (binomial) and abundance given occurrence (log-normal) components. We did not attempt to match years of aerial surveys with years of camera sampling with WMUs because this would severely limit sample size; however, the majority of camera data were collected within two years of the corresponding aerial survey. A total of 30 WMUs are used in this comparison, ranging in size from 1,917 to 21,463 km^2.

To compare the two methods, we fit a linear regression of camera density as a function of the aerial survey density (without intercept). Because of wide variation in the number of cameras per WMU (ranging from 10 to 162), we weighted the WMUs in inverse proportion to the precision of the camera estimate. Camera estimates were positively related to aerial estimates across WMUs ($r^2 = 0.81$), but with wide uncertainty at an individual WMU level. On average, camera-derived moose density estimates were 1.93 times higher than aerial survey-based estimates (90% CI: 1.66 - 2.20).

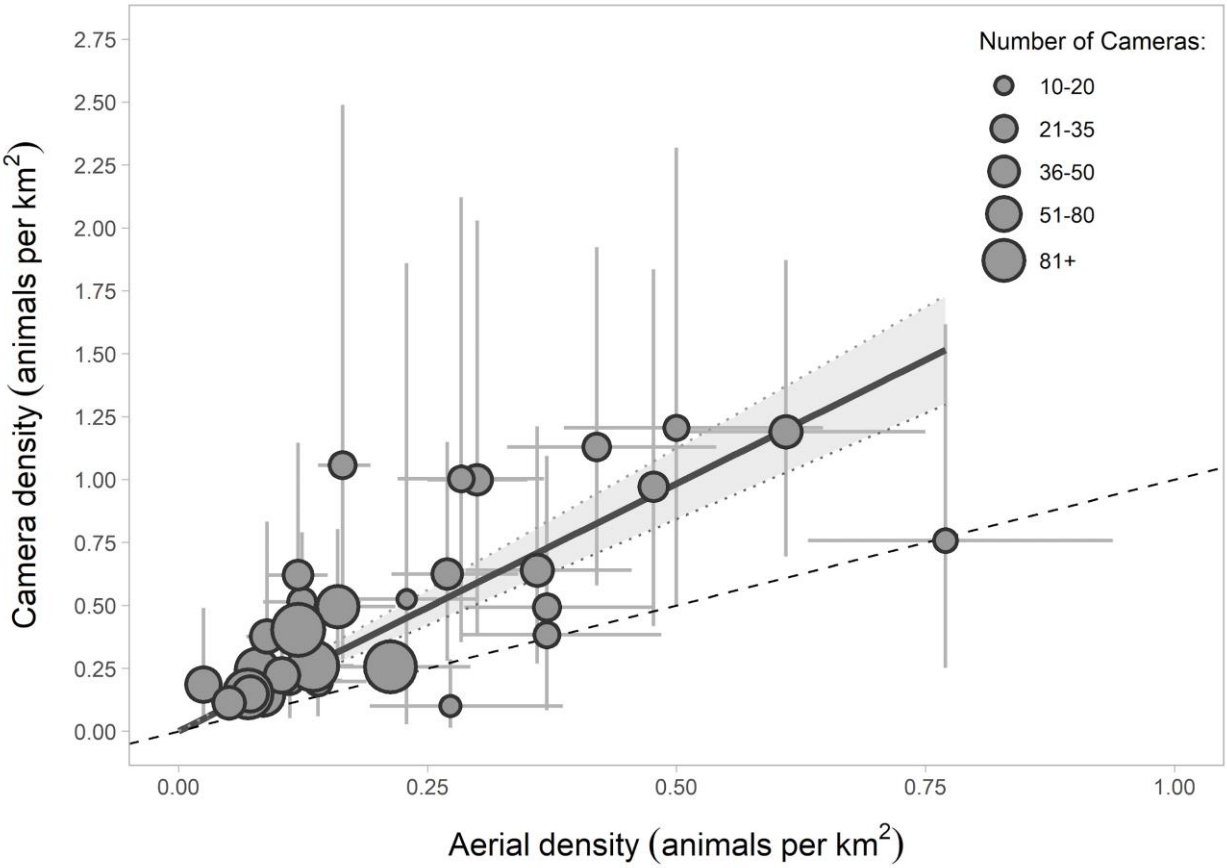

Figure 1. Relationship between moose density estimated with cameras and with aerial surveys (solid line, shaded area is 90% confidence interval, $r^2 = 0.81$). The dashed line represents the 1:1 relationship. Error bars represent a 90% confidence interval in both the aerial and camera estimate.

We expected higher estimates of moose density based on camera data because of the violations of assumptions we documented: moose spend high proportions of time investigating the camera and pole. Using the measured direct investigation times by habitat type and the known habitat types of each camera used in the WMU estimates, we removed the estimated time moose spent investigating the camera and pole, and re-calculated densities for each camera. With this adjustment, density estimates from camera traps were 1.05 times as high as estimates from aerial surveys (90% CI: 0.88-1.21). Higher initial density estimates from cameras in WMUs may have largely been due to this bias from moose investigating cameras. However, there was still a significant amount of uncertainty in the corrected relationship (which does not include additional uncertainty from the correction factor itself) and wide variation among individual WMUs.

Other sources of discrepancy between camera and aerial estimates of moose density are uncorrected effects of over-representing openings, mismatches in the timing of data collection, and limited coverage of some WMUs by cameras. Camera sites were not chosen to systematically sample a WMU (e.g. upland areas versus lowland areas, or in relation to human disturbance), thus the representativeness of sampling for each WMU may not be complete, particularly for WMUs with fewer cameras. Additionally, aerial surveys likely do not always meet the assumptions of perfect detection along the transect and moose detection by aerial observers is lower in dense vegetation. Aerial estimates that do not correct for imperfect sightability may therefore be biased downwards. All of these factors contribute to deviations in the overall relationship between density estimates from cameras and aerial surveys, and for individual WMUs.

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19. *Disentangling the relative influence of climate and landscape alteration in facilitating deer expansion in the boreal*

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Introduction:

In a rapidly changing world, one of the most pressing issues facing applied ecologists is disentangling the relative effects of climate change and landscape alteration on shifting animal communities (Scheffer et al., 2001). Climate change and habitat alteration can impose bottom-up population limitations, and as such are well-recognized causes of species declines (Pimm and Raven, 2000). Conversely, habitat alteration and climate change can facilitate the expansion of species, such as invasive species. Despite the recognized importance of landscape change resulting from both habitat alteration and climate change, the proximate mechanisms through which these two factors influence communities, their relative impacts, and their interactive effects are elusive for many systems. There is a longstanding need to rigorously test how species respond to environmental change, and determine when and how these changes lead to species declines (Caughley, 1994).

Within the western Canadian boreal forest, habitat alteration by natural resource extraction is thought to be a primary cause of boreal woodland caribou (*Rangifer tarandus caribou*) population declines (Festa-Bianchet et al., 2011; Hervieux et al., 2013; Johnson et al., 2020; Seip, 1992), with most hypothesized mechanisms relating to changes in the relative abundances and behaviour of the large-mammal community (Rettie and Messier, 2000, 1998; Wasser et al., 2011). Such changes include two major changes to the predator-prey system: increased abundance of non-caribou prey and their generalist predators (Bergerud and Elliot, 1986; DeCesare et al., 2010); and increased encounters between caribou and predators via increased predator incursion into caribou habitat that previously acted as refuge (DeMars and Boutin, 2017) and increased predator

hunting efficiency facilitated by habitat alteration (Dickie et al., 2017; Latham et al., 2011a). Ultimately, these changes result in unsustainable predation on caribou. However, climate also is increasingly being recognized as a potential driver of caribou abundance (Festa-Bianchet et al., 2011). Less severe winters increase white-tailed deer survival, and longer growing seasons increases food availability (Beier and McCullough, 1990; Dawe and Boutin, 2016). Higher abundances of white-tailed deer (*Odocoileus virginianus*) can therefore support higher numbers of wolves (*Canis lupus*) than the historical system, and lead to increased incidental predation (termed "apparent competition") on caribou (Holt, 1977; Latham et al., 2011b; Serrouya et al., 2021).

Previous studies have speculated that landscape alteration and climate change will combine to influence deer and caribou populations (Dawe et al., 2014; Fisher et al., 2020; Fisher and Burton, 2021; Laurent et al., 2020). However, the relative contributions of these impacts are difficult to quantify, primarily because climate and landscape alteration co-vary across much of Canada - winters become more severe and lands less altered by humans at increasing latitudes (Laurent et al., 2020). In spite of decades of research on caribou and the species implicated in caribou declines, a study design in which gradients in landscape alteration and climate are independently replicated across large areas has not been available because of inherent confounds across space and time. Disentangling these relationships using a space-for-time substitution can help understand effects of current and future climate change.

We leverage existing contrasts in habitat alteration between Alberta and Saskatchewan within similar climatic regions to disentangle the effects of habitat alteration from climate on an invading species in western Canada's northern boreal forests, white-tailed deer (Figure 1). Under both the Habitat Alteration Hypothesis and Climate Hypothesis, we predict that deer abundance will decline as latitude increases. However, under the Habitat Alteration Hypothesis, we predict that deer abundance will be higher in the highly altered landscape. Conversely, under the Climate Hypothesis, we predict that deer abundance will not differ across the levels of habitat alteration. We will be able to disentangle the effect of habitat alteration because of the unique design where habitat alteration differs (by 3.6 fold, Environment and Climate Change Canada, 2017a) while latitude, and therefore climate, is held constant across replicates.

Methods:

Study Design

Using a system of wildlife camera traps we contrast the relative density of white-tailed deer in high habitat-alteration and low habitat-alteration areas, at similar latitudes to remove the confound with climate (Figure 7). Beginning in 2017, twelve 50-km^2 clusters

of camera traps, with 25 cameras per cluster in a 12.5 km x 4-km area, were placed across northeastern Alberta (high habitat alteration) and Saskatchewan (low habitat alteration). Within the high habitat-alteration strata, 3 clusters were deployed in the East Side Athabasca River (ESAR) caribou range, 3 clusters were deployed in the West Side Athabasca River (WSAR) caribou range, and 1 cluster was deployed in the Cold Lake caribou range. In the low habitat-alteration strata, 5 clusters were deployed in the Saskatchewan boreal plains caribou range. Within each caribou range, clusters were placed in the northern, middle or southern portion of the caribou range limits, at approximately equal distances from the southern caribou range limit, which also represents the agriculture border. Clusters were therefore categorized as "North", "Mid", or "South", with each range having one replicate of each class except for Cold Lake, which has only one replicate, classified as "South", and Saskatchewan which had two replicates of "Mid" and two replicates of "South".

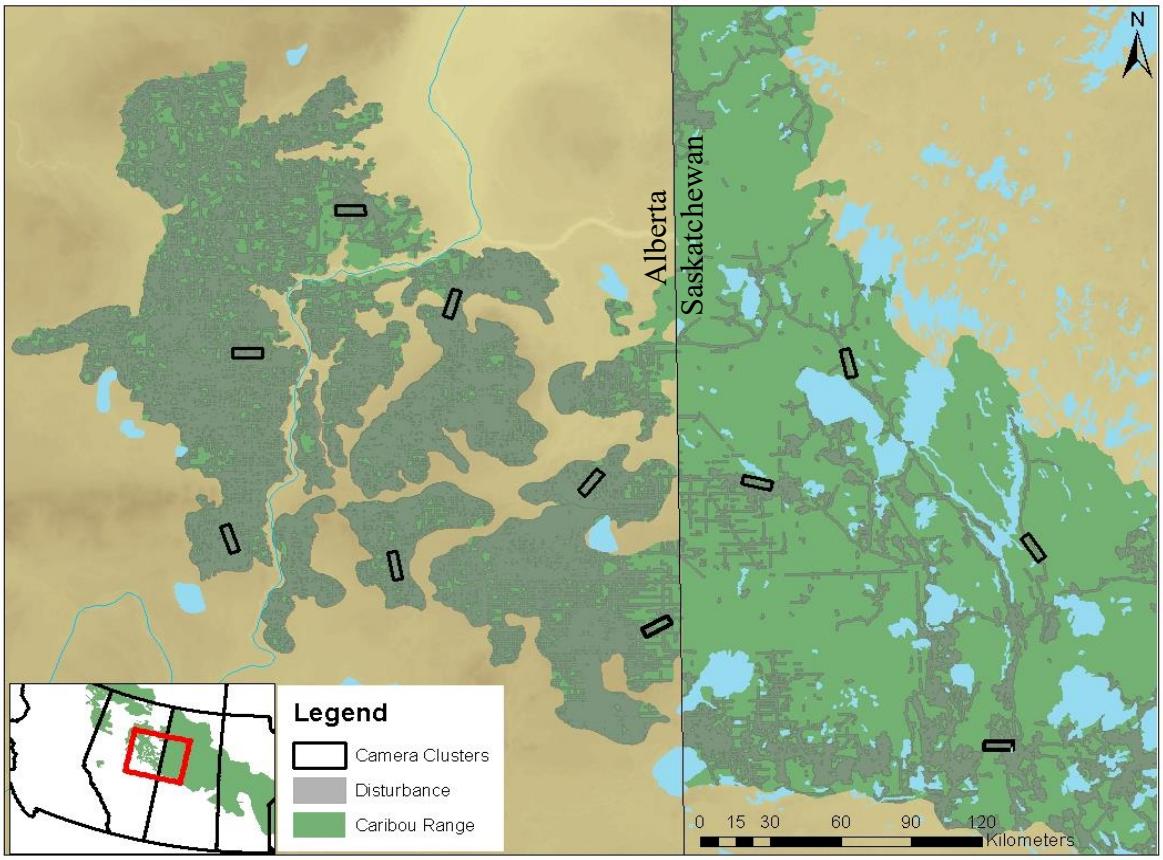

Figure 7: Location of camera clusters used to compare high habitat alteration to low habitat alteration. "Disturbance" shading represents human habitat alteration mapped by Environment and Climate Change Canada, buffered by 500m (Environment and Climate Change Canada, 2017a). The inset map shows the location of the study area within the context of Canada's woodland caribou range.

Cameras collect data year-round to increase the cumulative detection probability and are serviced once or twice per year. Clusters were placed within reasonable access to roads, such that roads typically bisect the shorter edge of the cluster and run parallel to the longest edge. Within clusters, cameras were placed randomly, with a minimum distance of 1 km apart. While this design will result in clusters biased towards areas with roads, this bias will be consistent across the strata of interest and there is no *a priori* knowledge that this will be problematic for the metrics of interest. However, bias with other habitat factors such as landcover, linear feature density, road traffic-levels and planned industrial developments which would result in drastic changes over the monitoring period, were avoided.

Calculating Density

We estimated deer density using the Time In Front of Camera (TIFC) approach, which uses basic sampling logic where the number of animals observed within a defined area, sampled using camera traps, is counted and divided by the area monitored, but also includes time captured and time monitored (Laurent et al., 2020). TIFC uses the formula:

$$D = \frac{\sum(N \cdot T_F)}{A_F \cdot T_O}$$

Where density D is calculated as the total number of individuals observed N multiplied by the time in front of the camera field-of-view T_F, divided by the area of the camera field-of-view A_F multiplied by the total camera operating time T_O. The units are animal-seconds per area-seconds, which equates to the number of animals per unit area.

We calculated the density of deer at each camera separately for two six-month periods, roughly corresponding to the snow and snow-free seasons (April 15 to October 15 and October 16 to April 14). When multiple individuals are observed, all individuals were counted. We then averaged the two seasons to calculate the average yearly density at each camera. To obtain cluster-level density estimates, we averaged the density across all cameras and calculate confidence intervals treating density estimates as a compound distribution of presence (1) and absence (0), and abundance given presence. This approach is similar to a zero-inflated log-normal distribution, but allows additional flexibility when modeling each component.

Preliminary Results and Discussion:

We present preliminary density averages collected from 2017 through 2019 across the latitude classes and disturbance strata in Figure 2. Preliminary results suggest that the

data support the Climate Hypothesis - deer abundance declined as latitude increases but did not differ across the levels of habitat alteration within a given latitude stratum. In future analyses we will model white-tailed deer density as a function of the interaction between caribou range and latitude class to evaluate the influence of habitat alteration while accounting for climate.

Quantifying the drivers of white-tailed deer expansion in Canada's northern boreal forests will reveal the mechanisms behind increased predation on caribou populations, and inform caribou management actions. While habitat restoration may reduce the negative effects of apparent competition on caribou, if climate is the primary driver of deer expansion, these management actions are unlikely to be effective on their own. In such cases, alternative management strategies such as predator or prey reduction programs will need to be considered. (Serrouya et al., 2019). Additionally, understanding the mechanism leading to deer expansion will have implications for the management of diseases common in deer that are transmittable to caribou, such as Chronic Wasting Disease (Hannaoui et al., 2017) which has been detected immediately south of caribou range in Alberta and Saskatchewan and is spreading.

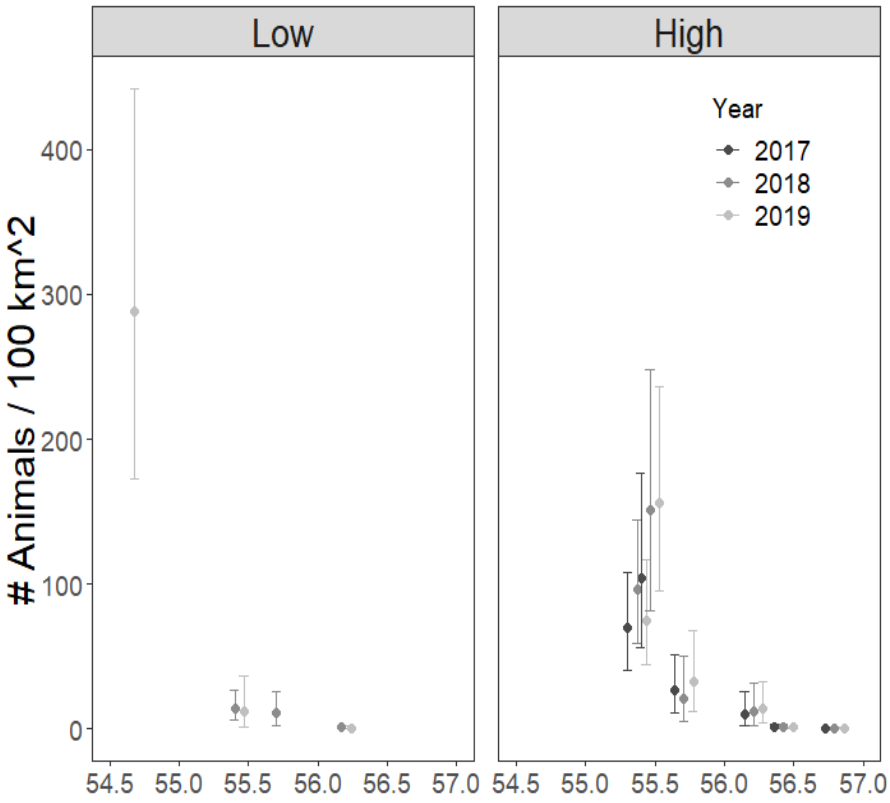

Figure 8: Average density (# animals / 100km^2) of white-tailed deer in each cluster from 2017 to 2019 as a function of latitude and habitat alteration (high vs low). Habitat

alteration was categorized as high (in West Side Athabasca River range and East Side Athabasca River range) and low (in Saskatchewan boreal plains). Error bars represent 95 % confidence intervals. Camera clusters (n=25 cameras per cluster) were placed along a latitudinal gradient from North to South in each habitat alteration strata.

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20. *Wildlife camera data standards and access in the Province of BC – integrating data across projects and jurisdictions*

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In September 2019 the Province of British Columbia's Resources Inventory Standards Committee (RISC) officially released a new protocol that aims to standardize wildlife camera data collection and management provincially. The protocol is available here: https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/wcmp_v1.pdf.

This protocol was developed over two years with key support and input from leading biologists in BC and Alberta that utilize wildlife cameras in their research. The core objective of this wildlife camera metadata protocol was to provide guidance to practitioners on the types of data that should be collected when using remote cameras to detect wildlife. However, an over-arching result of the protocol will be to support the creation of a consistent, consolidated wildlife camera dataset in BC. Therefore, this protocol provides opportunities for further amalgamation of datasets to answer research and monitoring questions across administrative jurisdictions.

The RISC protocol is accompanied by a data capture template (Excel; available here: https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-data-information/submit-wildlife-data-information/data-submission-templates) that allows users to submit their data to the Province's Wildlife Species Inventory (WSI) database using the standard fields, codes, and definitions found in the RISC protocol. Once data, including images, are loaded to the WSI database, they become accessible on the web through government applications such as the Species Inventory Web Explorer (http://a100.gov.bc.ca/pub/siwe/search_reset.do) and DataBC's data distribution service (https://data.gov.bc.ca/). We encourage users to manage and tag their images in a third-party software, such as Timelapse, and then submit the exported results to the Province for inclusion in the WSI database. To that end, we are actively working to develop solutions (such as Timelapse templates) to facilitate data entry and management at the local level that adhere to the RISC metadata protocol and hopefully streamline the data submission process.

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21. *From defining high conservation value to their utility and application in land management*

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Introduction

The objectives of this project were to use remote camera data to assess occupancy and connectivity of a variety of species in lands managed by Parks Canada, provincial agencies and regional partners, and to provide data based information in assisting managers in their work to maintain and enhance ecological connectivity in the southern Rocky Mountains of Canada.

There are some unique partnerships in this project. Parks Canada has had cameras out since 2011 and have over 1000 cameras deployed. Following the same protocol, government biologists started to deploy cameras in the East Kootenays in 2016 over 4 key management units. University of British Columbia and University of Montana are also collaborators on this project, helping with analysis of the data. These cross-jurisdictional relationships create great opportunities for research and collaboration.

Study area and methods

Parks Canada started with a 10km x 10km grid over 5 National Parks (Banff, Jasper, Yoho, Kootenay and Waterton National Parks, which was extended over the East Kootenay in 2016 when 96 more cameras were added using the same protocol. In total, the study area extended to be around 600km long north to south. More cameras have since been added in the National Parks. Cameras were deployed at targeted sites, where we expected to see a high number of wildlife (wildlife trails, pinch points, licks, etc.). In total, the study ranged from 2011-2019 and covered 1322 camera sites (Figure 1). We collected data on several species but are focusing on wolves and grizzly bear for this conference (Figure 2).

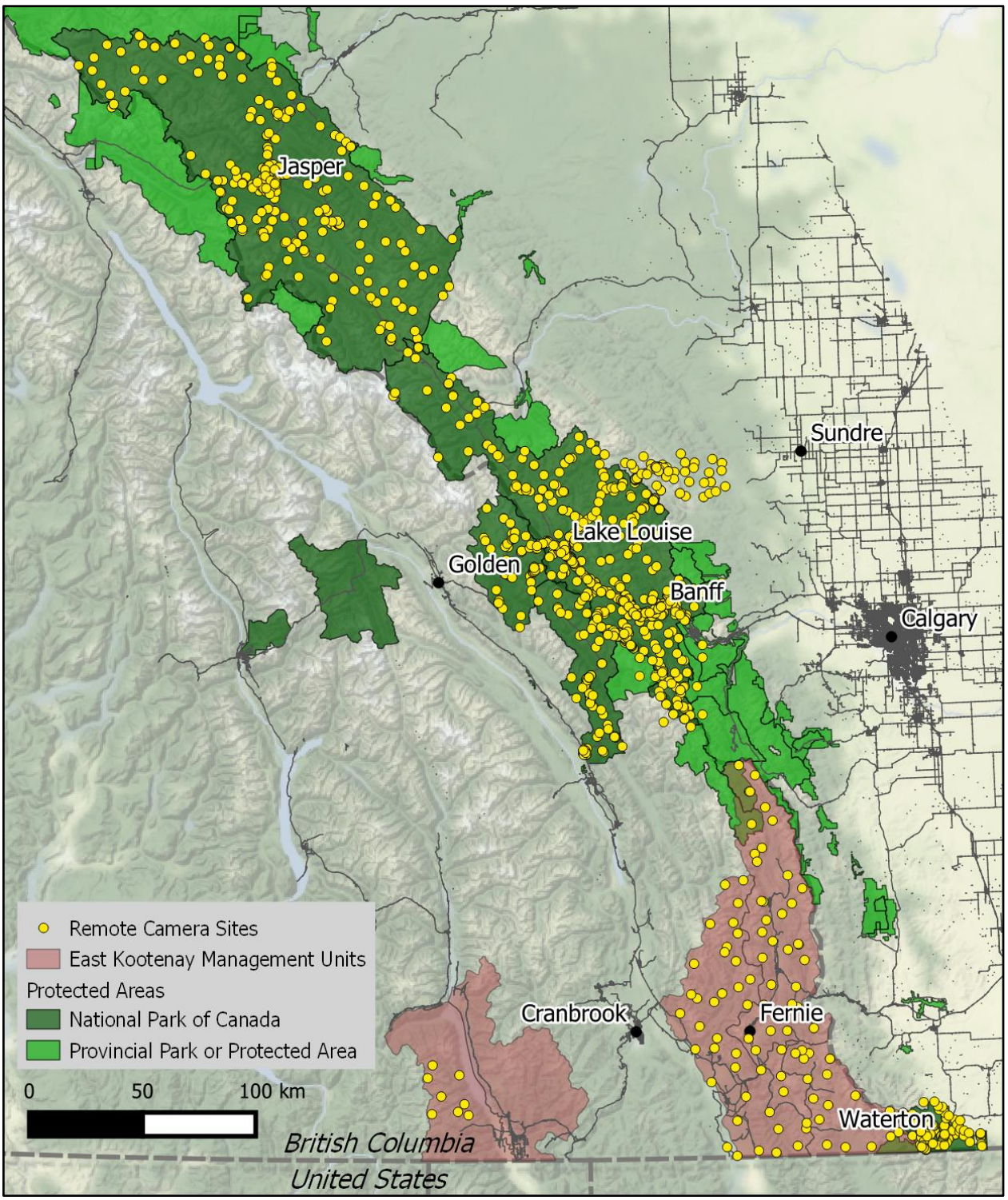

Figure 1. Study area and camera locations in the Rocky Mountains.

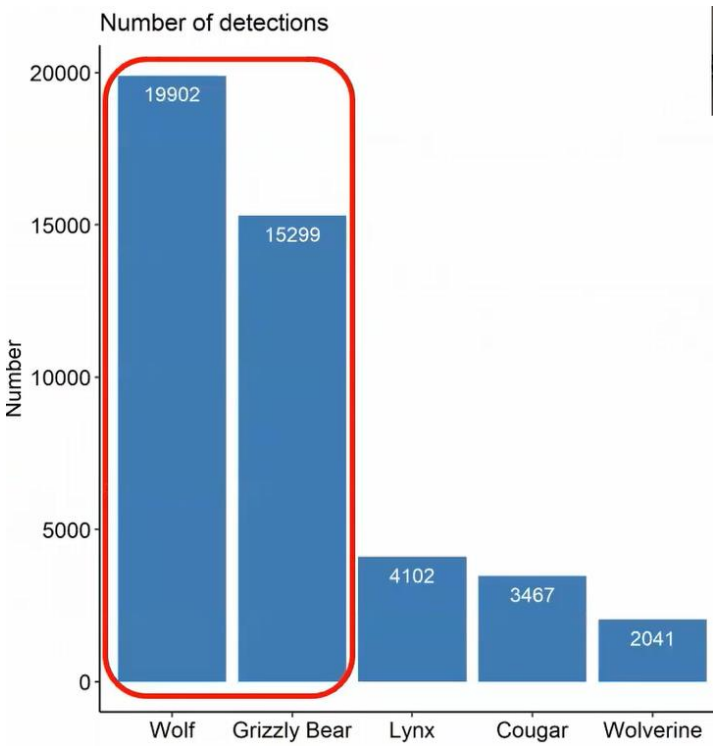

Figure 2. Number of detections of different species from 2011-2019.

Analytical Approach

Our analytical approach followed three steps: 1) occupancy models, 2) connectivity models, and 3) overlapping those model outputs to identify potential high conservation value areas. These are described in detail below.

1) Occupancy Models

Using the remote camera data, we predicted occupancy for each species across summer and winter seasons. Occupancy models are hierarchical models that account for imperfect detection of a species. They consist of two linked logistic regressions: 1) the first is related to the latent ecological process, also known as the state process, which is the true presence or absence of a species at a given site. This is governed by the underlying ecological distribution of that species. 2) The second logistic regression is related to the observation process which models whether a species is detected or not conditional on it being present at the site. We fit stacked single species-single season occupancy models to each of our species of interest. This means that we use data from one species across all years together in a single season model and includes a random effect for site in a Bayesian framework. We fit these models using a UBMS R package. We evaluated the environmental and human-use variables that influence occupancy and detection. We used a broad range of covariates on both psi and p model parameters. One of the main challenges was finding covariate data that covered the full study area. We fit

this suite of covariates to initial models and assessed univariately their significance on these model parameters.

Covariates include:

- Distance to:
    - edge
    - paved road
    - continental divide (at multiple decay lengths)
- Landover covariates:
    - % shrub
    - % herbaceous
    - % conifer
    - % deciduous (and aggregates of these categories)
- Landscape covariates:
    - Northing
    - Elevation
    - Slope
    - Aspect
    - quadratic northing
    - interaction between elevation and aspect
- Human Use as measured by night light intensity
- Within protected area that is 100 sq km or larger

Preliminary univariate models and assessed which variables to include for each species-season model, then we took our top model for each species-season and fit a global model with multiple covariates. Using the top model, we predicated the probability of occupancy across the entire study area (Table 1, 2). We stacked rasters of each of our covariate values and predicted the resulting probability of occupancy for each pixel across the study area (Figure 3).

Table 1. Probability of occupancy for grizzly bears during the summer and the covariates that had a significant influence on the probably of occupancy (PA = Protected Area).

Parameter	Mean	LCI	UCI
Intercept	-2.29	-3.36	-1.26
Slope	-0.75	-1.05	-0.47
Northing	-0.23	-0.56	0.09
Within PA	1.19	0.36	2.02
Dist. to paved road (5km decay)	3.22	2.42	4.10
Location RE	2.78	2.33	3.33

Table 2. Probability of occupancy for wolves during the summer and the covariates that had a significant influence on the probably of occupancy.

Parameter	Mean	LCI	UCI
Intercept	-1.27	-1.73	-0.82
DEM	-0.38	-0.62	-0.15
Slope	-0.61	-0.82	-0.41
Dist. to paved road (5km decay)	1.51	0.94	2.10
Location RE	1.97	1.69	2.28
Intercept	-1.27	-1.73	-0.82

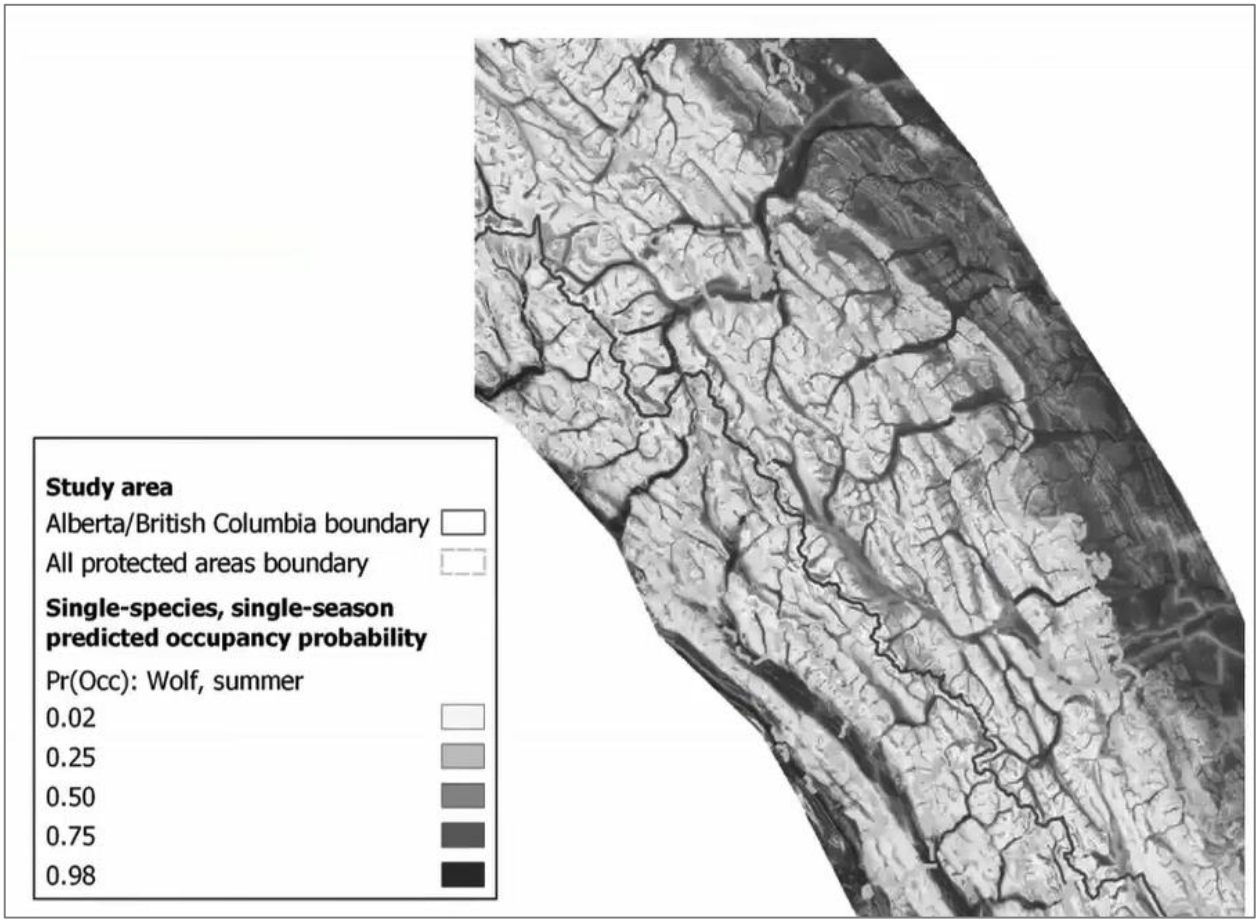

Figure 3. Example of predicted occupancy across a section of the study area. Darker section denote a higher predicted occupancy.

2) Connectivity Models

We used outputs from occupancy models to create a resistance surface to fit connectivity models for each species using the analytical program Circuitscape. Circuitscape uses electrical circuit theory to estimate current/conductance/flow between "nodes" across heterogenous landscape. We transformed the outputs of our occupancy models into resistance surfaces. The resistance values between nodes "reflect the degree to which the landscape facilitates or impedes movement (with higher values denoting greater resistance to movement)". We also included complete barriers to movement to show

areas that we did not expect animals to move through at all, including: areas of >35% slope that were a barren landcover type, and town boundaries. Circuitsacpe simultaneously evaluates contributions of multiple dispersal pathways between nodes and provides and overall map of flow across the study area (Figure 4). We implemented our models in Circuitscape in Julia, which allows for fast processing times.

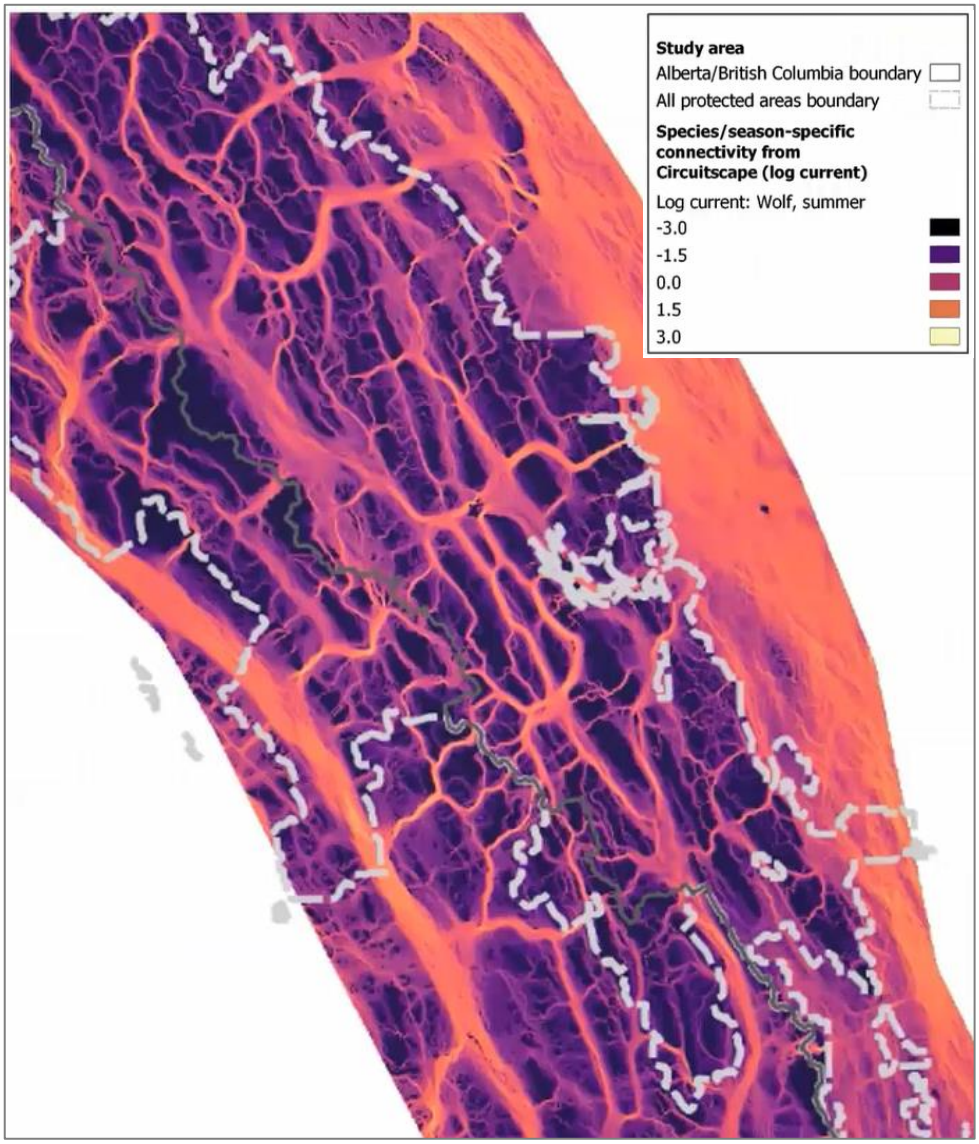

Figure 4. Example of a species/season specific connectivity output from Circuitscape for wolves during the summer.

3) High conservation value areas

We compared these outputs with each other to show areas of potential high conservation value across the study area (Figure 5, 6, 7).

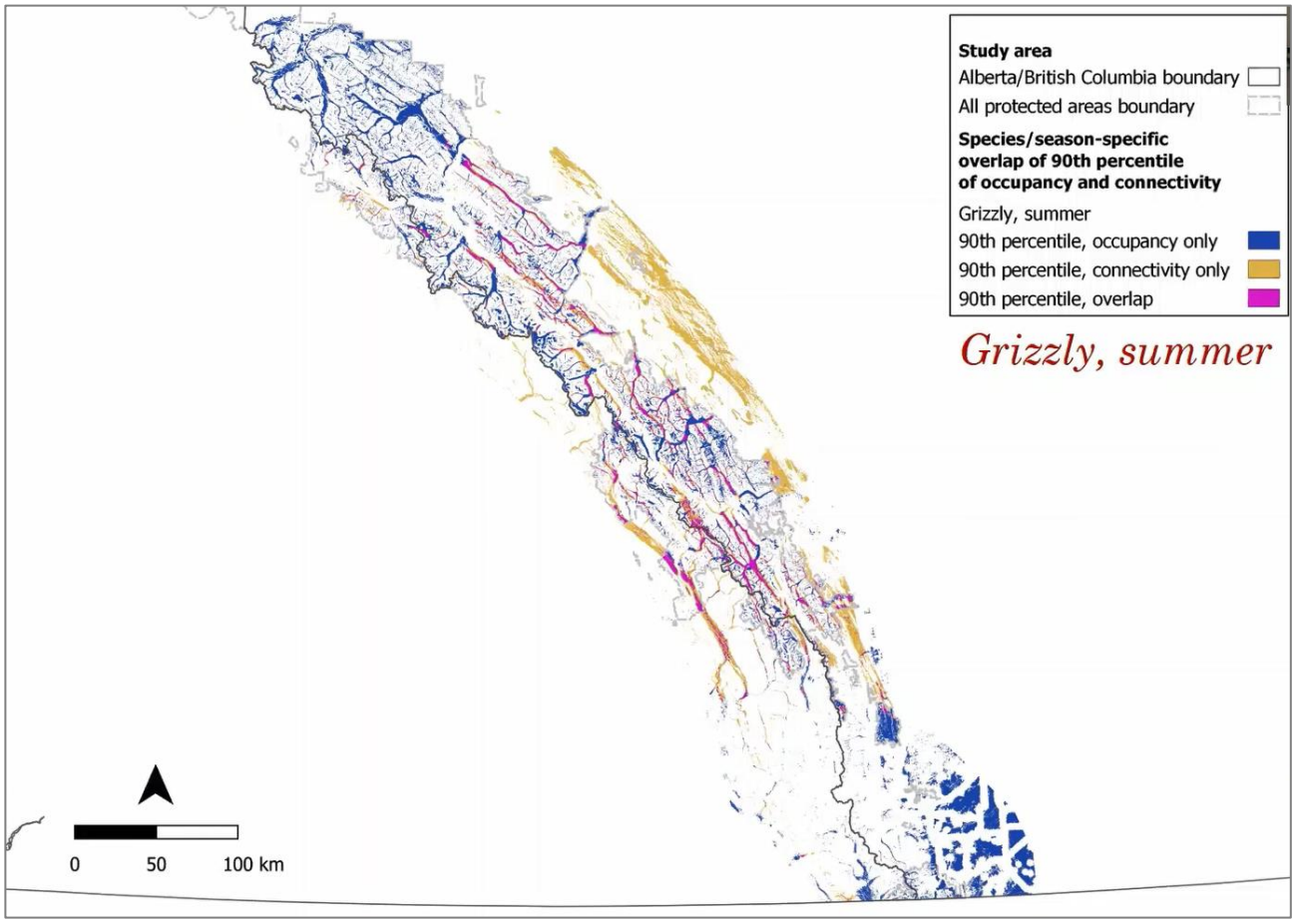

Figure 5. Example overlap between occupancy & connectivity models, with potential high conservation value areas (where high occupancy and high connectivity overlap) in pink for grizzly bears in the summer.

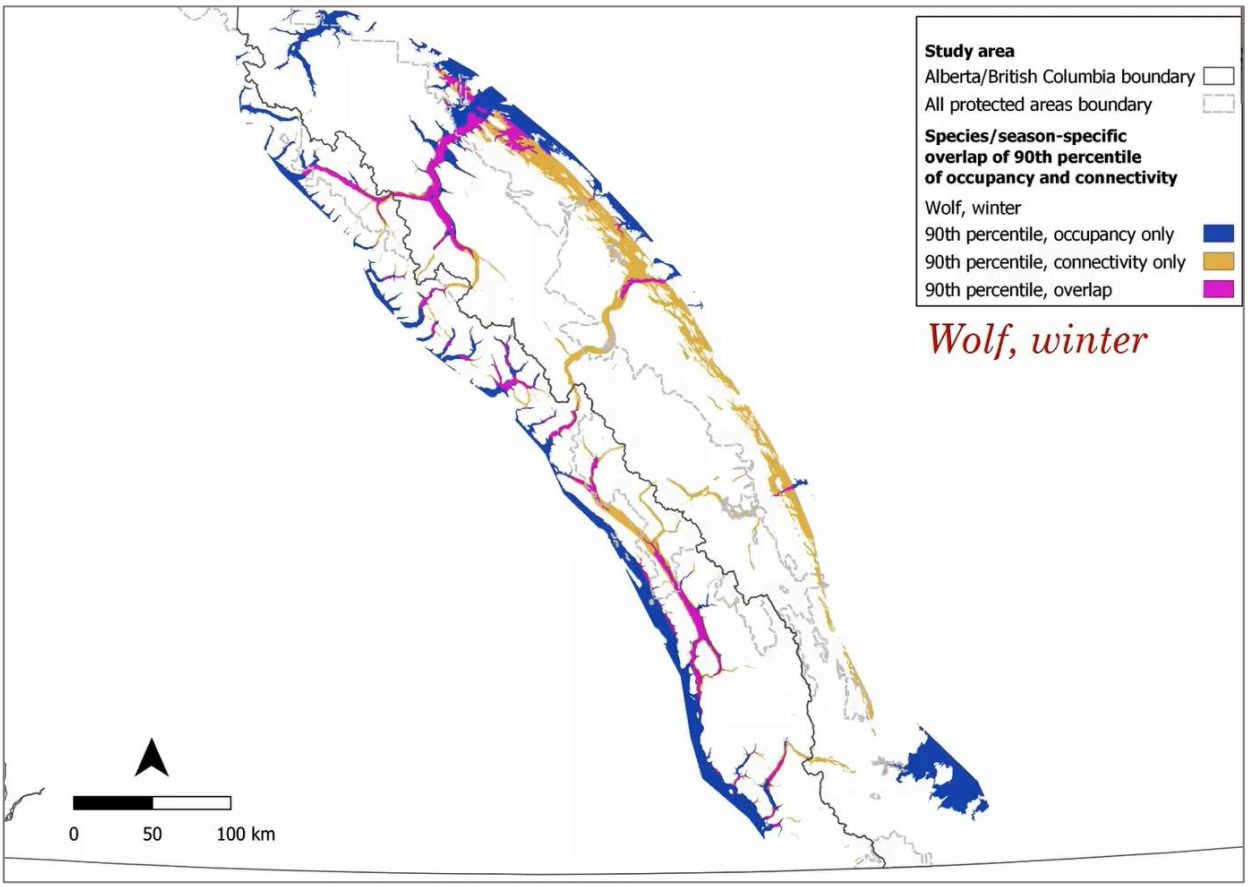

Figure 6. Example overlap between occupancy & connectivity models, with potential high conservation value areas (where high occupancy and high connectivity overlap) in pink for wolves in the winter.

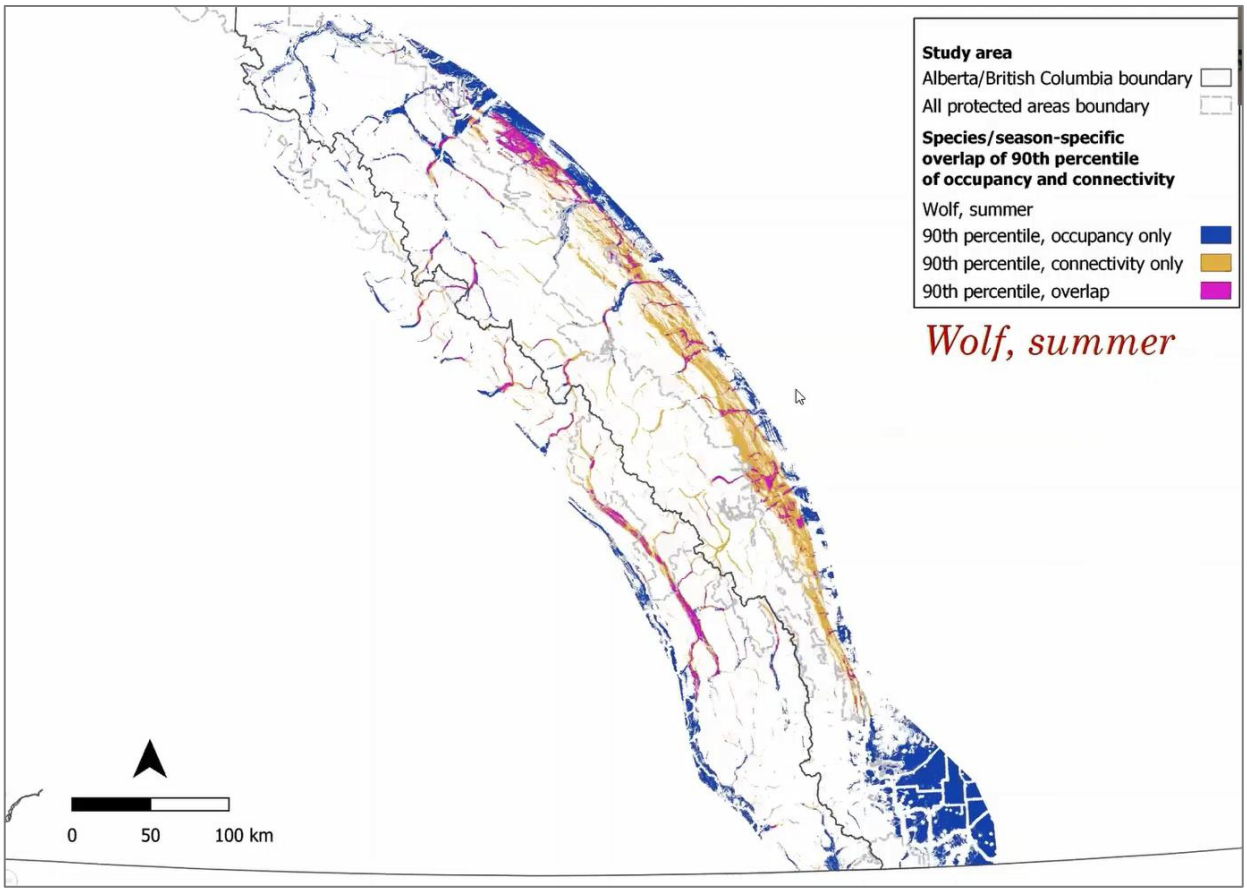

Figure 7. Example overlap between occupancy & connectivity models, with potential high conservation value areas (where high occupancy and high connectivity overlap) in pink for wolves in the summer.

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22. Assessing the impacts of human disturbances on terrestrial vertebrate communities in the Maya Biosphere Reserve, Guatemala

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Introduction

The monitoring of the distribution or abundance of medium and large vertebrate species in tropical forests has been an essential component in many conservation programs. This focus is due to the fact that wildlife hunting, either for subsistence or markets, is one of the most important threats for the integrity of tropical ecosystems. Large vertebrate taxa are key in maintaining tropical forests biodiversity through seed dispersal and seed predation. However, assessing this biodiversity component has been particularly challenging in tropical forests, given low species detectability and the analytical challenges of low sample sizes. The present study characterizes and quantifies the change in the structure of terrestrial vertebrate communities along a gradient of human disturbances in the Maya Biosphere Reserve, Guatemala. We use multispecies models (Dorazio & Royle, 2005; Sutherland, et al., 2016) to assess how occupancy and richness of terrestrial vertebrates change across a disturbance gradient. We use the Defaunation Index (Giacomini & Galetti, 2013) to further characterize the observed changes and identify which aspects of the community are being affected by hunting.

Methods

Study Area. We conducted the study in i) Uaxactun community forest concession and two protected areas further north to Uaxactun: ii) the Mirador Rio Azul National Park, and iii) the Dos Lagunas Wildlife preserve (we will refer to these two areas as MRANP). The harvest of forest products and agriculture is concentrated in an area of 5 km around the community. Zones further away within the concession are less frequently visited by subsistence hunters, xate palm (*Chamaedorea spp*.), and "ramon" nut (*Brosimum alicastrum*) harvesters. Human activities in the protected areas are limited to research, patrolling, and sporadic tourism. The spatial distribution of these activities creates a gradient ranging from higher human use and hunting frequency in areas near the community to areas less frequently used or visited by tourists or park rangers in the northern protected areas.

Camera trap surveys. We conducted camera trap surveys from April through June 2018 and from March to May 2019. We deployed 187 and 155 camera stations, covering an area of 747 km^2 and 580Km^2 for Uaxactun and MRANP, respectively. The focus of this study is medium (between 1 and 20 kgs) and large (more than 20 kgs) avian and mammal species with terrestrial foraging strategies.

Multispecies occupancy model. We used a multispecies occupancy model with data augmentation (Dorazio and Royle 2005) to estimate the occupancy probability of all medium and large species in the community. The model estimates species-specific and community detection responses; species-specific and community occupancy responses; and the size of the community for each of our study areas. Among the parameters estimated, the latent indicator variable *z* is the unobserved true presence-absence indicator of a species at a given site, conditional on the fact that species is part of the community. We use this latent indicator and occupancy estimates pers species per site to further derive community measures. To model species-specific occupancy probability, we included: i) Canopy height as a measure of the type of forest; ii) distance to water sources; iii) Elevation; iv) Potential access. Potential access on foot, was measured as the travel time in hours from human localities to any given site in our study area. This included locations in Guatemala, Belize and Mexico.

Community metrics. We derived the observed species richness from our occupancy model as the sum of the estimated z values per site on each of the areas. To understand how the communities from the study areas differed in species composition, we computed the Defaunation index (see Giacomini and Galetti, 2013), a similarity measure between a reference community and a local community. This index can be weighted by a factor so that it is possible to assign differential importance to each species in the community. It ranges from 0 to 1 with higher values indicating complete defaunation. We computed the Defaunation index using as *species importance* the species' body mass elevated to ¾, and as *species composition*, both i) the latent presence-absence indicator z (D_z = $Defaunation_Z$) and ii) the occupancy estimates (psi) per species per site (D_{psi} = $Defaunation_{psi}$). In the case of *species composition*, we used as the reference community, a hypothetical community where all 26 detected species were present. If a given site had those 26 species present, then the Defaunation index would have a value of zero. We also assessed how Defaunation (D_z) varied per trophic level. All community metrics were computed per camera trap location and then averaged per sampling hexagon. By assigning these values, we were also able to assess the spatial distribution as well as summarizing the measures per study area.

Results

For both areas, we detected a total of 26 species. The jaguarundi (*Herpailurus yagouaroundi*), was not detected in MRNA, while the coyote *(Canis latrans)* was missing from Uaxactun during the dry season.

Species responses. In terms of species responses, we did not find a significant effect of either canopy height or distance to water on species occupancy probability. At lower

elevations in Uaxactun, the ocellated turkey (*Meleagris ocellata*) had a higher probability of occupancy. At less accessible areas in Uaxactun, the occupancy probability for the great curassow (*Crax rubra*) and the tapir (*Tapirus bairdii*) was higher.

When occupancy estimates per camera trap location were averaged per study area, we found great variability, i.e large credible intervals for both areas but especially for Uaxactun. For both areas, the species with higher occupancy probability were the puma (*Puma concolor*), the great curassow, and the tapir (Figure 1). In the two protected areas, nine species had higher occupancy estimates than in Uaxactun. These included the jaguar (*Panthera onca*); white-lipped peccary (*Tayassu peccari*); ocelot (*Leopardus pardalis*); Yucatan-brocket deer (*Mazama pandora*); ocellated turkey; paca (*Cuniculus paca*); coati (*Nasua narica*); and two species of opossums (*Didelphis virginiana* and *Didelphis marsupialis*). In Uaxactun, higher occupancy probabilities were observed for only two species, the tayra (*Eira barbara*) and the striped hog-nosed skunk (*Conepatus semiestriatus*).

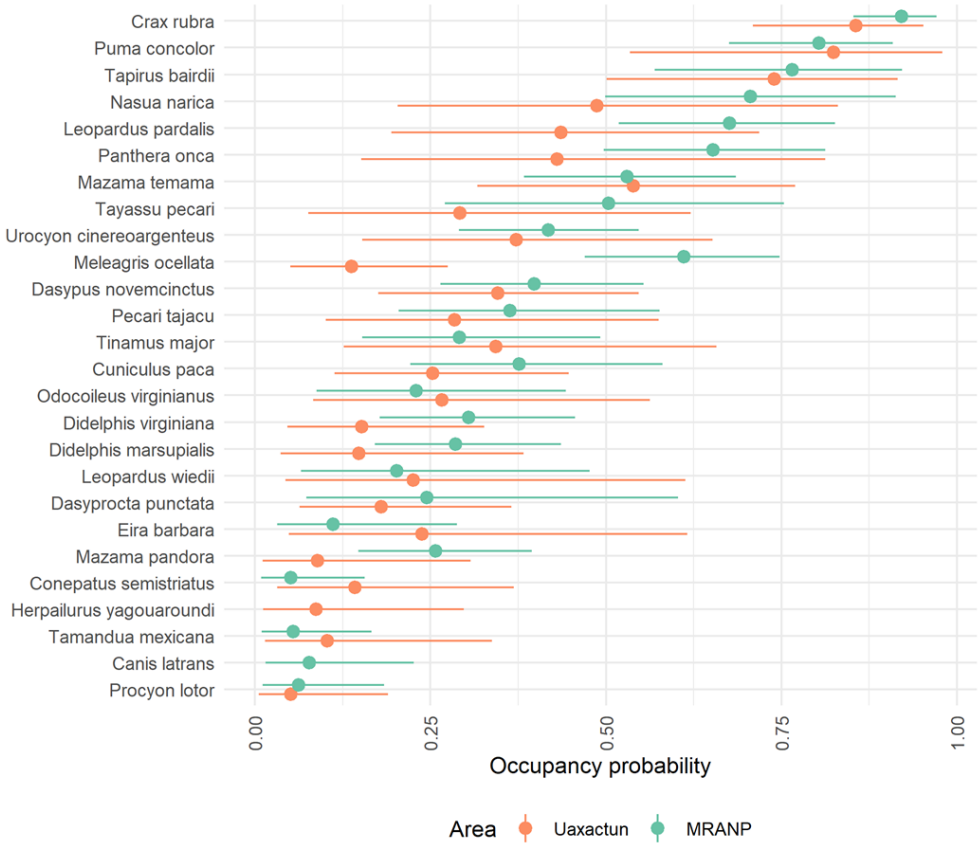

Figure 1. Mean occupancy probability per specie per study area.

Community metrics. We found that mean site species richness per study area was 14 ± 1.64 for Uaxactun and 15.7 ± 2.71 for MRANP. A simple linear regression, calculated to investigate the degree to which access predict site species richness, indicated a significant regression equation ($F_{(1,58)} = 22.68$, $p < .000$; R^2 of 0.268), but only for

Uaxactun, with higher species richness near the community or in more accessible areas. In contrast, the Defaunation values were higher in Uaxactun for both D_z and D_{psi} (see Table 1) . though both areas had medium levels of Defaunation. While D_z values were not associated with access, those of D_{psi} were associated with access in both areas (Uaxactun: ($F_{(1,58)} = 18.35$, $p < .000$; R^2 of 0.227; MRANP: ($F_{(1,46)} = 7.864$, $p = .007$; R^2 of 0.1274). The spatial distribution of the estimates highlighted the differences between the study areas only for the defaunation index metrics (Figure 2). The derived defaunation (D_z) values for each trophic level showed that only the lower tropic levels, the herbivores, had lower Defaunation (D_z) values in the protected areas than in Uaxactun. For mean and high trophic levels, there was not a clear spatial pattern of Dz among study areas (Figure 3).

Table 1. Summary of community metrics obtained at the two study areas.

Metric	Uaxactun	MRANP	Relation with access
Species richness	14.00 ± 1.64	15.70 ± 1.50	Negative and significant but just within Uaxactun
D_z	0.55 ± 0.05	0.47 ± 0.04	Not significant for either area
D_{psi}	0.54* ± 0.02	0.47* ± 0.02	Significant for both areas

*Values from the most current analysis, and updated here from those presented

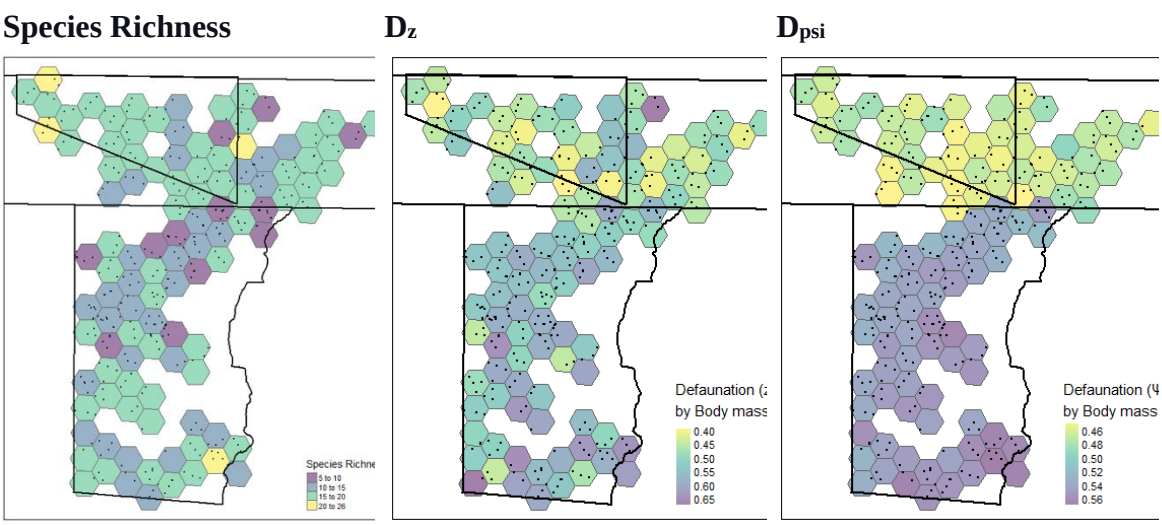

Figure 2. Spatial distribution of community metrics. From left to right Species Richness, Defaunation (z) and Defaunation (psi).

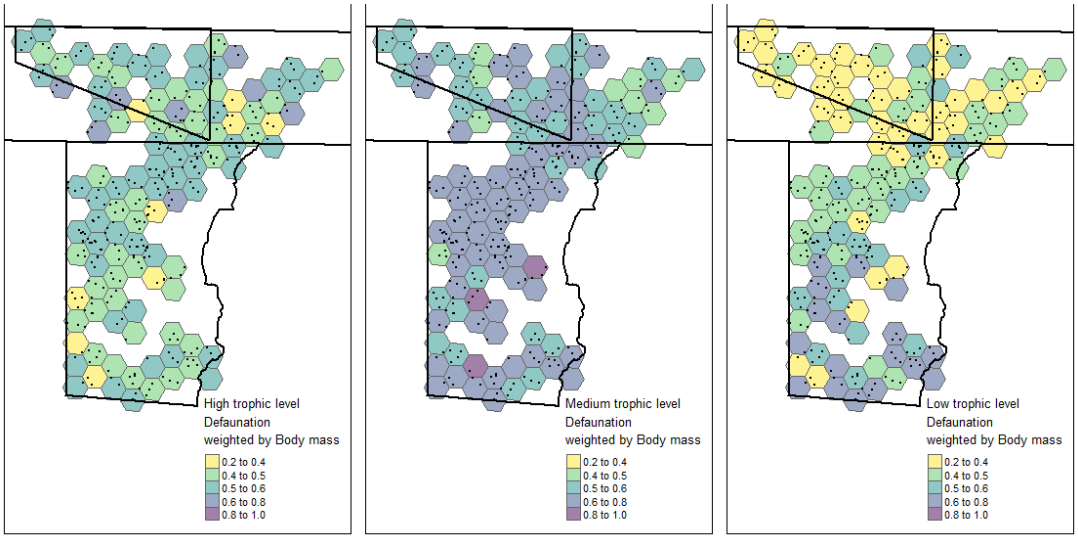

Figure 3. Dz values per trophic level. From left to right Dz for High, Medium, and Low trophic level species.

DISCUSSION

We observed great variability in terms of credible intervals on our species occupancy estimates for both study sites, but especially for Uaxactun. This finding might be either due to high variability across the community concession or to the need to improve the precision of the model in terms of the number of iterations or covariates included. The results reported here should be considered a work in progress; therefore, they need to be considered with caution.

These preliminary results highlight the vulnerability to human access of two species: the tapir, and the great curassow. The latter is a species preferred by subsistence hunters, whereas the former, not a species hunted by Uaxactun people (McNab 1999, McNab et al., 2019), may be sensitive to overall disturbance by humans. The greater occupancy of tapir in less accessible areas might indicate collateral susceptibility, inconspicuous behavior, or vulnerability to human disturbances.

Although we did not find a significant effect of access parameters on other species, we did find that some species had lower overall occupancy estimates in Uaxactun. These lower estimates could be related to greater levels of hunting or human disturbance near the community. By modelling human access from Belize, Mexico and Guatemala, the effect of access on occupancy in the MRANP might not have been well estimated if the frontier is crossed. Actual integrity of the frontier is an area for further investigation.

In terms of community measures, estimation of species richness did not highlight differences in community composition between the two study areas whereas the

Defaunation Index did. Perhaps, as others have found (Larsen et al., 2018, Stork et al., 2016), species richness is a relatively uninformative measure for some conservation applications. These results show that in general, there is lower terrestrial wildlife biomass in Uaxactun relative to a hypothetical community where all medium and large terrestrial bird and mammal species are present, particularly among herbivores. Although significant, the value of the Defaunation index was only 8% different between Uaxactun and MRANP, and both ranged near mid-defaunation levels. This narrowness indicates that, even in the protected area, our cameras rarely documented all species that occurred during the survey time. Further analysis might be needed to improve our conclusions for terrestrial vertebrates.

Regarding the Uaxactun model for wildlife conservation, our conclusions will also need to include the results of arboreal surveys for endangered taxa such as the Yucatán black-howler (*Alouatta pigra*) and Geoffroy's spider monkey (*Ateles geoffoy*i), both endangered primate species. In tropical forests, where hunting occurs, primates have served as the primary indicator species when assessing the impacts of hunting due to their detectability by both hunters and wildlife researchers (Levi et al., 2009). So far, for terrestrial vertebrates, the results highlight the importance of both: i) areas where resource use does not exert a substantial impact on wildlife populations; and ii) effective protected areas that can maintain source-sink dynamics at the landscape scale for wildlife populations.

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23. *Habitat predictors of a vertebrate community in a fragmented neotropical landscape*

Presenter: Keerthikrutha Seetharaman, University of British Columbia
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Habitat loss and habitat modification are considered two major threats to species persistence. Habitat predictors are environmental conditions which dictate patterns in species occupancy and thereby community distribution. Understanding habitat predictors at multiple spatial scales can aid conservation measures and advance theoretical knowledge in land-use decisions. Habitat predictors of ground-dwelling Neotropical vertebrates are often poorly known. To address this knowledge gap, we documented vertebrates, using camera traps, in 19 tropical premontane wet forest remnants in and around the UNESCO World Heritage Site, Área de Conservacíon Guanacaste, Costa Rica. For our study, we chose mammals and largely ground-dwelling birds, such as currasows and tinamous, as vertebrates. We detected 32 species in 5053 trap-days spread over three seasons. We calculated 13 aspects of the vertebrate community as response variables such that they characterise trophic functions, community composition and need for conservation. We tested the ability of 12 habitat variables to explain variation in the response variables using linear mixed effect modelling in an AIC-based model averaging framework. Two of the mail hypotheses we tested were: 1. Measures of connectivity can affect the dispersal of species and thereby, metacommunity persistence and 2. The amount of forest area, of a single forest and in the surrounding landscape, may limit high trophic level species. One of the most influential landscape variables was matrix type: more encounters of higher trophic levels and species were in forests surrounded by plantation matrix rather than pasture matrix. Species classified under the 'threatened' categories of the IUCN red list were mainly in large continuous forest areas. This study demonstrates how understanding the effect of habitat characteristics on different aspects of the vertebrate community, apart from solely species richness, can guide future priorities for land management.

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24. Closing comments

Presenter: Jason Fisher, University of Victoria, Applied Conservation MacroEcology Lab
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Jason Fisher took on the task of providing some concluding remarks and to synthesize the major themes from the group discussions that took place on day 3 of the conference around this query: *What questions do you have, or barriers do you face, with respect to integrating your camera trapping efforts into a regional camera network?*

PHOTO: Jason Fisher

This conference was all about giving people a shoulder up – supporting one another so that achievements can be made that together are bigger than the sum of their parts. The motivation for integration through camera traps is to generate better conservation decisions across larger scales and coordinating our work is one incredibly valuable tool to help make this possible. Towards this end, the WildCAM Network wanted to know *what questions participants have, or barriers they face, with respect to integrating their*

camera trapping efforts into a regional camera network? The primary barriers and questions identified, and Jason's interpretations were presented as follows:

What, a network? Why?

- What does a network even do?
- Who is doing what, where?
- How do you event start? Who do you talk to, especially when you're new?
- The view of the end-uses for the data is obscured; what scaffold are we building onto?
- Questions like those above show us that we need a very clearly articulated vision for a camera trap network, with clearly defined uses for the data in order to ensure people understand where we are going and why. We need to ensure that it's not just about more publications, and that it's really about contributing to better conservation decisions down the road.

Profit Motive: Why should I bother?

- The work involved in contributing network data to a network is not on (m)any people's workplans
- Governments and organizations do not provide time, resources, inducements to contribute data to regional networks
- How do we create a profit motive for researchers and especially their bosses who are the ones who could create the time to make reporting back to networks a part of workplans?

Big Problem: Knowledge of study designs

- How can I get good design advice specific to my local question, while still being useful to a network? This was a big and recurring theme in the group discussions.
- Study design guidance in addition to what exists would be extremely useful; currently design criteria is a recurring and substantial barrier.
- Many camera studies are deployed in a hurry and without substantial design investment – how do we overcome these limitations in capacity? Is there a way to have some robust design ideas available to people so that they can take advantage of financial opportunities when they arise on short timelines?

Questions: Data Interoperability

- How can we plan and design to make detectability common across camera studies?
    - How do you overcome the known barriers such as not all cameras are created equal, nor are all camera placements?
- How do we design to achieve network goals *and* local goals?

    - There were some concerns that they might need to compromise some of their own local/immediate goals in order to create something more valuable to the network.
    - Are species specific, site specific, feature-specific collection data conducive to larger networks? If so, how?
- Quality control: How can we achieve QAQC (quality assurance quality control) for multiple projects? This is exceedingly time-intensive.

Challenge: Constant change in technology

- Different camera models offer different data – in terms of detectability but also metadata.
    - Do cameras need to be the same? If not, how do we deal with that?
    - Data extraction platforms are various. Do we need to choose a standard one?

Challenge: Data Standardization

- Even in government there is no standardization. BC and Alberta do have published standards, but individual researchers still go and do what they want and need to do.
- What are the opportunities for standardization and will they limit our local research goals?
- Will I have to compromise my own research goals to make data compatible with a network?
- Metadata standardization is a particular sticky wicket – is there an app for that?

Challenge: Data sharing

- Data is often owned by industry or Indigenous groups, with reasons for keeping it to themselves.
    - How do we motivate sharing?
- In academia, students: How much control do they have over contributing data?
    - Are these student data or funder data?
- Ownership becomes difficult with multiple stakeholders and partners, and with private land-owners.
- Embargoes: sharing data pre-publication is not desirable. How do we prevent scooping?
    - We know on a strategic level that power is gained by sharing knowledge, not hoarding it. But how do we take that beautiful strategy and implement that tactically with a really diverse set of stakeholders?

Barrier: Communications and a common repository for a network

- We need platforms for communicating about shared data or standards, to all be on the same page. Again, being clear about what the data will be used for will help to create a communications and distribution plan.
- Can current multi-plexing platforms like WildTRax and Wildlife Insights communicate with one another? Or can we all get on board with using a single platform?
- With platforms vying for our data, who do we turn to?

Big Problem: Subverting the dominant paradigm

- There is a common sentiment out there amongst funders that camera traps are a new dodgy and insufficient technology.
- Can a network actually scale up sufficiently to compete with aerial surveys?
- How can we encourage government or other funders to make the shift from million-dollar aerial surveys to camera traps?
- How do we combat a pre-existing 'attitude' or belief system about camera traps?

Barrier: Money money, money, money. (and time and capacity)

- Collecting data from multiple sources, and curating them into a cohesive database, is a time-consuming task requiring dedicated resources
- Currently there is little funding for this outside academia
- Government, NGOs are time-stressed and don't have dedicated personnel for this, but would need some to contribute to a network
- *All challenges are surmountable with resources (money)*. With this in mind, the real question is: *How do we get a camera biodiversity network significantly funded?*

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Posters & Displays

1. *Evaluating the effects of a woodland caribou recovery strategy on grey wolf habitat selection using camera traps*

Presenter: Katherine Baillie-David, University of Victoria
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Co-Authors:
John Volpe, University of Victoria
Jason Fisher, University of Victoria

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Predator control is a common wildlife management strategy in North America to recover declining prey populations. While research has focused on the numerical release of mesocarnivore and prey species, there is a paucity of information on the behavioural shifts within the wider ecological community in response to predator control. We tested whether government-mandated predator control of grey wolves (*Canis lupus*) to conserve woodland caribou (*Rangifer tarandus caribou*) alters habitat selection of the remaining wolf population. We deployed a camera trap array in a prescribed wolf removal area 150 km southeast of Fort McMurray, Alberta. Wolf removal has taken place annually in this area since 2017 to recover the Cold Lake and Eastside Athabasca caribou populations. We measured wolf relative abundance in relation to landscape covariates before and after predator control. To evaluate changes in wolf habitat selection as a result of a population reduction, we created binomial GLMs using two camera trap datasets: a "pre-removal" dataset, collected from 2011 to 2014, and a "post-removal" dataset, collected from 2017 to 2020. Wolves exhibited a positive association with roads pre-removal, while negatively selecting for roads, seismic lines and pipelines post-removal. Our results suggest that wolves may be exhibiting a trade-off in their usage of linear features as movement corridors on the landscape depending on the amount of risk from human persecution. Understanding the potential for behavioural shifts within the remaining apex predator population and the implications for the broader ecological community is necessary to adequately assess the efficacy of predator management strategies aimed at conserving species at risk.

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2. *Forest-harvest prescriptions influence the seasonal distribution of southern mountain caribou, sympatric ungulates, and predators*

Presenter: Jacob L. Bradshaw, University of Northern British Columbia
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Co-Author:
Chris J. Johnson, University of Northern British Columbia

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Southern mountain caribou in British Columbia have experienced rapid population decline due to human-mediated changes to forest communities and a resulting increase in predation. We sought to identify the mechanistic drivers of predation risk as they relate to forest management. We investigated the effect of three forest-harvest prescriptions on the co-occurrence of caribou, sympatric ungulates, and predators: unharvested old-growth, clearcut harvesting, and group-selection harvesting. Group-selection is a partial harvesting system that restricts stand removal to 33% of the harvested area, maintaining old-forest structure and arboreal lichen. Although legally required across some portions of caribou range, group selection may create an environment that is more attractive to sympatric ungulates during snow-free periods. We deployed 65 wildlife cameras to investigate how human-mediated plant community dynamics influenced the distribution of caribou, moose, mule deer, and predators (on-going since spring 2019). Our preliminary results identify distinct differences in habitat use among the focal species. Caribou used old-growth forest and generally avoided areas where forest harvesting had occurred. Moose used the group-selection treatment most frequently. Mule deer favored clearcuts in spring while moose used that treatment in summer. Grizzly and black bears used stands harvested by group-selection more often than clearcut. Wolves regularly used roads in the group-selection treatment. Although preliminary, our findings emphasize that strategies designed to maintain forage for caribou must consider the unintended consequences of interspecific competition. Habitat management for forage must ensure that such activities do not increase predation risk by facilitating apparent competition between caribou and moose or deer.

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3. *Counting elk amongst the trees: comparing Roosevelt Elk population estimates, precision, and survey costs for aerial and camera based methods*

Presenter: Joanna Burgar, Ministry of Forests, Lands, Natural Resource Operations and Rural Development
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Co-Authors:
Dan Guertin, Darryl Reynolds, John Kelly and Josh Malt, all with Ministry of Forests, Lands, Natural Resources and Rural Development

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Conservation and management of Roosevelt Elk (*Cervus canadensis roosevelti*) requires accurate and precise estimates of elk abundance, to maintain sustainable populations that meet the needs of First Nations and stakeholders. The accuracy of current methods to estimate elk abundance is highly variable, subject to bias, and does not involve measures of precision. This project will examine alternative methods for estimating elk abundance accurately and precisely, with variance measures that empirically account for imperfect detection. This project is taking a two pronged, multi-year approach using collared and non-collared elk to estimate abundance and precision via: 1) aerial sightability survey data fitted to Bayesian logistic regression models, eliminating the right-skewed bias associated with modified Horvitz-Thompson correction factors; and 2) camera trap survey data fitted to Spatial Mark-Resight, Spatial Capture-Recapture for categorically marked populations, and Distance Sampling models, to capture precision gains/losses with varying amounts of 'known' information. This poster outlines the methods to achieve project objectives and provides preliminary simulation results. Results from this work will be used to inform management decisions (i.e., harvest allocation, habitat protection and objective-setting), and provide more transparent and clear communication with First Nations and stakeholders. A secondary objective is a cost comparison of methodologies, to equate improvements in precision with cost. The tertiary objective is to create reproducible methodology and simplistic R code that can be used by other projects to adapt project learnings elsewhere.

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4. *Utilizing camera traps in undergraduate research: bringing applied tools into the classroom*

Presenter: Justin A. Compton, Springfield College, Springfield, MA
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Real-world undergraduate research experience can encourage the scientific process, increase student motivation, engagement, and help instill a sense of scientific discovery within students. This research framework emphasizes a dynamic set of ideas and provides a general framework that can be used both as a benchmark and a guide. Here we explore how to combine research opportunities for students with limited resources while fulfilling several dimensions of this real-world undergraduate research framework. Remote camera-traps are commonly used in wildlife research to estimate a broad range of indices such as abundance and diversity. In addition, remote camera-traps provide a non-time intensive method for robust data collection, which can be a critical variable for students and faculty alike at predominately undergraduate teaching institutions. The undergraduate students that participated in this research actively sought out research opportunities outside of the standard classroom environment. The undergraduate research students were first educated on the common use and applications of remote-cameras in ecological studies and given a series of background literature to read before engaging in the research. Students used remote-cameras to address questions of animal diversity, behavior, and habitat use. Students were then instructed in using R and photo identification software as they developed hypotheses to test. The utilization of remote-camera traps in undergraduate research experiences allowed us to bridge the gap between application and theory. The undergraduate research experience guides students through, data collection, data analysis, interpretation, and synthesis. Students gain computational and science writing skills while linking theory and application. Data formatting and processing, statistical analysis in R and multiple writing activities culminate in a final research paper. Students will present their research findings at a college wide research symposium.

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5. *Use of Data Mule UAS to remotely download camera trap data on military lands*

Presenter: David Delaney, U.S. Army Construction Engineering Research Laboratory
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Camera traps are often placed in remote areas to collect important natural resource data which informs management decisions on military installations and other land management agencies. Data are often collected manually (i.e. by vehicle, by foot) which is time consuming, costly, and can risk personnel safety in rugged terrain. Moreover, access to field equipment can be restricted due to military training, inhospitable weather, or to reduce disturbance during sensitive periods (i.e. breeding season). This can delay data acquisition and lead to missed opportunities to make informed management decisions. There is a need for technology that can improve access to ground-based sensor data. We demonstrated the use of a Data Mule UAS to remotely collect camera trap data at artificial water provisioning sites on Air Force land in 2019 and to monitor sensitive bird species on Navy land in 2020. The Data Mule UAS autonomously flew to and circled over each ground station and wirelessly uploaded data from the ground station to the UAS payload. The UAS then returned home loaded with sensor data, which was offloaded by the flight crew upon landing. We successfully conducted flights, some of which were upwards of 12 km, to multiple field sites and conducted missions where multiple ground sensors were visited and data downloaded in a single flight. The results of this project are widely applicable across all military facilities, federal, state, or any lands of interest where there is a need for alternative cost-effective methods for collecting data from camera traps and other remote ground-based sensors.

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6. *Principles for the socially responsible use of conservation monitoring technologies*

Presenter: Douglas Clark, University of Saskatchewan
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Co-Authors:
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Tuuli Toivonen, University of Helsinki

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Wildlife conservation and research benefits enormously from automated and interconnected monitoring tools such as remote cameras, which can collect data on humans either accidentally or deliberately. There is increasing evidence that such technologies, and the data they yield, can have both positive and negative impacts on people, raising ethical questions about how to use them responsibly. We recently proposed a provisional set of principles for the responsible use of such conservation surveillance technologies (CSTs) and their data (Sandbrook/Clark et al. 2021: http://doi.org/10.1111/csp2.374): 1. recognize and acknowledge CSTs can have social impacts; 2. deploy CSTs based on necessity and proportionality relative to the conservation problem; 3. evaluate all potential impacts of CSTs on people; 4. engage with and seek consent from people who may be observed and/or affected by CSTs; 5. build transparency and accountability into CST use; 6. respect peoples' rights and vulnerabilities; and 7. protect data in order to safeguard privacy. These principles require testing and could conceivably benefit conservation efforts, especially through inclusion of people likely to be affected by CSTs. These principles become particularly important considerations for plans to scale up any deployment of a conservation surveillance technology.

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7. *Multi-species mammal monitoring in Cathedral Park*

Presenter: Mitch Fennell, University of British Columbia
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Co-Authors:
Cole Burton, University of British Columbia

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Parks and protected areas in British Columbia are world renowned for their unique landscapes, diverse species, and considerable recreational opportunities. Managing lands, wildlife, and people for these different values presents a unique challenge of balancing multiple mandates, especially with increasing visitation and recreational activity within parks. Crucially, knowledge as to the effects of varying levels of human use must be incorporated into management of these areas, particularly as related to wildlife, which has generally been lacking to this point in British Columbia. We seek to fill these knowledge gaps to inform improved science-based management of wildlife and habitat both in and outside of protected areas. Our research occurs in Cathedral Provincial Park in the Okanagan-Similkameen region, where 45 remote camera traps have been deployed on and off-trails to quantify both human and mammal use of habitat spatially, as well as temporally. Using Bayesian regression models to test hypotheses regarding the influence of human recreation, as well as environmental variables, on spatiotemporal habitat use by seven medium and large bodied mammal species, we show that responses to human use vary by species, including positive relationships for mule deer and mountain goats, while also suggesting that habitat use is often strongly tied to environmental variables, particularly vegetative productivity. Analyses are ongoing, with final results pending collection of additional data. Information from these analyses will be provided directly to land managers including BC Parks and First Nations, to assist in informing land use planning and habitat management.

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8. *Plant phenology and productivity: detecting and understanding climate change*

Presenters: Heather Klassen, Ministry of Forests Lands, Lands, Natural Resources and Rural Development
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Jessica Pyett, Mount Arrowsmith Biosphere Region Research Institute
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There is increasing evidence that global climate change will impact plant physiology, resulting in changes to plant growth, reproduction, and survival. Plant phenology studies provide important information on biological response to climate change, supporting natural resource management, including wildlife habitat conservation. While the history of plant phenology data collection goes back over a hundred years, there are significant gaps in the species studied and the availability of observations recorded here in British Columbia. Our current research on Vancouver Island aims to establish plant phenology and microclimate relationships for indicator species in south coast ecosystems to evaluate potential impacts of climate change to plant productivity and community assemblage. This project integrates government and university collaboration with initiatives in citizen science. We use both person and camera observation data collection techniques. We are evaluating the ability of various field cameras to identify phenophase development for individual species through the seasons. Our poster presentation will include preliminary results and highlight opportunities and challenges when applying camera trap techniques for plant phenology observations.

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9. *Optimizing camera trap methods for Giant Pangolin*

Presenter: Naomi Mathews, Chester Zoo and University of Chester
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Co-Author:
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Giant pangolins, *Smutsia gigantea,* are rare and elusive across their central African range. Due to their solitary and nocturnal nature, the species is difficult to study and therefore poorly understood. Pangolins are considered the most-trafficked mammals, so accurate population estimates are essential to determine the impact of exploitation and inform conservation management. Camera traps are a popular tool for surveying rare and cryptic species. However non-targeted camera trap surveys yield low camera trapping rates for pangolins. Here we use long-term monitoring data from camera trap surveys conducted within three protected areas in Uganda to test whether targeted placement of cameras improves giant pangolin detections. We use single-season state occupancy models and focus on differences in detection probabilities. The results indicate that giant pangolin detectability is highest when camera traps are targeted on burrows. The median number of days from camera deployment to first giant pangolin event was 12, with 97.5% of events captured within 32 days from deployment. The median interval between giant pangolin events at a camera trap site was 33. We demonstrate that camera trap surveys can be designed to improve detectability of giant pangolins and outline a set of recommendations for future giant pangolin surveys to maximise the effectiveness of efforts to survey and monitor the species.

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10. *Variable influence of settlement proximity on temporal activity patterns of mammals in Israel*

Presenter: Itai Namir, Tel Aviv University and The Steinhardt Museum of Natural History
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Ron Chen, The Steinhardt Museum of Natural History

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There is increasing evidence that land use and land cover change due to human activity, particularly in the form of human settlements, can affect animal activity patterns. Understanding the impact of human settlements on organisms is a crucial step in devising habitat management practices for species conservation. The objective of this study is to quantify the effect of settlements on temporal activity patterns of large mammals in Israel. In order to assess the influence of human activity on mammals' temporal patterns, motion sensitive camera traps were located in two sampling zones: near settlements (up to 100 m from their perimeter), and far from settlements (between 500 and 2000 m from their perimeter). In each zone, nine cameras were placed for a continuous period of 10 days. We sampled 25 settlements across three different ecological units in Israel. Using the data obtained, we examined the effect of settlement proximity on the temporal activity patterns of mammalian species using Generalized Additive Models. We found that temporal activity patterns tended to vary with settlement proximity, but this response varied across species. For some species, e.g. the Indian crested porcupine, we found that the time window of nocturnal activity near settlements was narrower. For "opportunistic" species we found variations in temporal activity in the different proximities, e.g golden jackal, exhibit two clear peaks of activity (in the morning and in the evening). Near settlements, the evening peak is more pronounced and activity levels remain relatively high through the night. The results of this study indicate that large mammalian species in Israel vary in their response to human settlements. Understanding the sources of this variation can inform management actions aimed at decreasing undesired behavioral responses of species to human settlements.

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11. *Innovations in movement and behavioural ecology from camera traps: day range as model parameter*

Presenter: Pablo Palencia, Instituto de Investigación en Recursos Cinegéticos (IREC) CSIC-UCLM-JCCM.
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Camera-trapping methods have been used to monitor movement and behavioural ecology parameters of wildlife. However, some concerns have emerged. For instance, some wildlife populations present movement patterns characteristic of each behaviour (e.g. foraging or displacement between habitat patches), and further research is needed to integrate the behaviours in the estimation of movement parameters. In this respect, the day range (average daily distance travelled by an individual, DR) is a model parameter that relies on movement and behaviour. This study aims to provide a step forward concerning the use of camera-trapping in movement and behavioural ecology.

We describe a machine learning procedure to differentiate movement behaviours from camera-trap data, and revisit the approach to consider different behaviours in the estimation of DR. Secondly, working within a simulated framework we tested the performance of three approaches to estimate DR: DROB (i.e. estimating DR without behavioural identification), DRTB (i.e. estimating DR by identifying behaviours manually and weighting each behaviour on the basis of the encounter-rate obtained) and DRRB (i.e. estimating DR based on the classification of movement behaviours by a machine learning procedure, and the ratio between speeds). Finally, we evaluated these approaches for 24 wild mammal species with different behavioural and ecological traits.
The machine learning procedure to differentiate behaviours showed high accuracy (mean = 0.97). The DROB approach generated accurate results in scenarios with a speed-ratio (fast relative to slow behaviours) lower than 10, and for scenarios in which the animals spend most of the activity period on the slow behaviour. However, when considering movement behaviours to estimate DR, is mandatory to include in the formulation the speed-ratio, otherwise the results will be biased. The new approach, DRRB, generated accurate results in all the scenarios. The results obtained from real populations were consistent with the simulations.

In conclusion, the integration of behaviours and speed-ratio in camera-trap studies makes it possible to obtain unbiased DR. Speed-ratio should be considered so that fast behaviour is not overrepresented. The procedures described in this work extend the applicability of camera-trap based approaches in both movement and behavioural ecology.

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12. *Analysing zones of influence around an underground gold mine in Nunavut: making the most of minimal detections*

Presenter: Hannah Visty, ERM.
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Co-Authors:
Laurie Ainsworth, ERM

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Greg Sharam, ERM

Link to this poster not available

Effectively monitoring the impacts of industrial projects is a major challenge for species occurring at low densities and varying among seasons and years. The Canadian Arctic is home to several such species, including barren-ground caribou and wolverine, which are also species of conservation concern and predicted to be more sensitive to disturbance from mining development. We implemented a remote camera monitoring program around an underground gold mine in Nunavut to assess whether there was a zone of influence of the mine on caribou or wolverine distribution. We designed the program with balanced camera placement at varying distances to infrastructure, expanding outward from the mining development.

Cameras were designated by zones, with 21 treatment cameras (< 2 km from infrastructure), 19 cameras in a possible zone of influence (2 to 10 km from infrastructure), and 19 cameras in the control zone (> 10 km from infrastructure). We matched camera sites within and among zones, controlling for habitat components, including distances to waterbodies and known travel corridors. We developed analysis methods to address several challenges, including low camera effort during winter months and low detection rates. Low detection rates were improved by creating binomial Generalized Additive Mixed Models (GAMM) of camera site occupancy (at least one detection in a month), first using categorical zones to assess for differences between treatment and control areas; where significant differences were seen, we conducted additional analyses to determine the size of the potential zone of influence, using distance to infrastructure as a continuous measure.

Categorical GAMM analyses indicated a significant difference between caribou detection rate at treatment versus control zone cameras. However, GAMM models using distance to infrastructure as a continuous variable did not indicate a zone of influence (i.e., distance had no effect in the model). Camera data corroborated caribou collar data documenting changes in the annual patterns of migration of the Dolphin Union and Beverly/Ahiak caribou herds, which may help explain the variation in results between

models. For wolverine, categorical analysis between treatment and control zones did not indicate a zone of influence around the mining development, though wolverine were only detected at about 5- 10% of camera sites per year. Compared to the previous detection rates of these species around the mining development, we effectively minimized the limitations of camera monitoring by improving study design and analysis methods. However, for species occurring in extremely low densities (such as wolverine), more effort-intensive sampling methods are still recommended.

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Workshop: WildCo Tips & Tricks for the Exploration and Analysis of Camera Trap Data: Part 2

A workshop was presented by Chris Beirne, post-doc student with the University of British Columbia's WildCo Lab. While the workshop was originally intended to be quite hands-on and in-person, it was later adapted for online delivery a long presentation supported with take-home resources and plenty of time for questions and discussion.

WildCo Tips & Tricks for the Exploration and Analysis of Camera Trap Data: Part 2

The use of camera traps to study wildlife communities is rapidly growing, thus we need tools to rapidly explore and interrogate the data which camera traps produce. Chris used his experience compiling multiple datasets for global synthesis projects to guide participants through the key elements of exploring camera trap data – from essential error checking to basic analyses. The workshop will assumed that participants had *already* watched Chris Beirne's primer workshop on data standardization found in this CREDtalk here.

This workshop was designed to be of use to any individual or organization using camera traps to collect information on wildlife populations. All participants were provided with a copy of the slides, and online guide, data that was used in the guide, links to detailed data standards, and a number of other resources.

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Resources summary & slide shows

Conference participants were invited to submit their "best of" camera trap photos for a slide show that cycled through the breaks – the collection of photos received are incredible! A general show featuring a large number of submissions can be found here, and a show featuring submissions from Paul Jones and Roland Kays is here.

Like any conference there are zillions of resources shared amongst participants to help inform and assist everyone's work. At this conference we had a volunteer monitor the chat in Zoom for resources being shared – below is a summary of various items that may prove to be helpful provided in the order they were presented during the conference. Thank you to Doris Hausleitner for taking on this task.

Note that this list does not include all of the information posted to the event Slack channel. Be sure to visit the Slack channels for more details, resources, discussions and debates. The Slack channel has been taken over by the WildCo Lab and remains an open discussion forum for folks working with camera trap networks.

- Metadata standards for camera trap data – *Biodiversity Data Journal*, Forresterm O'Brien, Fegraus, Jansen, Palmer, Kays, Ahumada, Stern, and McShea
- Wildlife Insights AI Models: data standards and general information
- Recommended guiding principles for reporting on camera trapping research – *Biodiversity & Conservation*, Meek, Ballard, Claridge, Kays, MOseby, O'Brien, O'Connel, Sanderson, Swann, Tobler and Townsend
- Tech report: Automated image recognition for wildlife camera traps: making it work for you. Greenberg.
- Microsoft Megadetector
- Dr . Greenberg wrote a guide for the WildCAM network on Image Recognition - check it out here.
- Camera mounts used by Pamela Narvaez Torres with University of Calgary: Genius mounts from Cuddeback
- Recommendation from Robyn Naidoo for statistical matching techniques: Schleicher et al cons biol 2020
- Calgary City Nature Challenge link
- Numerous resources around the topic of security and theft, check the discussion on Slack here

- High-density camera trap grid reveals lack of consistency in detection and capture rates across space and time, Kolowski, Oley and McShea. This paper is related to the high variability in encounter rate that @RolandKays describes:

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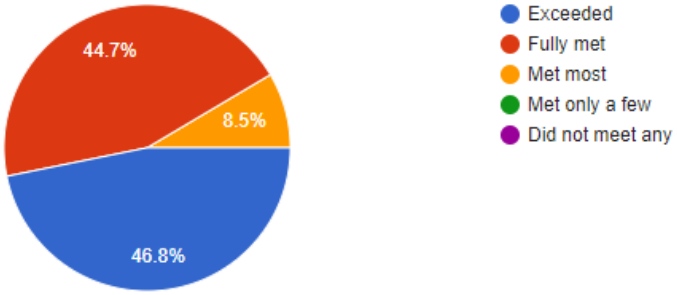
Summary of conference evaluations

There were just over 200 people registered for this online conference. An average of 160 people attended each day of the event with many people emailing in to say that they had not planned to stay tuned in the whole time but that the conference was "just too engaging to leave!" We received 47 evaluations.

We have not listed all responses below as they are too numerous for this format, just a sample to provide the flavour of the feedback received.

How well did the conference meet your expectations?

47 responses



Please share the top two things you got out of this conference. Are there things that you will be doing differently in the future?

46 responses

This field is evolving so quickly. I will be referring to some of the larger project websites more often. Standards seem so important, but studies are so variable. Try to use BC RISC standards and tailor to each project

Logical approach for managing camera trap data, and a couple of tools for it

Learning about similar / inspiring projects elsewhere that can help inform my projects. Just the importance of standardization - will be checking out AI to help initially sort photos.

Connections to new people, awareness of other projects going on (so many cameras!)

Importance of metadata!! I'll be revisiting this for my work. Also, the variety of data analysis methods to consider.

I got great ideas for my upcoming field program re. study design and metadata management.

The slack channel really changed the game. It was so much easier to meet and interact with new people and continue conversations sparked by presentations. The break out room was great as well

Was there anything you had hoped to learn that you did not?

36 responses

I'm a hands-on learner, so I wish the workshop was half a day or spanned two days so that we could work through code or go into breakout rooms and analyze the a small sample dataset, where each breakout room had a different theme (occupancy vs. species interactions vs density)

more specific on sample size and relevant statistical analyses

Yes. Chris's data analysis workshop opened up some doors for me.

Not that I can think of

NA

Nope.

Even virtually a more hands on workshop would have been nice/helpful to determine what existing tools could be of use to us. I had already dedicated time for this workshop so needing to now find the time to walk through it all myself will be a bit tough but, with the resources Chris supplied definitely doable.

I was hoping to learn about software for identifying and tracking individuals. Was mentioned in Saul's talk

This is CMI's first time offering a full conference online. Please tell us about your online experience and anything we can do to improve in the future.

44 responses

This was an amazing conference with lots of opportunities to ask questions. Travel can sometime be a barrier due to the extra time.

Sound delivery, doesn't quite replace in-person meetings, but allows a wider range of folks to attend.

It was pretty good. As everyone else, I miss the actual in-person conversations. But the slack was a great option in lieu of chatting and maybe even better as it allows documentation that we can refer back to.

This was very smooth and well handled! The use of Slack was an excellent choice and really allowed more engagement to take place.

The combination of zoom and slack was great. Maybe an opportunity for more break out rooms - choose your topic (deployment methods, analysis, etc) to encourage more conversations.

The three half days was a GREAT schedule and allowed for better work/conference balance for professionals. I wish there was more time between talks for questions as things got a bit lost in the comments section (people added comments and responses so quickly, it was distracting and also hard to catch them all). The Slack line was a great addition and glad to hear you'll keep it active for a couple

Are there any other general comments you'd like to share about this conference?

37 responses

well facilitated and great diversity in the presenter experiences

Thank you so much for putting this together! Great job.

Awesome set of presenters!!

Nice work team, this wasn't easy, but I appreciated all the effort required to pull this off! Curious to see if there will be a follow up in a couple years!

Thank you so much for a wonderful conference! See my comments to the question above.

You all did a great job facilitating and keep the events moving and upbeat. Well done!

Greatly appreciated.

You should plan more of these types of workshops on various subjects because you get a great turn-out.

Three Questions from the WildCam Network:

1. What is your biggest challenge in running a camera trap survey or program?

43 responses

data analyis and not misinterpreting data

Survey design with limited knowledge. This conference was very helpful

Data Management for long-term camera trap programs

Buy-in from my organization (bc gov)

Organizing logistics and processing immense data

Time - only one component of my job, but deployment, data collection and analysis is time consuming.

study design when it is influenced by project/equipment costs

funding and powerful study design

Analyzing the data in a meaningful way

2. What is one key benefit you would like to receive from being part of a network?

44 responses

I like the detailed discussion on specific topics with other knowledgeable people in the same field, I love how diverse geographically this audience was

Updates on latest methods, technology, etc.

Access to others' experiences, we don't have to all go through trial and errors to learn

Shared knowledge and resources

Collaboration with and advice from other members (much like is happening on the Slack channel)

Being able to answer big questions around cumulative effects - ability to join in on regional projects.

input on analysis, connecting with colleagues to collaborate on analysis

advice/guidance based on my study system and question

3. Is there a significant constraint or barrier to your participation in a network? (Feel free to repeat issues you raised in Thursday's group discussion.)

40 responses

data security, standardization, privacy, covariants that may be biasing my date collection on purpose for my project, but may bias interpretations

A lot of project I work on are for private industry. Most often not willing to share their data.

Data access restrictions, we have a lot of pictures we cannot share because our client won't let us.

None that I see, just hurdles to overcome

Data sharing agreements for collaborative projects

Sharing data from projects funded by private industry (I'm a consultant). Costs/effort to input into a regional network.

standardization, time investment, being a grad student (not necessarily having the agency to join a network)

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