Camera trap monitoring to assess wildlife responses to environmental change in BC Parks

Summary Progress Report for BC Parks, March 2021

Camera trap captures, Top left: Mountain goat (*Oreamnos americanus*) in Cathedral Provincial Park.
Top right: Wolf (*Canis lupus*) in Cathedral Provincial Park.
Bottom left: Wolverine (*Gulo gulo*) in Joffre Lakes Provincial Park.
Bottom right: Spotted skunk (*Spilogale gracilis*) in Golden Ears Provincial Park.

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Summary

Protected areas (PAs) represent a fundamental strategy in efforts to protect threatened biodiversity and the ecosystem services they provide. British Columbia has a large and diverse PA system, covering 15% of the province's land area, but BC's parks face increasing pressures from land use change, climate change, and recreational demands. There is thus a need for effective monitoring methods to inform management actions and ensure PA effectiveness.

In this project, we are testing the use of camera trap (CT) monitoring to assess the status of terrestrial wildlife in BC parks, and to understand the impacts of recreational activities and other stressors on medium- and large-bodied mammals. We are conducting CT surveys in five provincial parks and their adjacent landscapes: Cathedral, Garibaldi, Golden Ears, Joffre Lakes and South Chilcotin Mountains parks (a WildCo project has also been initiated in Itcha-Ilgachuz Provincial Park but is focused on caribou conservation and not included here). To date, we have deployed 214 CTs across these parks, and processed more than 2 million images of wildlife and people from approximately 100,000 camera-days of sampling effort. In doing so, we are developing rigorous protocols for CT data collection, processing, analysis and sharing that we intend to disseminate through the WildCAM camera network (wildcams.ca).

As of March 2021, CT sampling is ongoing in all five parks, with a wide range of species detected in each (e.g. 29 mammal species in Cathedral, 32 in South Chilcotins), across a range of habitat types and recreational pressures. These include commonly detected species, such as mule deer, black bear, and coyote, as well as a variety of less frequently observed species (e.g., lynx and bobcat, wolverine, wolf, elk). Our surveys have documented high variation in human recreational activity across space and time, and we have developed preliminary statistical models (with data collected up to fall 2020) to test hypotheses about the relationships between focal mammal species, human recreational activities and environmental variation. Data analyses for Cathedral, Golden Ears and South Chilcotin Mountains are being undertaken as part of MSc thesis projects within the WildCo lab at UBC (Fennell, Procko and Colton, respectively). Naidoo and Burton published results from the initial year of sampling for the South Chilcotin Mountains (*Conservation Science and Practice*, 2020:e271) and Naidoo is leading updated analyses using all 3 years of data collected, with a particular focus on grizzly bears. We anticipate submitting results of these analyses for peer-reviewed publication in 2021-22.

This report provides an update on the progress in CT sampling and analysis across all five parks, as well as related initiatives being undertaken by the WildCo lab and collaborators. The latter include analysis of vegetation phenology from CT timelapse photos and continued work with the WildCAM network to support coordination among CT surveys across large scales. The COVID-19 pandemic has presented a unique challenge in implementing research activities, but also an unprecedented opportunity to learn about wildlife responses to the significant changes in visitor use of provincial parks associated with the pandemic. We will continue this project through the coming 2021-22 year, with CT checks commencing in the late spring/early summer, and data processing and analysis continuing through the year. In consultation with BC Parks, we will make a decision on ending the camera trap sampling in some or all parks in late 2021, finalizing analyses, and disseminating data and results in ways that maximize the utility of these camera trap projects for supporting PA management and wildlife conservation.

Acknowledgements

This project is supported by funding from the Province of British Columbia's Ministry of Environment and Climate Change Strategy (via BC Parks), the Natural Sciences and Engineering Council of Canada (NSERC), the Canada Research Chairs Program, and the University of British Columbia. Support for the WildCAM network has also been received from the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD), BC Parks Foundation, Mitacs, and the University of British Columbia (Faculty of Forestry and Biodiversity Research Centre). Work in South Chilcotin Mountains Park has also been supported by WWF-US, HCTF, Tyax Adventures, and the Lillooet Naturalist Society.

We are very grateful for support and assistance received from staff at BC Parks (including Melanie Percy, James Quayle, Jennifer Grant, Tory Stevens, Joanna Hirner, Sam Stickney, Erin Rutherford, Daris Lapoine, Kevin Wilson, Kirk Safford, Zsana Tulcsik, Kevin Wagner, David Whiteside), Malcolm Knapp Research Forest (Ionut Aron, Cheryl Power), Cathedral Lakes Lodge, and the BC Ministry of FLNRORD (Bill Harrower, Craig Mclean, Andrew Walker). At the University of British Columbia, we thank Lily Chua, Joanne Dean and others in the Faculty of Forestry for administrative support. We also thank members of the WildCo lab for technical and logistical support, particularly Taylor Justason for assistance in the field and with WildCAM, Chris Beirne for helping with summary statistics and fieldwork, An Hoang for work on phenology (with previous input from Tom Howey, Taylor Justason and Joanna Burgar), and Isla Francis, Debra Sinarta, Jessica Low, Gerlissa Chan, and Cydney Swan for their integral assistance with photo processing. The following undergraduate student volunteers also helped with photo processing and other tasks: Joey Krahn, Charles White, Katelyn Mayhew, Eliza Eslake, Levi Robson, Nicholas O'Connor, Simon Campbell.

We would like to acknowledge with sincere gratitude and humility that our work in Cathedral Provincial Park takes place on the unceded territory of the Syilx (Okanagan) Nation, our work in Golden Ears Provincial Park takes place on the traditional, unceded territory of the Stó:lõ Peoples, in particular the Katzie First Nation, our work in Garibaldi Provincial Park takes place on the territories of the Squamish and Lil'wat Nations, our work in Joffre Lakes Provincial Park takes place on the territory of the Lil'wat Nation and N'Quatqua and our work in South Chilcotin Mountains Provincial Park takes place on the unceded territory of the St'át'imc Peoples. We also acknowledge that these lands have been occupied by each respective nation since time immemorial. We look forward to fostering relationships founded in respect and appreciation with each nation as we conduct our research moving forward.

Some details of this project have been described in previous progress reports, which are available by request from cole.burton@ubc.ca.

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Introduction and Objectives

Protected areas (PAs) represent a fundamental strategy in regional, national, and global efforts to protect threatened biodiversity and the ecosystem services they provide (Chape et al., 2008; Coristine et al., 2018; Naidoo et al., 2019). British Columbia (BC) has a large and diverse protected area system, covering approximately 15% of the province's land area (Environmental Reporting BC, 2017) and representing the third largest parks system in North American (after Canada's National Parks and the United States' National Park Service; BC Parks 2019). BC is world-renowned for maintaining large ecosystems with complete assemblages of large-bodied mammals, and their associated predator-prey dynamics, including grizzly bears, grey wolves, wolverine, caribou, moose, and mountain goats. However, despite the significant proportion of land area protected, PA's in BC and elsewhere face many threats from expanding human pressures, including habitat loss (Heino et al., 2015), isolation (Saura et al., 2018), climate change (Mahony et al., 2018), and various development and recreational pressures in and around parks (Buxton et al., 2017; Kays et al., 2017; Parsons et al., 2016; Radeloff et al., 2010; Reed & Merenlender, 2008; Wittemyer et al., 2008). The effectiveness of protected areas has been questioned, and in many cases is poorly known due to inadequate monitoring systems (Chape et al., 2005; Geldmann et al., 2013).

Park recreation and nature-based tourism provide important revenue and public support for wildlife protection, on top of promoting human health and community engagement (Larson et al., 2019). Yet it is less certain how recreational activities can impact wildlife populations in parks, now or in the future. Without careful, evidence-based management, growing recreational demands could undermine the effectiveness of protected areas at meeting conservation objectives. Knowledge of the effects on wildlife of different types and amounts of recreation, acting alongside climate change and other stressors, must therefore be incorporated into protected area management (Merkle et al., 2019). Accordingly, there is a need for increased focus on reliable and cost-effective monitoring systems for wildlife in PAs and surrounding landscapes (Jetz et al., 2019; Lindenmayer & Likens, 2010). This is particularly true in BC, where nature-based tourism is an important and growing sector of the economy, yet the PA system--including many large and remote parks--has not received adequate funding to implement detailed ecological monitoring (Wright & Stevens, 2012). The Covid-19 pandemic has emphasized the importance of provincial parks and other outdoor spaces for public health and well-being, as well as the need to carefully manage visitor impacts to park biodiversity. The pandemic has also provide a unique opportunity to learn more about wildlife responses to dramatic changes in visitor use over relatively short periods (e.g. park closures).

The impacts of recreation on wildlife have received increasing attention in the literature; however, most studies have been limited to particular species and contexts, and general patterns remain elusive. For instance, Reed and Merenlender (2008) reported that coyote and bobcat densities responded negatively to high levels of recreation, while Brodeur et al. (2008) noted predator preference for trails and roads, and Muhly et al. (2011) suggested that prey species were more likely to use areas of higher human use as a "predator-shield". Such seemingly contradictory results reveal significant gaps in our understanding of how to manage recreational impacts on wildlife. More broadly, it is clear that wildlife communities are shifting under the cumulative impacts of multiple interacting stressors, but far less clear which species and conditions will result in "winners" or "losers" under environmental change (Fisher & Burton, 2018; Parsons et al., 2016; Shackelford et al., 2018; Toews et al., 2018).

In this project, we seek to fill such knowledge gaps and guide improvements in science-based management of multiple wildlife species, both inside and outside of protected areas in BC. We are developing and testing new field and analytic methods in camera trapping (aka remote camera surveys) to quantify animal responses to human activities and anthropogenic land uses at different spatial and temporal scales. Camera traps are non-invasive, cost-effective, and capable of monitoring sites for long periods of time without much maintenance (Burton et al., 2015; Wearn & Glover-Kapfer, 2017). Recent advances in these technologies have enabled researchers to begin estimating large-scale changes in wildlife communities, which will assist in the identification of biodiversity trends at regional and even global scales (Steenweg et al., 2017). Hence, the use of camera traps in wildlife research is a key focus in UBC's WildCo lab (wildlife.forestry.ubc.ca). We are using camera traps to simultaneously sample wildlife and people, as well as local environmental dynamics (e.g. plant and snow phenology). We anticipate combining these data with remotely sensed data on landscape conditions to discern the relative importance of recreational pressures on shaping mammal community dynamics within and around parks.

This overarching research project is composed of multiple sub-projects focused in and around five provincial parks in southwestern BC (Fig. 1): Cathedral Provincial Park in the Okanagan-Similkameen, Golden Ears Provincial Park near Vancouver, Joffre Lakes and Garibaldi Parks in the Sea to Sky corridor, and South Chilcotin Mountains Provincial Park near Gold Bridge. These parks span a range of environmental and climatic conditions, as well as intensities and types of human uses. The goal of the project is to provide results directly useful to management issues in these parks (e.g., mountain goat conservation in Cathedral, dog leash policies in Golden Ears, and visitor use management planning in the South Chilcotin Mountains, Garibaldi, and Joffre Lakes) while also developing generalizable methods and recommendations applicable to other key wildlife habitats in the province. In particular, the camera traps surveys in these parks comprise a key case study in the development of a western Canadian camera trap network—WildCAM (Wildlife Cameras for Adaptive Management, wildcams.ca)—which has a goal of supporting standardization, coordination, and synthesis of camera trap surveys for evidence-based wildlife management. We also note that WildCo has initiated a new collaborative project in and around Itcha-Ilgachuz Provincial Park (with BC Parks and FLNRORD Caribou Recovery program) involving deployment of 149 camera traps in October 2020 and focused on caribou conservation; this project is not included in this report.

This research is supporting training of young scientists at UBC, including parts of 3 MSc theses, 1 Master's directed study, 2 postdoc projects, and multiple undergraduate research assistantships. Specifically, surveys in Golden Ears form part of the MSc project for Michael Procko; surveys in

Cathedral are part of the MSc project for Mitch Fennell; camera trap data from South Chilcotin Mountains are being used in Chris Colton's MSc project and Cydney Swan's directed studies; postdoc Dr. Catherine Sun is leading the investigation of phenology from camera traps in these parks, and postdoc Dr. Alys Granados is leading a synthesis analysis using data from multiple parks. Data from multiple parks are also being integrated into a global analysis of wildlife responses to changes in human activity associated with the Covid-19 pandemic (led by Cole Burton and other WildCo members).

Focal Park Descriptions

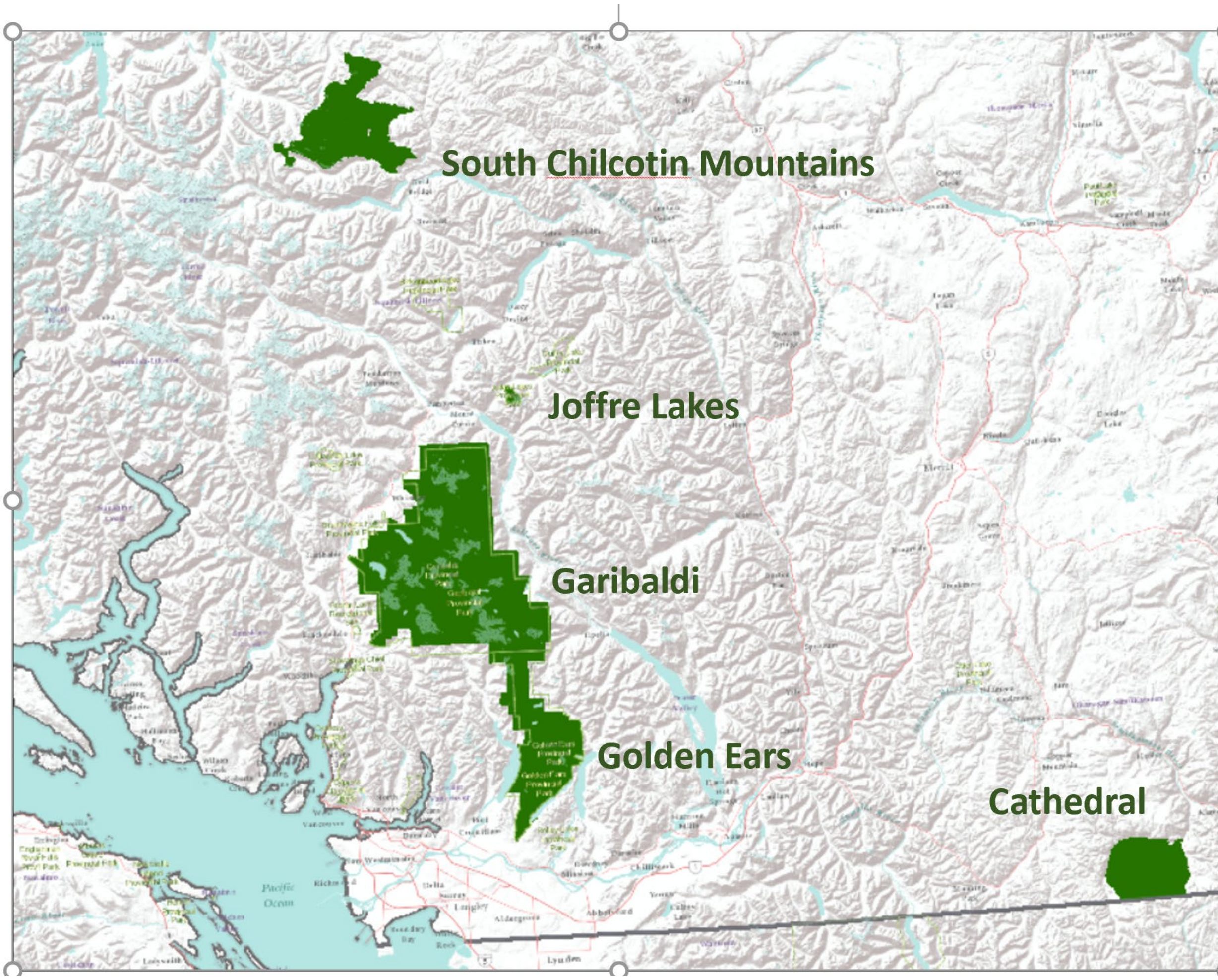


Figure 1. Location of the five focal provincial parks in which camera trap surveys are being conducted.

Cathedral Provincial Park

Cathedral Provincial Park is situated within a unique landscape in south-central British Columbia, along the Washington state border, approximately 25 kilometers southeast of the town of Princeton (Fig. 2). This park was established in 1968, and covers an area of approximately 330 km^2. Cathedral park's ecosystems represent a transition zone between the wet forests of the

Cascade Mountains and the drier Okanagan Valley. As this park spans across a large elevational gradient (ranging from river valleys to high alpine), numerous species are found spread throughout distributed habitats. Predominant tree species range from Douglas fir dominant at lower elevations, lodgepole pine and Engelmann spruce at mid-elevations, and sub-alpine fir, balsam fir, and Lyall's larch at higher elevations. Large mammal species include but are not limited to black bear (*Ursus americanus*), cougar (*Puma concolor*), mule deer (*Odocoileus hemionus*), grey wolf (*Canis lupus*), and mountain goats (*Oreamnos americanus*), the last of which the park is particularly well known for. Recreational activities within the park include hiking, horseback riding, angling, and hunting (outside of a core area). A small parcel of private land exists in the center of the park upon which a private lodge is operated, which also provides the opportunity for access via 4x4 shuttle into the core of the park, drastically easing access and increasing visitation to otherwise remote areas.

Cathedral Park was closed to visitors from April 8, 2020 until June 1, 2020 due to the COVID-19 pandemic. However, the core area of the park is snowbound until late June each year, so we anticipate that the closure had limited impact on visitor use.

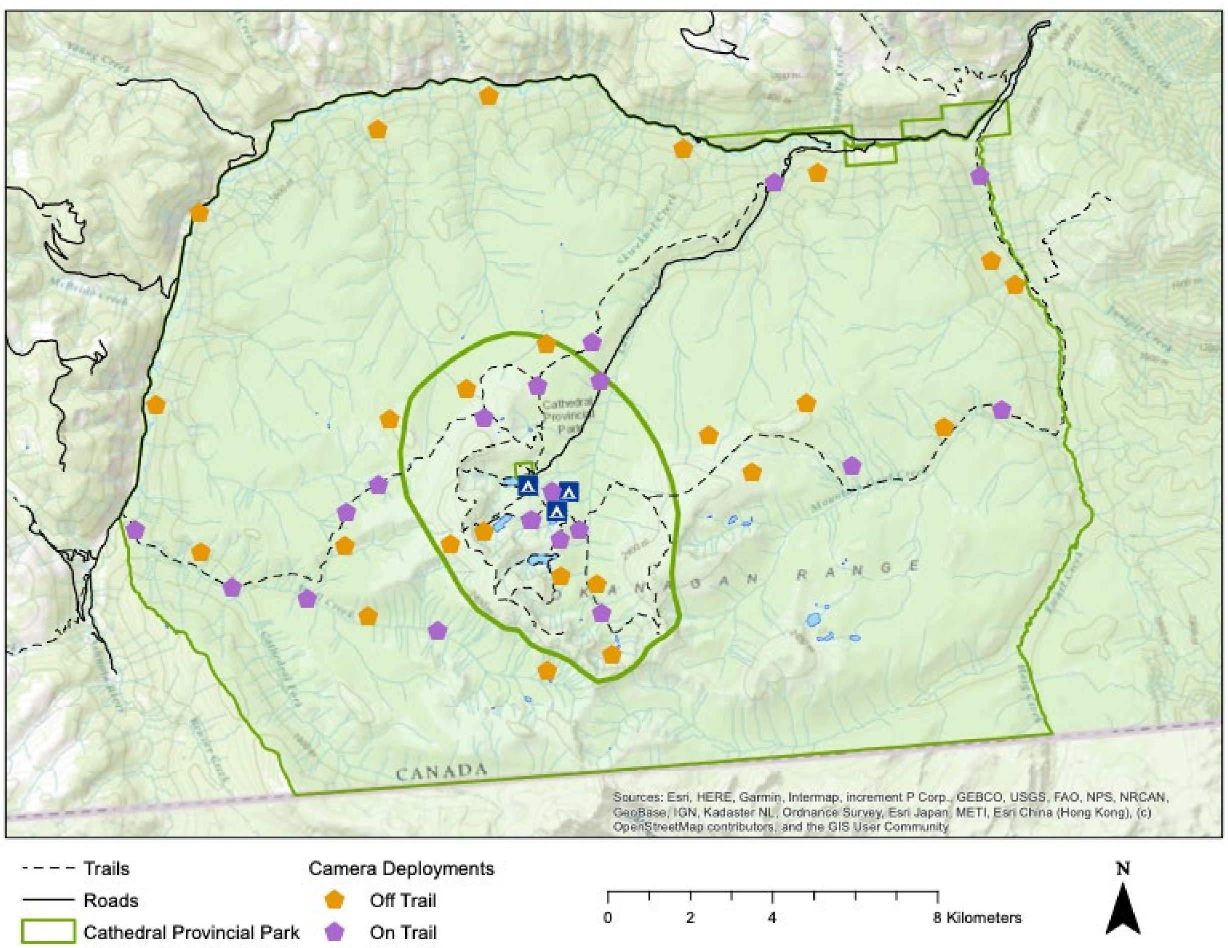


Figure 2. Locations of all camera traps deployed in Cathedral Provincial Park (n=45). Purple pentagons denote on-trail camera traps, and orange are off-trail camera traps. The outer green polygon is the park boundary, and the inner is the park core area. Solid black lines are roads, dashed lines are hiking trails.

Golden Ears Provincial Park

Located just north of the Fraser River in the district of Maple Ridge, Golden Ears Provincial Park (Figs. 1, 3) spans approximately 625 km^2 and receives nearly one million recreational visitors annually (BC Ministry of Environment, 2019). While it was originally identified in 1933 as a portion of Garibaldi Provincial Park, Golden Ears was split off as a separate class A park in 1967 in order to allow a greater degree of focus on the recreational aspects near Alouette Lake. As a class A park, Golden Ears has been named and described in Schedule C of the Protected Areas of British Columbia Act, which dedicates the land to the "preservation of natural environments for the inspiration, use, and enjoyment of the public" (BC Ministry of Environment, 2013). Golden Ears hosts a variety of recreational activities such as camping, hiking, backpacking, horseback riding, swimming, fishing and boating, and contains the largest campground in the province. The park also recently boasted the most annual campers, and the second most annual day-users of any B.C. provincial park (BC Ministry of Environment, 2019). This immense recreational activity is the main form of anthropogenic disturbance in the park, as logging operations have been prohibited throughout since 1929, rendering the park a prime example of a protected coastal forest with great levels of human visitation. The park includes BEC Zones of Coastal Western Hemlock and Mountain Hemlock and subzones of very wet maritime, moist maritime, and dry maritime.

Based on the most recent park management plan for Golden Ears, the most common mammal species in the park include black-tailed deer (*Odocoileus hemonius*), snowshoe hares (*Lepus americanus*), black bears (*Ursus americanus*), cougars (*Puma concolor*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), raccoons (*Procyon lotor*), and striped skunks (*Mephitis mephitis*) (BC Ministry of Environment, 2013). Other mammal species that may occur in the park include the blue-listed wolverine (*Gulo gulo*), blue-listed fisher (*Pekania pennanti*), possibly threatened spotted skunk (*Spilogale gracilis*), American pine marten (*Martes americana*), a reintroduced population of Roosevelt elk (*Cervus canadensis roosevelti*), the blue-listed grizzly bear (*Ursus arctos*), and gray wolf (*Canis lupus*). However, the presence of these species in the park is mostly unconfirmed due to a lack of detailed wildlife survey or monitoring.

UBC's Malcolm Knapp Research Forest (hereafter Malcolm Knapp) borders Golden Ears's southwestern park boundary and contains a similar landscape, but with various logging operations throughout the forest, providing an interesting contrast to the park landscape. Designated as a research forest reserve in 1943, the forest was established by a Crown Grant to the University of British Columbia in 1949, and serves many purposes (e.g. research, demonstration, and education) (Power and Marcoux, 2014). Throughout the forest, there is an extensive network of over 100 km of roads, and activities within the forest include timber harvesting and thinning operations, as well as replanting, hiking, and an abundance of independent research projects. Consequently, the forest hosts thousands of visitors annually. However, Malcolm Knapp is only 52 km^2—less than 10% of the size of Golden Ears park (Power and Marcoux, 2014). Still, the usage of Malcolm Knapp for recreational purposes is widespread, as the forest contains more than 30 km of trails for hiking and interpretive use.

Similarly, the logging roads can also be used for recreation, but these are often less traveled due to the frequency at which logging trucks are present. Furthermore, camping is not permitted at any time throughout the forest. Therefore, the main drivers of human disturbance in this landscape are largely related to forestry operations, with some areas also seeing moderate levels of day-use recreation. Wildlife occurring in this area is expected to be of a comparable makeup as Golden Ears, but is similarly understudied.

In the Spring of 2020, both Golden Ears and Malcolm Knapp were closed due to the COVID-19 pandemic for approximately five weeks and ten weeks respectively. Specifically, Golden Ears was closed to the public on April 8, 2020, and reopened for day-use on May 14, 2020, though camping remained prohibited within the park until June 1, 2020. Malcolm Knapp, on the other hand, was closed to the public on March 23, 2020, and reopened for day-use June 6, 2020.

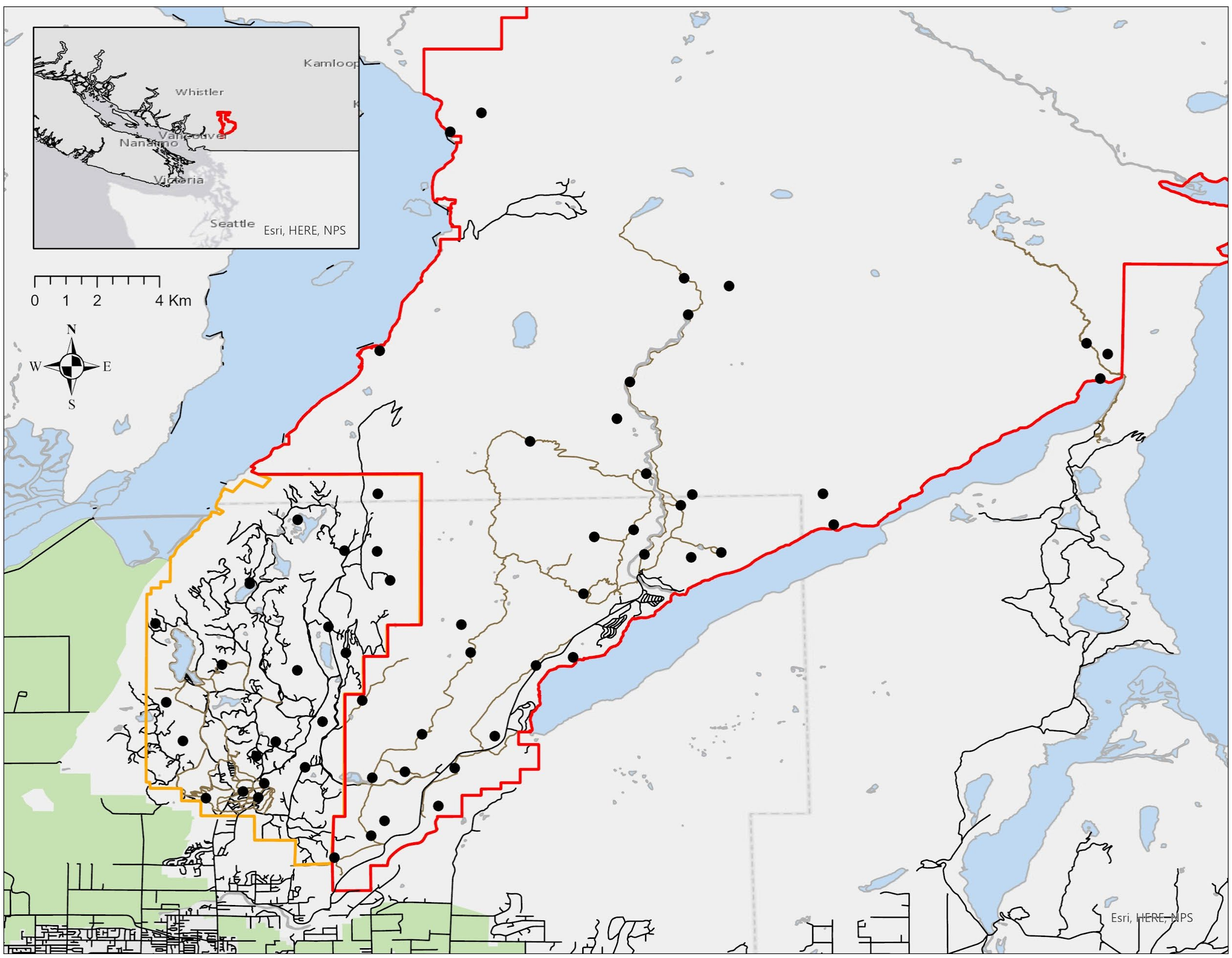


Figure 3. Golden Ears Provincial Park (red outline) and Malcolm Knapp Research Forest (orange outline) in southwestern British Columbia, Canada. Black circles represent camera trap deployment locations (both on and off of recreational trails). Black lines represent roads, brown lines represent recreational trails, green polygons represent agricultural land reserves, and blue polygons represent water bodies.

South Chilcotin Mountains Provincial Park

South Chilcotin Mountains Park (hereafter South Chilcotin or SCM) is located in southwest British Columbia, within the Thompson-Cariboo parks region (Thompson section), approximately 80 km west of Lillooet and 180 km north of Vancouver (Figs. 1, 4). The park was established in 2010 and covers approximately 568 km^2 of rolling mountains and alpine terrain, connecting with the 679 km^2 Big Creek Park (to the north) and three designated Mining and Tourism Areas (which were formerly part of the Spruce Lake Protected Area that preceded South Chilcotin park). The 2019 management plan (for South Chilcotin and Big Creek parks) highlights the importance of this park as a centre for biodiversity in the surrounding area, due to its large size, diversity of ecosystems, and predator-prey communities. Its Biogeoclimatic Ecosystem Classification (BEC) zone consists largely of drier Englemann Spruce – Subalpine Fir and variants, with some Montane Spruce, Sub-boreal Pine Spruce, and Interior Douglas-Fir variants. Key wildlife species identified include grizzly bear (the threatened South Chilcotin Ranges Population Unit), moose, bighorn sheep, mountain goat, mule deer, gray wolf, cougar, lynx, wolverine and fisher. The park management plan notes the area's internationally recognized trail system (for horseback riding, hiking and mountain biking) while emphasizing management of backcountry recreational activities to maintain the park's conservation values. In addition to the protected area, the surrounding region contains a mix of logging, mining, ranching, tourism, and private land holdings. The main drivers of anthropogenic change in the region appear to be recreation, particularly increased mountain biking and off-road vehicle use, and an increasing level of logging. Other aspects of the expanding human footprint include residential use, hydroelectric development, and mining. Taken together, the human presence in the study area is growing tremendously, and at present land-use managers lack data on how these potential stressors may be affecting wildlife.

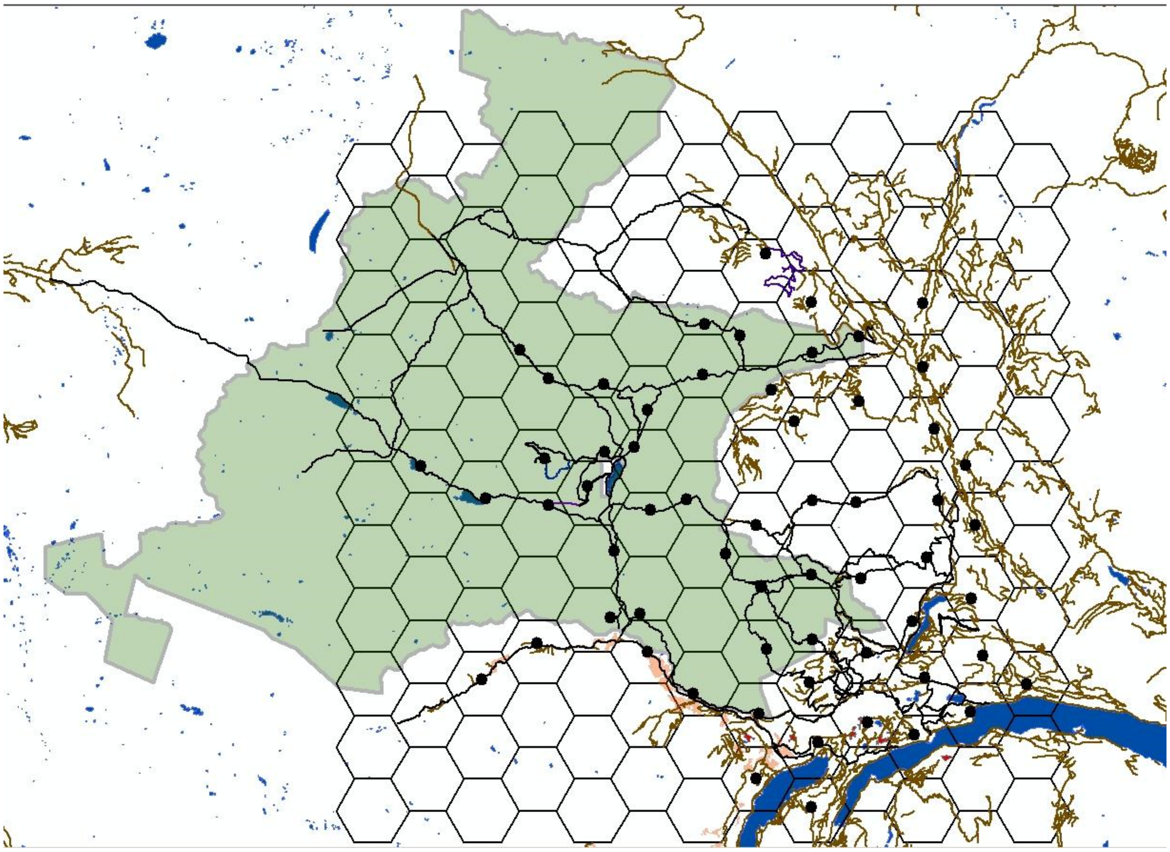


Figure 4. Sampling grid (3km wide hexagons) and camera trap locations (black points) in and adjacent to South Chilcotin Mountains Park (green shading). Roads are shown as brown lines and trails as black lines; water bodies are in blue.

Joffre Lakes Provincial Park & Garibaldi Provincial Park

Joffre Lakes Provincial Park

Joffre Lakes Provincial Park is located in the Sea to Sky corridor of southwest British Columbia about 30 km east of Pemberton, BC (Figs. 1, 5). The park was established in 1988 and covers an area of 14.6 km^2 which borders the Nlháxten/Cerise Creek Conservancy. The park contains three glacier-fed lakes which have contributed to dramatic increases in tourism in the park in the last decade, with almost 200,000 people visiting the park in 2019 (BC Parks, 2021). This increased human visitation of the park has resulted in BC Parks partnering with the Lil'wat Nation and N'Quatqua to create a Visitor Use Management Strategy which has been drafted and is currently open for public review and comment (BC Parks, 2021).

The elevational gradient in the park from coastal forest to subalpine forest to alpine provides habitat for a variety of vegetation and wildlife species. Four different biogeoclimatic (BEC) zones are represented in Joffre Lakes Park: Coastal Western Hemlock, Mountain Hemlock, Engelmann Spruce - Subalpine Fir, and Interior Mountain-heather Alpine. Mammal species of interest expected to occur in the park include mule deer, black bear, pika, and marten (BC Parks, 2021). Additionally, mountain goats, wolverine, and grizzly bears may use the park infrequently (BC Parks, 2021). Joffre Lakes park was closed to visitors on March 24, 2020 due to Covid-19 and remains closed, providing a unique opportunity to understand the impacts of visitor use on wildlife activity in the park.

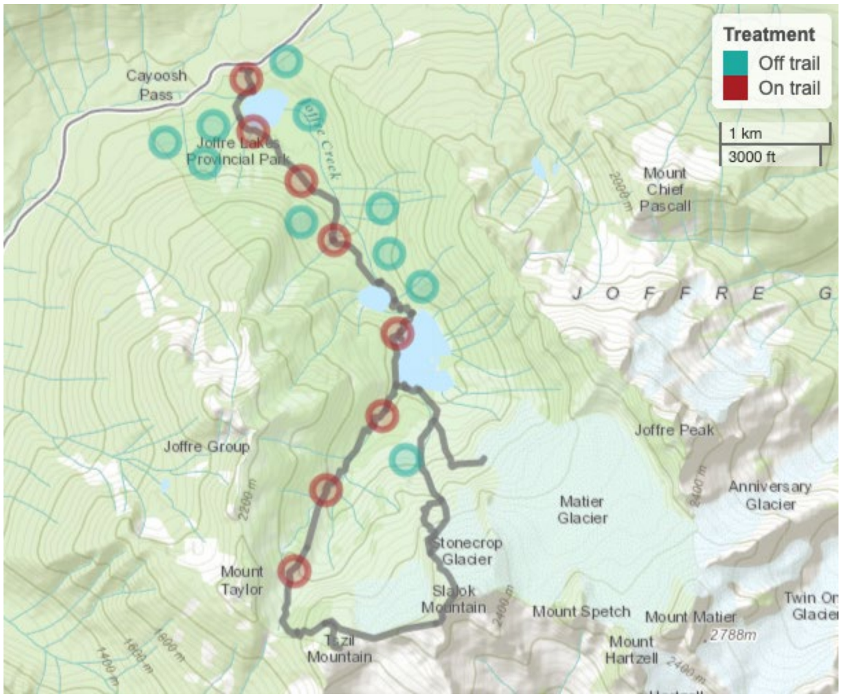


Figure 5. Camera trap locations off-trail (blue) and on-trail (red) in Joffre Lakes Provincial Park. Trails are shown in grey, roads are shown in purple.

Garibaldi Provincial Park

Garibaldi Provincial Park is also located in the Sea to Sky corridor and is situated between Squamish and Whistler, approximately 70 km north of Vancouver (Figs. 1, 6). The park was established in 1927 and covers an area of about 1950 km^2 including over 90 km of hiking trails and 10 campgrounds. Due to its vast hiking and backcountry recreation opportunities and proximity to Vancouver, Garibaldi Park has high human visitation rates year round.

Similar to Joffre Lakes, the elevational gradient present in Garibaldi provides a diversity of habitats for low-elevation, subalpine, and alpine species. Garibaldi Park contains three different BEC zones: Coastal Western Hemlock, Subalpine Mountain Hemlock, and the Alpine Tundra. Key wildlife species in the park include mule deer, mountain goats, black and grizzly bears, cougars, and wolverine (BC Parks, 1990).

Garibaldi Park was closed to visitors on April 8, 2020 due to Covid-19, then was reopened with reduced capacity using a day-pass system on July 27, 2020. Day-use passes were no longer required after October 13, 2020 due to a seasonal decrease in park visitors. For this study, we focused on the portion of the park from Rubble Creek trailhead to Taylor Meadows and

Garibaldi Lake; this portion receives very high visitor use and provides an interesting comparison with Joffre Lakes park.

Figure 6. Camera trap locations off-trail (blue) and on-trail (red) in the Rubble Creek - Taylor Meadows - Garibaldi Lake section of Garibaldi Provincial Park. Trails are shown in grey.

Methods

Camera Trap Deployments

The use of camera traps (CTs) in wildlife research is increasing rapidly due to several advantages of the method, including its non-invasive and cost-effective nature and ability to sample a wide range of species continuously for long periods of time without requiring direct observation (Burton et al., 2015; Caravaggi et al., 2017; Meek et al., 2014; Wearn & Glover-Kapfer, 2019). CT data can be used to make inferences on animal occurrence, distribution, habitat use, abundance, behaviour, reproduction and health. In contrast to hair-snagging or radio telemetry, CTs are also capable of directly measuring human activity. CTs can also collect data on phenological patterns via timelapse photos, which can be set to capture images at regular intervals over long periods (see phenology section below). Given the range of information that can be collected using CTs, and their potential as a cost-effective remote monitoring method, we are testing their utility for assessing wildlife responses to human activities and other environmental changes in the focal landscapes.

There are several different factors to consider when deploying CTs, including the characteristics of target species, CT make/model/settings, set-up protocols, and environmental context (Burton et al. 2015; Hofmeester et al., 2019; Miller et al., 2017). WildCo surveys use Reconyx Hyperfire 2 (HP2X) models, as Reconyx has been the industry leader for reliable, research-quality camera traps, and our experience has consistently shown less expensive models to be less dependable (see also Newey et al. 2015), although we note there may be certain advantages to some other models (e.g. higher image/video quality). To facilitate standardization of data collection, as part of our work with the WildCAM network we have developed a protocol for setting up camera traps. This guide is posted on the WildCAM website for anyone to download (www.wildcams.ca/protocols). Also included are datasheets for data collection during camera trap deployment and retrieval.

Our general protocol involves setting a CT approximately 0.5-1 m above ground level on a tree located approximately 3-5 m from the anticipated point of detection, perpendicular to the expected direction of travel. Although some studies have concluded that the optimal degree of orientation for maintaining the highest probability of detection for people on trails is around 20˚ from the direction of the trail (see Miller et al., 2017), our cameras were set at 90˚ (perpendicular with the trail) to prevent an excessive number of human captures and to prioritize wildlife captures and be consistent with our previous wildlife surveys. Wearn & Glover-Kapfer (2017) suggested that a perpendicular orientation to the animal's expected path of travel is appropriate as it maximizes the side-to-side motion registered by the sensor, which should maximize detection probability. Our cameras were set to record one picture for every motion trigger event, with no delay period between subsequent triggers, and to record 1 timelapse photo every day at 12:00 pm (noon) to record camera functionality and allow analysis of site phenology (see below).

We used slightly different approaches to sampling design in each of the parks, reflecting individual sampling priorities within the parks as well as preferences of the respective project leaders. Specific features of the CT sampling designs and deployments for each park are described below. We note that effective sampling design is a key topic in camera trap research, and part of our overall effort is to evaluate and ensure compatibility among surveys across parks, and to develop recommendations for future CT surveys in parks.

Cathedral Provincial Park

We deployed 45 Reconyx camera traps throughout Cathedral Provincial Park beginning in early July 2019, with final deployments completed in July 2020 (Fig. 2). The main objectives of our Cathedral park survey include a) informing a framework for inventory and monitoring of the medium- and large-bodied terrestrial mammal community, b) assessing interactions between human use of the park and wildlife habitat use, and c) supporting more detailed investigation of mountain goat population dynamics (including predation risk), since they are a key species of management concern in the park. To develop a sampling design suitable to these interlaced objectives, we delineated the core area of the park, which receives the most recreational use, using GIS layers provided by BC Parks (K. Baric and K. Safford). We aimed to deploy a roughly even number of CTs inside and outside of the core area, in order to provide a general contrast between areas with higher and lower recreational pressure, as well as an overall sample representative of the broader park and its habitat heterogeneity (rather than a focus only on the higher elevation core area). To select specific locations for CT deployments (hereafter "sites"), we first created on- and off-trail sampling strata. We delineated all official trails or roads within the park in GIS, and generated a set of random points on these features (n=19 on-trail CT sites, n=2 on-road CT sites, representing roughly half of the total sites, and approximately evenly split between the core and non-core areas). For the off-trail comparison, we generated a similar number (n=24) of random off-trail points, each a minimum of 350 m from the nearest trail, and again split between the core and non-core areas of the park.

CTs were placed as close as possible to the random point as identified by field teams using handheld GPS units, travelling on foot. Once within the immediate vicinity (~100m) of each random point, camera sets were chosen using the judgement of field team members to maximize the probability of detecting wildlife (e.g., game trails or other features facilitating animal movement past the camera detection zone). On human-use trails, we attempted to set cameras in less conspicuous areas to minimize detection by hikers, without compromising the camera detection zone for both animals and people. Site data were collected at each CT deployment, including variables such as camera height and orientation, distance to targeted hiking or game trail, forest type, and any notable terrain or landscape features. We attempted to keep variation in such site details minimal across CT deployments, but by recording these metadata we can examine their potential influence on detection probability.

A relatively understudied population of mountain goats occurs in Cathedral park, commonly overlapping with areas of high human use in the core zone. Concerns raised by managers for this population include impacts of increasing human recreation, such as increases in conflict or stress, which could affect population demography and viability for this small, isolated population that may also be impacted by climate change (C. Mclean, M. Percy and K. Safford, pers.comm.). A GPS collar study of this mountain goat population is currently occurring within Cathedral park (L. Balyx and A. Ford, UBC Okanagan, in prep.). Our CT surveys should provide additional information on this population; for instance, using unique markers (numbered cattle tags) affixed to mountain goats during the collaring process, we expect to be able to conduct spatial capture-recapture analyses (e.g. spatial mark-resight models) to provide an estimate of population density (Augustine et al., 2018; Burgar et al., 2019; Burgar et al., 2018; Sun et al., 2017). Through this population estimate, as well as additional CT information such as kid/nanny ratios (recruitment) and spatiotemporal overlap between people and goats, and predators and goats, we expect that our project will provide substantial information to park managers and collaborators to support management of this unique population of interest.

Golden Ears Provincial Park

In Golden Ears (and Malcolm Knapp), our goal is to sample across gradients in expected human recreational activity (i.e. trail use). We deployed a stratified random CT grid both on and off trails and roads to monitor medium- and large-bodied mammals, hikers, mountain bikers, horseback riders, domesticated dogs, and vehicles. Strata used in the determination of our sampling locations in Golden Ears included high human use trails, low human use trails, and off-trail, with trail use designations based on local knowledge and expert opinion of park managers (Senior Ranger, S. Stickney), since the park does not currently have an empirical system for monitoring trail use. To determine sampling locations in Golden Ears, we generated three sets of random points: one set of ten points along high-use trails, one set of ten points along low-use trails, and one set of twenty points outside a 250m buffer of all trails in the area. We used a buffer of 250m due to difficulty accessing off-trail locations further than this distance in the steep park terrain. In Malcolm Knapp, two strata of fifteen points each were used: on-trail (or road) and off-trail, with the latter similarly restricted outside a buffer zone of 250m from all trails and roads.

The full resulting grid of random points provided seventy (70) locations of varying levels of human influence at which to deploy a CT. We then navigated as close as the landscape would permit to each of these points and attached a Reconyx Hyperfire Pro 2 (Reconyx, Holmen, WI, USA) camera to a nearby tree, facing the trail or road at a 90 degree angle. For off-trail locations, cameras were pointed towards the nearest “game trail” that could be located in the area (i.e. signs of recent or potential animal travel). Of the original 70 points, 12 were inaccessible due to terrain, and therefore did not receive a CT deployment. The resulting CT array consisted of n=58 cameras, 20 of which were on-trail in Golden Ears, 17 were off-trail in Golden Ears, 13 were along trails or roads in Malcolm Knapp, and 8 were off-trail in Malcom Knapp.

Cameras were deployed at or below 1 m in height to maximize detection probability of medium- and large-bodied wildlife species, while simultaneously restricting the amount of identifiable human features that would be captured in photos, as was requested in prior consultation regarding the protection of public privacy. At each camera location, we recorded the camera height, distance to intended path of target (for on-trail locations, the center of the trail; for off-trail locations, the center of the nearest “game trail”), and the cardinal direction of the camera’s orientation. The distance from each camera lens to the nearest permanent obstacle (i.e. dense vegetation, rock wall) was also measured to provide an account of the approximate detection zone of each camera. These variables were all considered in subsequent statistical modeling. Most cameras were initially deployed in May-August 2019 (with the exception of 4 opportunistic deployments set up on trails in Malcolm Knapp in March 2019) and have been active for at least one year, with SD cards being collected most recently in August-September 2020.

South Chilcotin Mountains Provincial Park

The camera trap survey in SCM is led by Dr. Robin Naidoo (WWF-US and UBC), with support from UBC’s WildCo lab through this project. Results from the first summer of camera trapping (May-August 2018) have been described in a manuscript published in 2020 (Naidoo and Burton 2020).

Sixty-one Browning StrikeForce Pro HD camera traps (www.browning.com) were deployed in May 2018 using a systematic sampling design (hexagonal grid) to space cameras at ~3 km intervals across approximately 600 km^2 of the park and adjacent unprotected land (Fig. 4). Since a key focus of the SCM survey is to assess human-wildlife interactions in and around the park, cameras were deployed along trails and logging roads where interactions were expected to occur (an extension to include additional off-trail cameras in SCM is being considered, pending additional funding). Guided by provincial databases on the locations of logging roads and other linear infrastructure (https://www2.gov.bc.ca/gov/content/data/geographic-data-services/topographic-data/roads), as well as maps of the multi-use trail network (https://www.trailforks.com/region/south-chilcotin-mountains-provincial-park), one camera trap was placed at the location on the trail or road closest to the grid cell centre. Budgetary constraints restricted the total number of cameras (n=61), and some cells within the study area did not have any logging roads or multi-use trails within them. As a result, 11 of 71 total grid cells within the study area did not have a camera. In summer 2020, an additional 4 cameras were placed at new stations along trails further in the park, increasing the spatial coverage and the total sample size to 65 camera stations.

At each site, camera traps were positioned on a tree about 1 m above trail level, a height that allowed a wide range of terrestrial wildlife to be detected. Trail width, distance to trail, and camera height were recorded at each site for inclusion in subsequent statistical modelling. Most cameras were deployed in late May or early June (when high elevation terrain started to become snow-free). Cameras have been left active continuously since initial deployment in spring 2018, with checks to retrieve SD cards and replace batteries before snowfall in 2018, and again in spring and late summer 2019. During 2019, it was determined that some of the Browning cameras were failing; therefore, we replaced 20 of them with higher quality Reconyx HF2X camera traps. In 2020, we replaced all remaining Browning cameras with Reconyx models, thanks to the generous support of BC Parks. We also retained Browning cameras at 10 stations, thereby providing a means to directly compare species and human detection rates of the two camera types.

Joffre Lakes Provincial Park & Garibaldi Provincial Park

Restrictions on recreational activities in provincial parks due to the COVID-19 pandemic have provided a unique opportunity to assess wildlife responses to park visitation. To capitalize on this opportunity, we deployed 39 Reconyx HP2X camera traps in Garibaldi (21 cameras from the Rubble Creek trailhead to Garibaldi Lake area) and Joffre Lakes (18 cameras) provincial parks from August 3-6, 2020 (one Garibaldi camera was deployed on on October 5, 2020). The goal of this project is to compare wildlife use on- vs. off-trail sites and across a gradient of human use within and between parks.

In both parks, we deployed cameras on recreational trails to monitor both human and wildlife use of trails. We also deployed a set of off-trail cameras at least 250 m away from recreational trails, in order to assess wildlife activity further from human activity (all camera stations were at least 250 m from neighbouring stations). Camera locations were selected from a randomly generated set of potential on- or off-trail points (if a random off-trail point could not be accessed, the next random point was selected or a camera was set at the nearest accessible location). In Joffre Lakes, 10 cameras were deployed off-trail and 8 were on-trail (Fig. 5). In Garibaldi, 9 cameras were deployed on-trail and 12 were placed off-trail (Fig. 6). Cameras spanned a gradient of elevation and expected human activity in both parks.

Data Processing

Camera traps were revisited during summer and fall 2020 to retrieve images on the SD cards. A copy of images was archived and then images were processed to identify animal species and human activities, following standards being developed by the WildCo lab. To protect the privacy of people photographed on cameras, all identifiable images of humans were processed through a facial redaction (blurring) application. For the Cathedral, Golden Ears, Garibaldi and Joffre Lakes surveys, images were uploaded to the custom WildCo camera trap database, where they are stored securely on cloud servers within Canada (Fig. 7). This relational database provides an efficient system for storage and processing of hierarchically structured CT data, including project-level, site-level (i.e. camera deployment), and image-level data. Images of animals were identified for species, sex, age, behaviour, and number of individuals. For images containing humans, the number of individuals and type of recreational activity was recorded. Domestic dogs were also counted and classified as either on- or off-leash. We defined independent events for each species as those occurring more than five minutes after the last image of the same species. Thresholds for defining independent detections vary in the literature (e.g. Burton et al. 2015), but we have conducted preliminary sensitivity analyses that suggest that detection rate indices are not very sensitive to variations in these thresholds across a range from 5-60 minutes. We have developed WildCo metadata standards for camera trap studies that follow recently developed provincial and global standards (BC Resource Information Standards Committee 2019; Forrester et al. 2016; wildlifeinsights.org). Dr. Chris Beirne in the WildCo lab developed R scripts for standard summary analyses of camera trap data stored in our standardized formats. These standards and tools were shared with other researchers and practitioners in a October 2020 webinar led by Dr. Beirne organized by the Columbia Mountains Institute for Applied Ecology (CMIAE) and facilitated by WildCAM. Over the coming year we will explore additional avenues in which to continue developing and sharing these useful tools.

For Joffre Lakes and Garibaldi, human detections at on-trail sites were classified using a machine learning algorithm (MegaDetector, developed by Microsoft AI for Earth; Beery et al., 2019) in conjunction with the WildCo database. MegaDetector automatically detects four classes within CT images: animals, humans, vehicles, and blanks. While trained human processors are able to classify 300-500 images per hour, MegaDetector is able to process an average of 10,080 images per hour on a high powered desktop. For sites which experience exceptional levels of human use, and thus capture a large number of human images, this 95% increase in processing efficiency drastically increases our ability to provide timely results. Prior to implementing this procedure, sensitivity analyses were conducted on approximately 165,000 images from Cathedral Park, with resulting accuracy above 95% for identification of human images (Fennell, Beirne & Burton, in prep). In order to confirm accuracy for these parks, all human images were visually inspected against MegaDetector classifications prior to analysis. Data were then separated into independent events using thresholds as described above.

Data processing for the SCM project preceded development of the WildCo tools and followed a different procedure for 2018 and 2019. We used the Camelot software package (Hendry & Mann, 2017) to identify to species all pictures containing wildlife observations, including mammals, birds, and amphibians. We also counted the number of individuals of each species in each picture and recorded the number and type of human activities detected by cameras (assigning each to one of 4 categories: hikers, horseback riders, mountain bikers, or motorized vehicles). The time threshold for defining independent detections for SCM analyses (described below) was set at 20 minutes. In 2020 we migrated all SCM imagery processing and storage to the WildCo database as described above.

Since WWF is a partner in the Wildlife Insights project (wildlifeinsights.org), Dr. Naidoo with Master's student Cydney Swan is also investigating the potential of that platform to provide computer-generated identifications for camera trap images via their custom Artificial Intelligence algorithms. Our assessment at this time remains in progress, given that WI is still under development, but pending our results, this could prove a viable, time-saving option for future seasons. The WildCo lab is also evaluating the WildTrax image processing platform (www.wildtrax.ca).

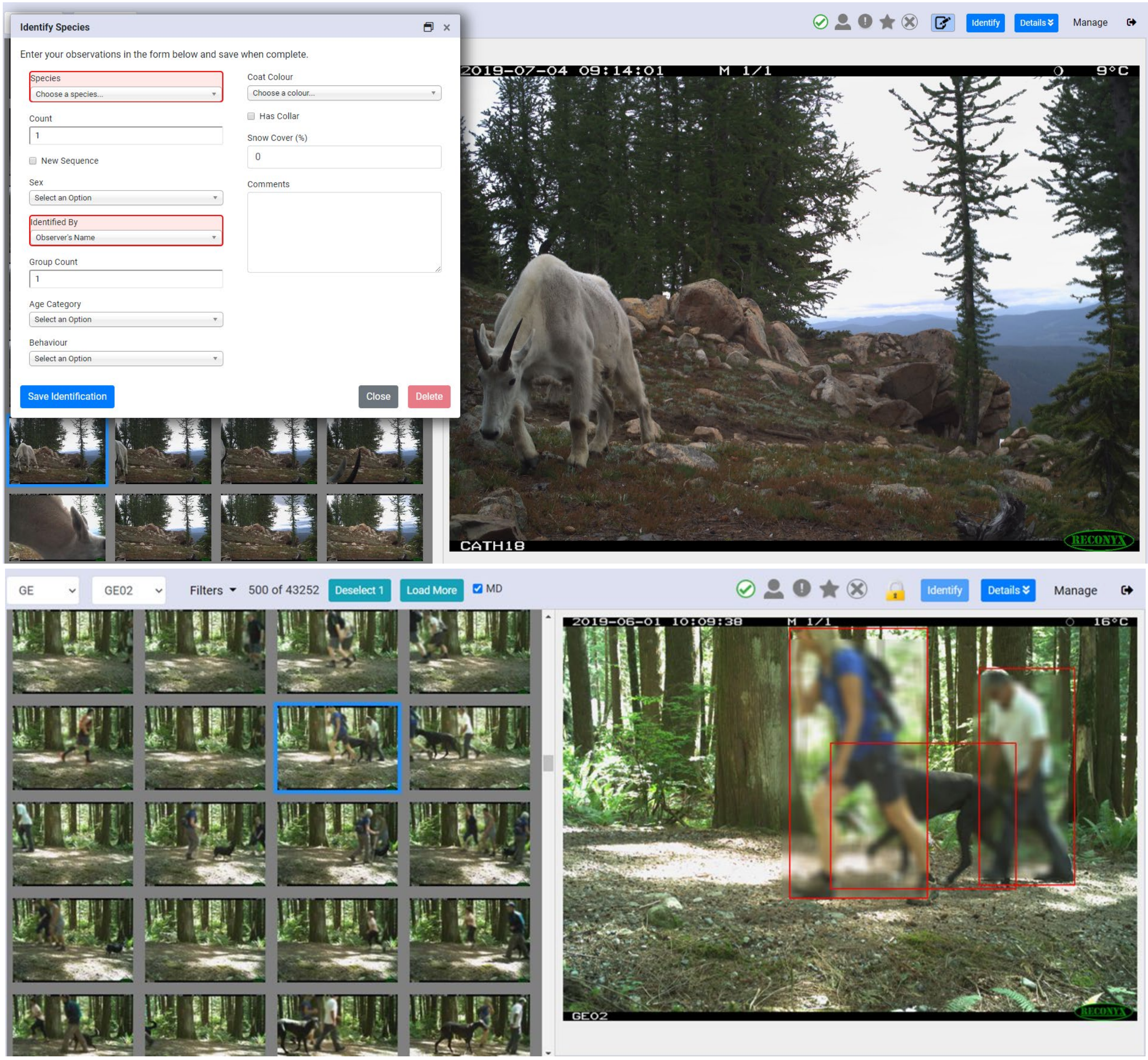


Figure 7. Screenshots of the image identification interface within the custom camera trap data management system developed for the Wildlife Coexistence Lab at UBC. The bottom image highlights the AI tools to automatically distinguish and blur images of humans.

Statistical Analyses

Each project is pursuing related but complementary statistical analyses designed to meet project-specific objectives.

Cathedral Provincial Park

We evaluated variation in wildlife habitat use within a Bayesian regression modelling framework for seven focal species: moose (*Alces alces*), coyote (*Canis latrans*), Canada lynx (*Lynx canadensis*), mule deer (*Odocoileus hemionus*), mountain goat (*Oreamnos americanus*), cougar

(*Puma concolor*), and black bear (*Ursus americanus*). Once images are classified, the number of independent detections for each of our focal species per week at each site is summed, serving as an index of habitat use through both space and time. This relatively fine-scale of observation permits evaluation of temporal trends within and across sites, while reducing the abundance of zeros present in even finer-scale temporal units (e.g. daily detections) (Naidoo & Burton, 2020). This is particularly relevant considering the large seasonal changes in human recreation in Cathedral park when access is limited by snow from October to June.

To test the hypothesis that human recreation is a major determinant of wildlife habitat use, we derived indices of human use to provide a direct signal of recreational pressure, calculated as the number of independent human events (defined by a five-minute independence threshold) per active week at each camera site. We also accounted for other variables expected to influence animal occurrence and detection at camera sites. Environmental variables include the distance from camera sites to trails or roads (as an alternative, less direct measure of human disturbance), elevation, terrain ruggedness (vector ruggedness measure, see Sappington et al., 2007), percent open habitat within 500m of the site, and vegetation productivity indices extracted from satellite imagery, which we hope to additionally supplement with CT derived indices in the future (see phenology section)(Table 1). We included camera height as a variable to account for potential variation in detectability of animals passing in front of each camera, particularly smaller animals (although we expected this influence to be minimal, given our standardized set protocol). We included the camera site as a random effect to account for nonindependence among repeated observations at the same site, as well as a lag covariate to account for potential temporal autocorrelation, which represents whether a given species was detected at the same site in the previous week (Naidoo & Burton, 2020). All non-binary independent variables were standardized and centered to allow direct comparison of the direction and magnitude of effects on species use of habitat (Gelman, 2008). We interpreted parameter estimates as being statistically significant when Bayesian 95% credible intervals did not overlap zero. Models were run in R v4.0.2 (R Core Team, 2020), via the package BRMS (Bürkner, 2017), using 5000 iterations, with the first 2500 discarded as burn-in.

We plan to further investigate the temporal aspects of wildlife habitat use in the park using Avoidance-Attraction Ratios (AAR's; see SCM section below and Parsons et al., 2016; Naidoo & Burton, 2020). Specific questions and hypotheses are still being developed around investigating temporal shifts in habitat use at different scales within Cathedral Park, with analyses slated to begin in Spring 2021.

An additional analysis with the Cathedral data will be an estimation of population density for mountain goats, using the mark-recapture data from collared and tagged goats (as noted above). This method uses CT detections of collared goats, along with unmarked goats, to provide an estimate of population density within the sampled area (Augustine et al., 2018; Burgar et al., 2018; Royle et al., 2014). This method is dependent on capturing enough images of marked individuals; initial capture rates based on the CT data collected to date suggest we will have sufficient data to generate robust estimates. To further increase the precision of density estimates we have added data from seven additional camera traps in the park, operated by Kirk Safford (BC Parks Conservation Specialist). Once completed, these will be the first rigorous density estimates for this population of management interest. Additionally, our data on the distribution of goat predators (e.g. wolf, coyote, lynx) will inform the goat telemetry project being led by Dr. Adam Ford (UBC-Okanagan, with MSc student Laura Balyx) in collaboration with BC Parks and the BC Ministry of FLNRORD.

Table 1. Independent (predictor) variables used in hierarchical Bayesian regression models of weekly detections of seven wildlife species across 45 camera trap sites sampled from July 2019 to October 2020 in the Cathedral Provincial Park.

Variable	Description	Category
Elevation[1]	Elevation at site (m)	Environmental
VRM[1]	Topographic ruggedness within 90m of the camera (level of topographic heterogeneity)	Environmental
$Open_{500}$[2]	% of non-forested habitat within a 500m radius of the camera	Environmental
$NDVI_{sat}$[3]	Normalized difference vegetation index – from MODIS imagery (500m productivity)	Environmental
Humans	# of human detection events per week at each camera site	Human use
Distance to linear[4]	Distance from camera to nearest trail or road (m)	Human use
Camera height	Height of camera above trail/ground surface (m)	Detectability
Lag detection	Was the same species detected at this site in the previous week? (1/0)	Temporal Autocorrelation

[1] Source: Digital Elevation Model – Province of British Columbia
[2] Source: Data Management and Access - Province of British Columbia
[3] Source: MODIS Satellite Product VNP13A1
[4] Source: OpenStreetMap Contributors

Golden Ears Provincial Park

As noted above, analysis for Golden Ears will focus on assessing the impacts to wildlife of recreational activity, while also considering habitat variation and the effects of forest harvest activity in the adjacent Malcolm Knapp. MSc student Michael Procko has checked all 58 cameras at least once, with the last checks in August-September 2020. These data will form the basis of his MSc thesis. Camera traps have been left active in Golden Ears and Malcolm Knapp to extend sampling through another summer affected by Covid-19 influences on park use. Camera retrieval is currently planned for late summer or fall 2021.

Analyses to date for the Golden Ears data have employed a Bayesian generalized linear regression framework to model a binary response of a species being detected (1) or not detected (0) at a given camera station during a particular week (hereafter “site-week”), as a function of the recreational activity, plus additional environmental and landscape-level variation across site-weeks (Naidoo & Burton 2020). We quantified the CT detection rate for humans as a measure of recreational trail use (e.g., Kays et al., 2017). Specifically, we counted the total number of independent camera detections of park visitors per unit of time (e.g. day, week, month), as well as the specific activities each visitor was taking part in (e.g. hiking, horseback riding). Additional explanatory variables in these models included forest structure metrics such as stand height, seasonal vegetation “green-up” (i.e. NDVI), proximity metrics to various resources such as water bodies and agricultural lands in the nearby Maple Ridge, as well as landscape topography, and variables specific to how the camera was positioned (Table 2). All numerical predictor variables were scaled to compare relative effects, and all human-related measures were log-transformed to account for some sites seeing disproportionately greater levels of activity. This analysis was performed for species that meet three criteria: (1) mammalian species with greater than 30 independent detections, that were (2) detected at approximately 50% or more of all camera stations, and (3) whose probability of detection is expected to be similar across all camera stations, based on both locomotion strategy (i.e. focusing on strictly terrestrial species, as opposed to semi-arboreal, as in Douglas squirrel, *Tamisciurus douglasii*) and body size (i.e. ignoring species smaller than snowshoe hares, *Lepus americanus*).

We also propose to perform an analysis to account for mammalian temporal responses to recreation, in which activity times of focal species will be calculated using the same protocol as Nickel et al. (2020), wherein “time since noon” of detections is used to measure the degree of nocturnality in animal activity. By taking the absolute value of this measure, we can observe which portions of the day (e.g. dawn, dusk, night) these species are most commonly detected and whether or not they are shifting their behaviours in response to increasing human disturbance, as has been noted in other areas (e.g. Gaynor et al. 2018). However, this work is still under development, with preliminary results anticipated in the summer of 2021.

Table 2. Independent (predictor) variables used in Bayesian generalized regression models of weekly detections of 6 wildlife species across 58 camera trap sites sampled from May 2019-September 2020 in Golden Ears and Malcolm Knapp.

Variable	Description	Category
hikers	# hikers detected in a week at site	Human-use
mountain bikers	# mountain bikers detected in a week at site	Human-use
horseback riders	# horseback riders detected in a week at site	Human-use
motorized vehicles	# motorized vehicles detected in a week at site	Human-use
crown closure[1]	% crown closure at site	Habitat
stand height[1]	projected height (m) of forest at site	Habitat
NDVI[2]	normalized difference vegetation index in a week at site	Habitat
distance to water[3]	distance to the nearest stream, river, or lake from site (m)	Resources
distance to agriculture	distance to the nearest plot of agriculture (m)	Resources
elevation[4]	elevation at site (m)	Topography

slope[4]	slope at site (degrees)	Topography
on/off-trail	binary indication of whether site was on or off-trail or road	Camera set
camera height	height (m) the camera was position at each site	Camera set
distance to target	the distance from the camera lens to the anticipated path of the target (the centre of the trail/road or nearest game trail) (m)	Camera set

[1] Source: Data Management and Access - Province of British Columbia
[2] Source: MODIS Satellite Product VNP13A1
[3] Source: Freshwater Atlas – Province of British Columbia
[4] Source: Digital Elevation Model – Province of British Columbia

South Chilcotin Mountains Provincial Park

Data from the first four months of sampling in SCM (May-August 2018) have been published in *Conservation Science and Practice* (Naidoo & Burton 2020), and we refer readers to that article for full details (open access: https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/csp2.271). Data collected subsequent to that period, i.e., from September 2018 to September 2020, have been processed by Dr. Naidoo and assistants, but not yet analyzed in detail. A forthcoming and separate report on the relationship of human recreation with grizzly bear detections will delve into further detail on the latest SCM data.

Naidoo & Burton (2020) focused inferences on the 13 species of wildlife with at least 30 independent detections, and used Bayesian regression models to quantify the impacts of recreational activities relative to environmental conditions on wildlife at the weekly scale (Table 3). They also tested whether recreational activities caused finer-scale temporal displacement of wildlife from trails using "Avoidance-Attraction Ratios" (AAR; Parsons et al., 2016).

Table 3. Independent (predictor) variables used in hierarchical Bayesian regression models of weekly detections of 13 wildlife species across 61 camera trap sites sampled from May-August 2018 in the South Chilcotin mountains (modified from Naidoo & Burton 2020).

Variable	Description	Category
road length[1]	Length of roads in cell (km)	Environment (cell)
harvested area[2]	% of grid cell harvested for timber	Environment (cell)
biomass[2]	Average biomass of forest stands in cell (Mg/ha)	Environment (cell)
open[2]	% grid cell in non-forested habitat	Environment (cell)
elevation	Elevation at site (m)	Environment (site)
forested	Whether site is in forest (1/0)	Environment (site)
trail width	Width of trail that site is at (m)	Detectability
distance to trail	Distance to centre of trail from camera (m)	Detectability
camera height	Height of camera from bottom of tree (m)	Detectability
mountain bikers	# mountain bikers detected in a week at site	Human trail-use
hikers	# hikers detected in a week at site	Human trail-use
horseback riders	# horseback riders detected in a week at site	Human trail-use
motorized vehicles	# motorized vehicles detected in a week at site	Human trail-use
lag detection	Species detected at site in previous week (1/0)	Temporal autocorrelation

[1] Source: Digital Road Atlas - Province of British Columbia
[2] Source: Data Management and Access - Province of British Columbia

In addition to the SCM camera trap study, Dr. Naidoo and WWF-US have undertaken a concurrent e-DNA study to compare the effectiveness of this method and camera trapping for detecting the occurrence and relative abundance of mammals within the study area. DNA samples in water were collected from aquatic sources (e.g. streams, rivers) during 2018 and 2019, and processed in a genetic analysis lab. The results of this comparison have been submitted for publication and are currently in review at *Scientific Reports*.

Finally, for grizzly bears, we are exploring the utility of machine learning techniques for helping with the identification of individual grizzly bears (e.g. BearID, Clapham et al. 2020). We will use the individual identities to extend our spatial capture-recapture modelling of grizzly bear density in the South Chilcotins region.

Joffre Lakes Provincial Park & Garibaldi Provincial Park

Due to the early stage of the Joffre and Garibaldi camera trapping project, analysis of the preliminary data from Joffre Lakes and Garibaldi is limited to standard summary analyses using the WildCo Lab R script (development of which has been led by postdoc Chris Beirne). This script provides summaries of camera activity through time, number of raw and independent detections of species detected in each project, and a breakdown of sex, age, behaviour, and group size of animal species detected.

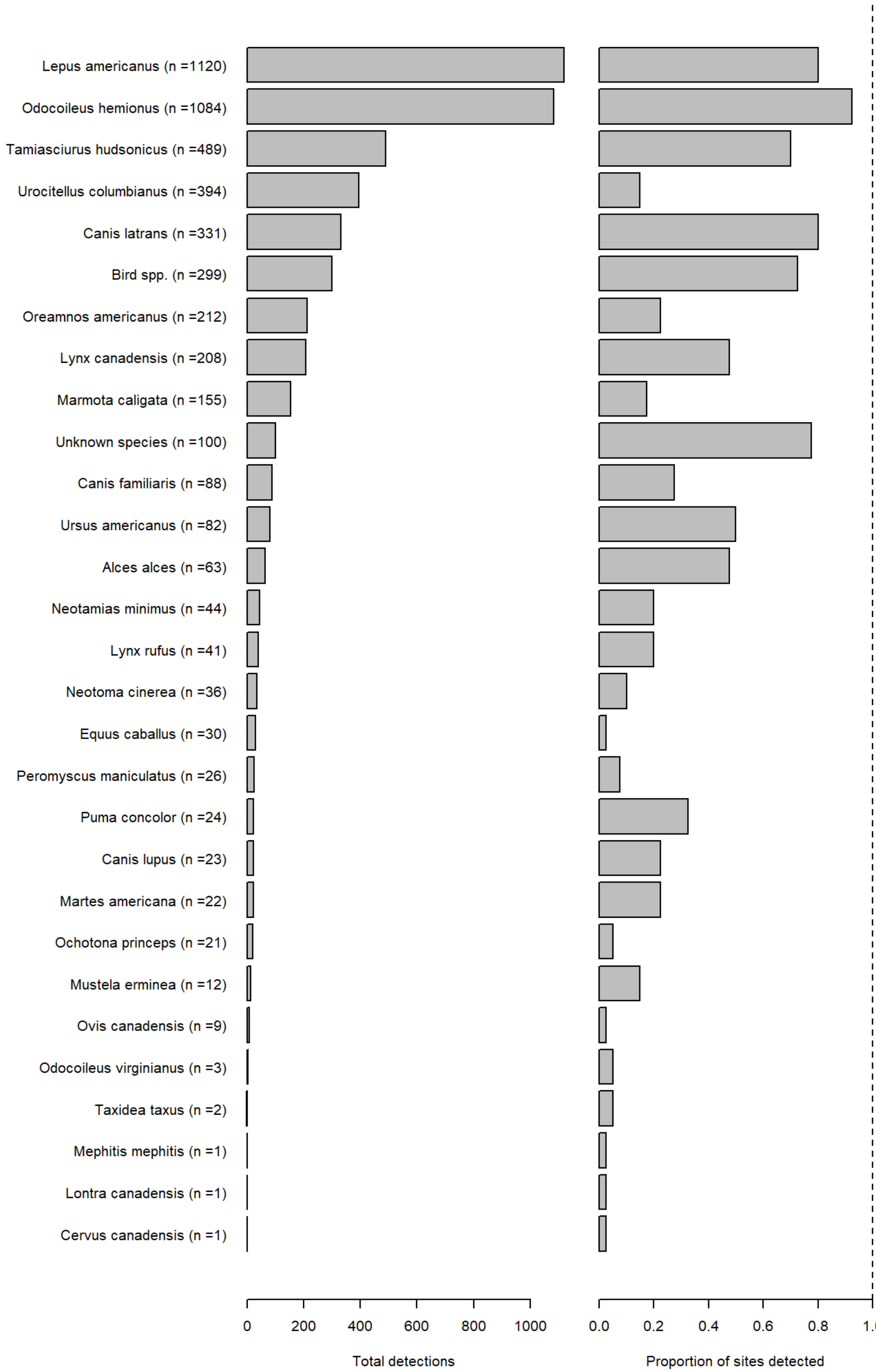
Preliminary Results

Cathedral Provincial Park

During summer 2020 we checked and serviced all 40 camera traps previously deployed in Cathedral park, with the majority of the core area cameras serviced at least twice between June and October. Camera trap (CT) data collected so far covered 17,869 trap-days of sampling effort (mean of 345 active days per CT). From this sample we collected 186,764 images, all of which have been classified following the protocol described above. Five additional CT stations were deployed in 2020, for data will be collected in 2021.

We have identified 29 different species at these 40 cameras, ranging from marten (*Martes americana*) to moose (*Alces alces*) to wolf (*Canis lupus*). Humans are by far the most commonly detected species across this CT sample, with over 13,000 independent detections of humans when using an independence threshold of 5 minutes. After humans, the next most detected species were mule deer (*Odocoileus hemionus*) and two smaller mammals: red squirrel (*Tamiasciurus hudsonicus*) and snowshoe hare (*Lepus americanus*). Each of these species was detected at over half of the CT sites (Fig. 8). In comparison to the data from summer 2019, human use of the park increased in summer 2020 (Fig. 9), which is consistent with anecdotal reports of increased park visitation during the Covid-19 pandemic (after park closures).

Preliminary outputs from Bayesian regression models for our seven focal species (Fig. 10) indicate some positive associations between wildlife occurrence and human recreational activity at the weekly scale. Specifically, our modelling to date showed an increased likelihood of occurrence for mule deer and mountain goats in site-weeks with more human detections, and a decreased likelihood of occurrence for mountain goats, lynx, cougars, and coyotes further from roads or hiking trails. Other variables were also associated with wildlife activity. Increasing terrain ruggedness was negatively correlated with mule deer occurrence, and positively correlated with mountain goat occurrence. Higher vegetation productivity increased the likelihood of occurrence within a site-week for all focal species except cougars and moose. Elevation had a positive relationship with mountain goat and lynx occurrence, and a negative relationship with black bear occurrence. Black bears were the only species for which camera height was a significant predictor, showing a positive correlation between camera height and occurrence (or detectability). Increasingly open habitat within a 500m radius of a site was significantly negatively correlated with cougar occurrence. The lag covariate representing temporal autocorrelation was significantly positive for mule deer, black bears, cougars, and coyotes. No predictors were statistically significant for moose.



Lepus americanus (n =1120)
Odocoileus hemionus (n =1084)
Tamiasciurus hudsonicus (n =489)
Urocitellus columbianus (n =394)
Canis latrans (n =331)
Bird spp. (n =299)
Oreamnos americanus (n =212)
Lynx canadensis (n =208)
Marmota caligata (n =155)
Unknown species (n =100)
Canis familiaris (n =88)
Ursus americanus (n =82)
Alces alces (n =63)
Neotamias minimus (n =44)
Lynx rufus (n =41)
Neotoma cinerea (n =36)
Equus caballus (n =30)
Peromyscus maniculatus (n =26)
Puma concolor (n =24)
Canis lupus (n =23)
Martes americana (n =22)
Ochotona princeps (n =21)
Mustela erminea (n =12)
Ovis canadensis (n =9)
Odocoileus virginianus (n =3)
Taxidea taxus (n =2)
Mephitis mephitis (n =1)
Lontra canadensis (n =1)
Cervus canadensis (n =1)
0
200
400
600
800
1000
Total detections
0.0
0.2
0.4
0.6
0.8
1.0
Proportion of sites detected

Figure 8. [*previous page*] Independent camera trap detections per species, with human detections excluded, in Cathedral Provincial Park, from 40 camera traps representing 17,869 trap-days of sampling between July 2019 and October 2020. Independent events were derived using a threshold of five minutes between events (left). The proportion of total sites where each species has been detected (right).

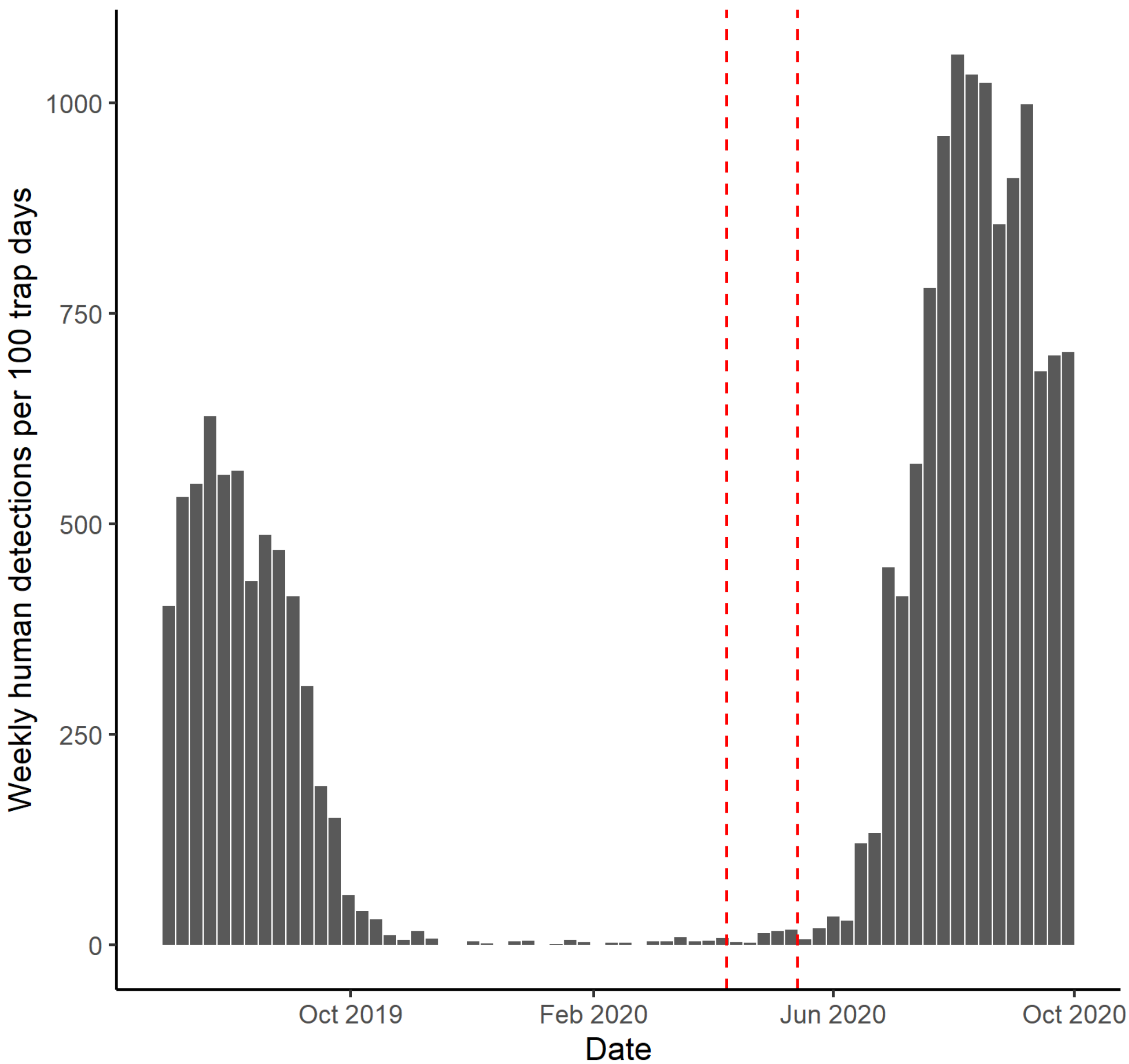


Figure 9. Weekly independent detections through time of humans (all activities) per 100 active trap days, at an independence threshold of five minutes, restricted to only on-trail camera locations within Cathedral Provincial Park. The space between the red lines denotes weeks where the park was closed due to the COVID-19 pandemic.

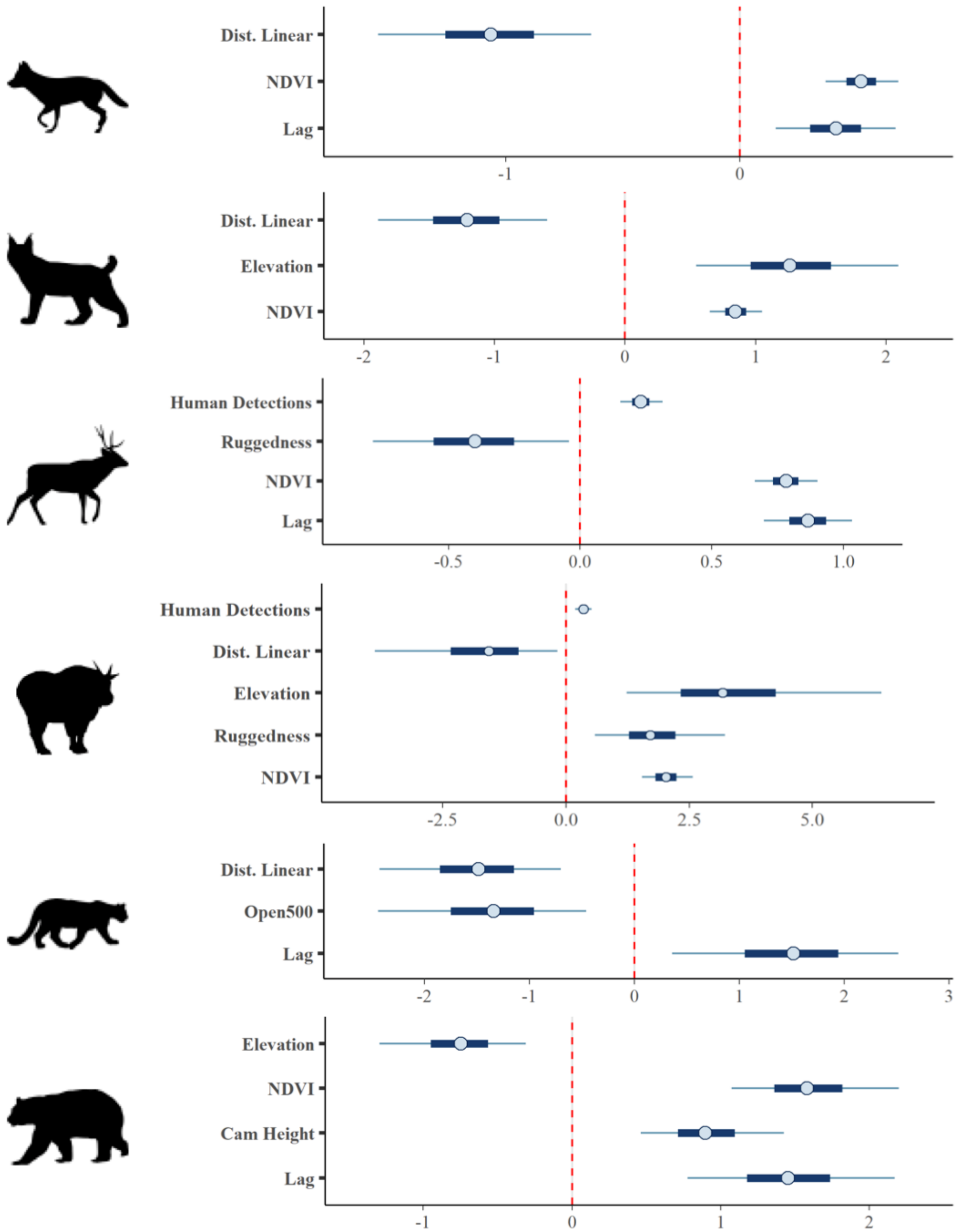


Figure 10. Significant parameter estimates of preliminary Bayesian regression models to explain weekly variation in wildlife occurrences at camera stations in Cathedral park, for six of our seven focal species (from top to bottom: coyote (*Canis latrans*), Canada lynx (*Lynx canadensis*), mule deer (*Odocoileus hemionus*), mountain goat (*Oreamnos americanus*), cougar (*Puma concolor*) and black bear (*Ursus americanus)*). No covariates were statistically significant for moose (*Alces alces*), so they are not displayed here. Positive relationships show the 95% credible interval (CI) bar on the right side of the red dashed line at 0 (no effect), while negative relationships show 95% CI bars on the left side of this line. Note the different scales for model parameter estimates across species.

Formal analyses have not yet been conducted for the mountain goat density estimates described above. However, we have summarized the recaptures of both collared and un-collared mountain goats which will be used to parameterize models beginning in Spring 2021 (Table 4).

Table 4. Mountain goat (*Oreamnos americanus*) detections from 47 camera traps in Cathedral Provincial Park from July 2019 to October 2020. Detections are summarized by the number of collared males, collared females, Juveniles, sub-adults, and unmarked adults detected. Independent events are defined as separated by an independence threshold of five minutes. Independent events for the collared classes contained at least one collared individual. The number of individual goat detections is the sum of the group counts across independent events within each class.

Class	Number of independent detection events	Number of individual goat detections
Collared Male	13	13
Collared Female	151	165
Unmarked Male	152	165
Unmarked Female	77	186
Sub-Adult	84	113
Juvenile	145	188

Golden Ears Provincial Park

From the 58 cameras deployed within both Golden Ears and Malcolm Knapp, we have collected and classified 1,059,703 images. These processed images come from 23,928 camera-trap-days of sampling effort, in which 23 species were identified (Fig. 11). However, as with Cathedral park, humans were detected much more frequently than wildlife, with over 96,000 independent detections (at a threshold of 5 minutes). Broken down into independent detection events of specific activity types, we identified 93,913 hiker events, 617 mountain biker events, 884 horseback rider events, and 1,037 vehicle events, with nearly all of the vehicles being identified at our cameras in Malcolm Knapp. At the scale of weekly detections, there appears to be some seasonal variation in human activity (Fig. 12), while the daily scale reveals interesting fine-scale fluctuations that are likely driven by higher activity on weekends (Fig. 13). Park closures as a result of the COVID-19 pandemic were also noted to be highly effective, as close to zero park visitors were identified during these times, aside from park staff or researchers checking the cameras. Although we did have some issue with park visitors vandalizing cameras near the southern end of the park during the closure (trails near the horse corral), which may have resulted in some illegal park use not being documented during this time.

Six focal wildlife species met our criteria for statistical modeling, including black-tailed deer (*Odocoileus hemionus*), coyote (*Canis latrans*), black bear (*Ursus americanus*), snowshoe hare (*Lepus americanus*), bobcat (*Lynx rufus*), and cougar (*Puma concolor*). Beyond these six, additional notable species detected include the possibly threatened spotted skunk (*Spilogale gracilis*) and reintroduced elk (Roosevelt subspecies; *Cervus elaphus roosevelti*).

Preliminary results of our Bayesian generalized linear regressions for each of the six focal species (Fig. 14) suggest some significant associations between wildlife occurrences and human activity. Specifically, model results to date have shown a lower probability of detecting cougars and black-tailed deer at site-weeks with a higher number of hiker detections, a lower probability of detecting snowshoe hares at site-weeks with a higher number of mountain bikers, a higher probability of detecting bobcats at site-weeks with a higher number of horseback riders, and a lower probability of detecting black bears at site-weeks with a higher number of vehicles. There were significantly more detections of carnivore species at on-trail cameras than off trail. The distance to the nearest plot of agriculture was also a significant factor for five of the six species (all except cougar). Nevertheless, these results are only preliminary explorations and further analysis is ongoing.

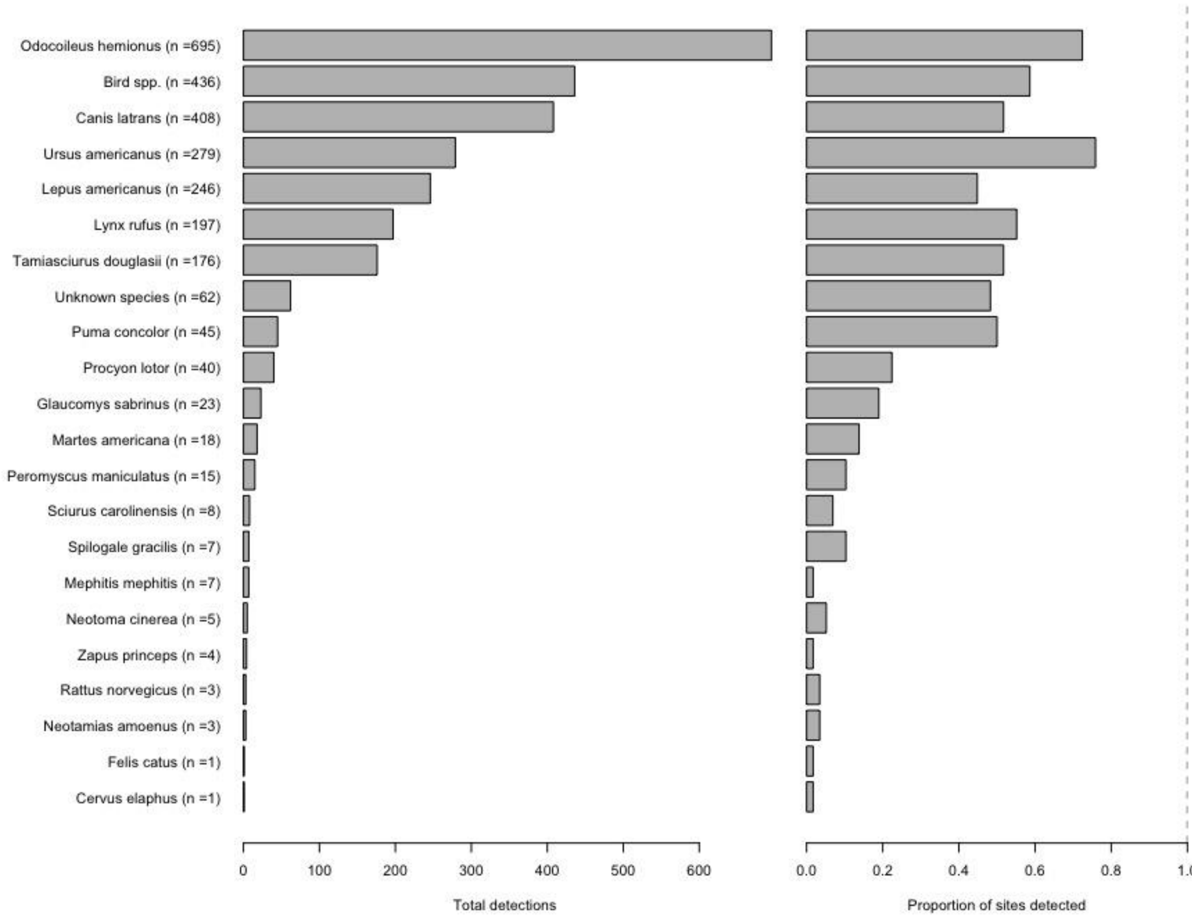


Figure 11. Independent camera trap detections (left) and proportion of sites with detections (right) for wildlife species in Golden Ears Provincial Park and Malcolm Knapp Research Forest, based on 23,928 trap-days of sampling effort across 58 locations between March 2019-September 2020.

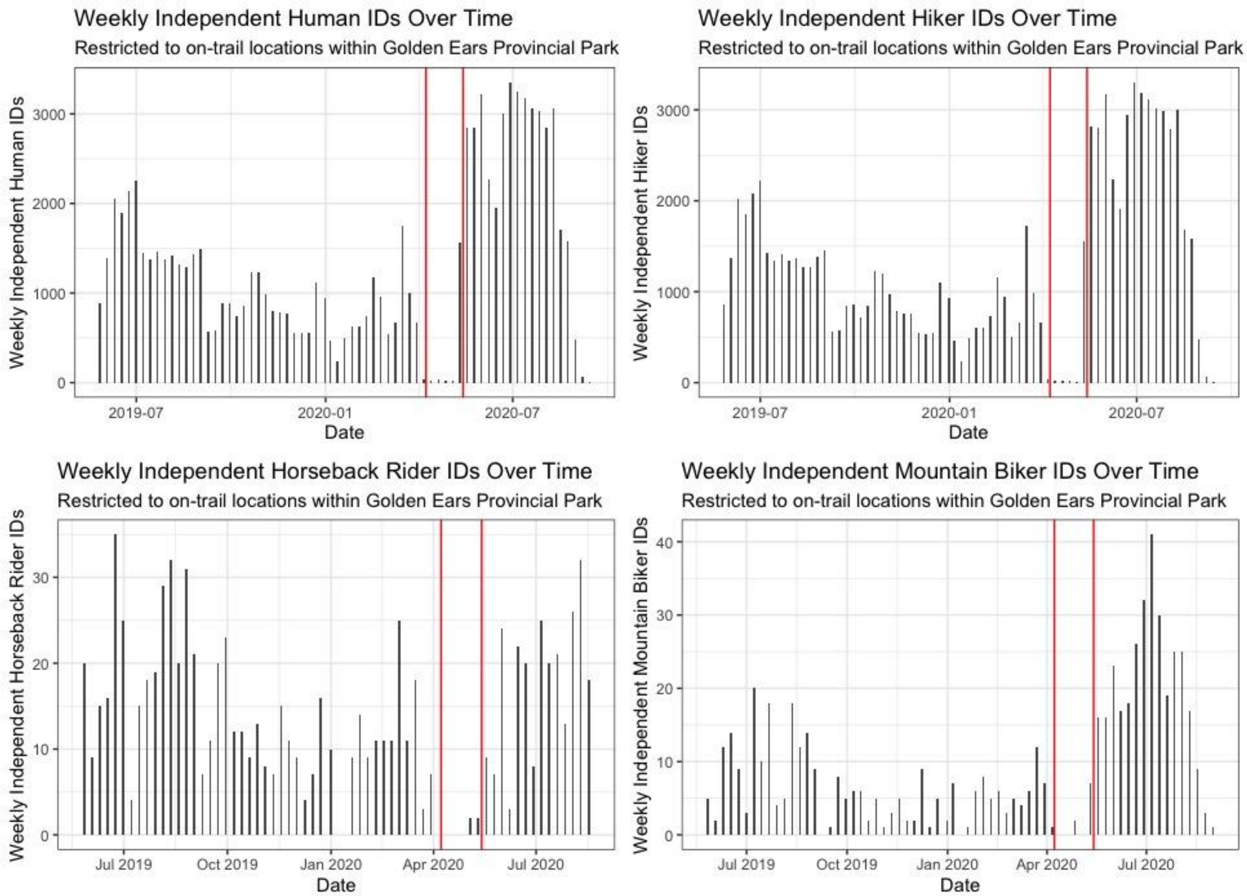


Figure 12. Weekly independent detections throughout time of humans (all activities), hikers, horseback riders, and mountain bikers at an independence threshold of five minutes, restricted to only on-trail camera locations within Golden Ears. The space between the red lines denotes weeks where the park was closed due to the COVID-19 pandemic. Note that "weeks" here begin on a Monday, so the park closing on Wednesday, April 8th, 2020, and reopening on Thursday, May 14th, 2020 results in the weeks adjacent to the closure appearing to have visitors. These are not necessarily indicative of park closure violations. Additionally, these plots are not corrected for sampling effort, which varied slightly over time.

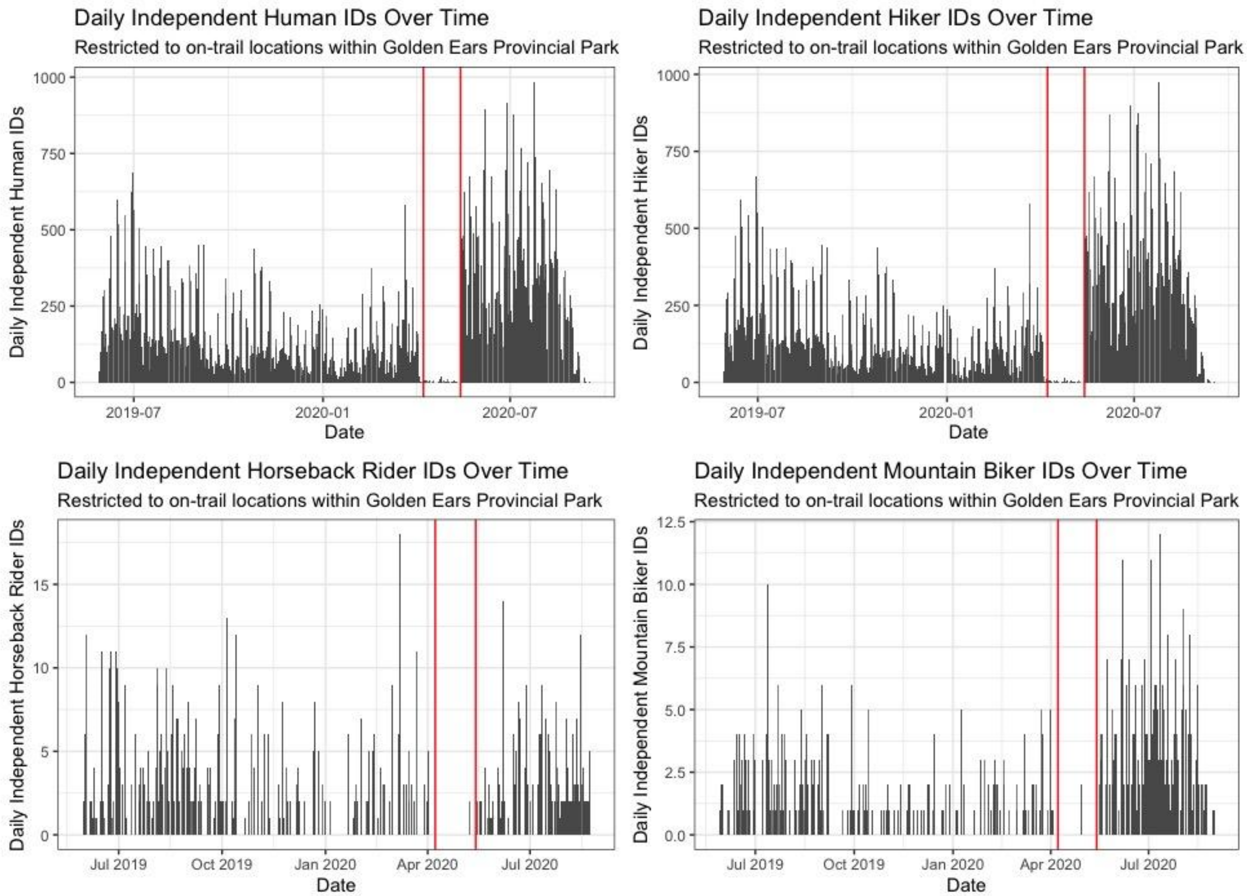


Figure 13. Daily independent detections throughout time of humans (all activities), hikers, horseback riders, and mountain bikers at an independence threshold of five minutes, restricted to only on-trail camera locations within Golden Ears. The space between the red lines denotes weeks where the park was closed due to the COVID-19 pandemic. Note that fine-scale fluctuations are evident here, which were not present in the weekly plots, indicating a “weekend effect” where park visitation is sometimes double or triple on weekends what it is during the week. As before, these plots are not corrected for sampling effort, so should be considered preliminary.

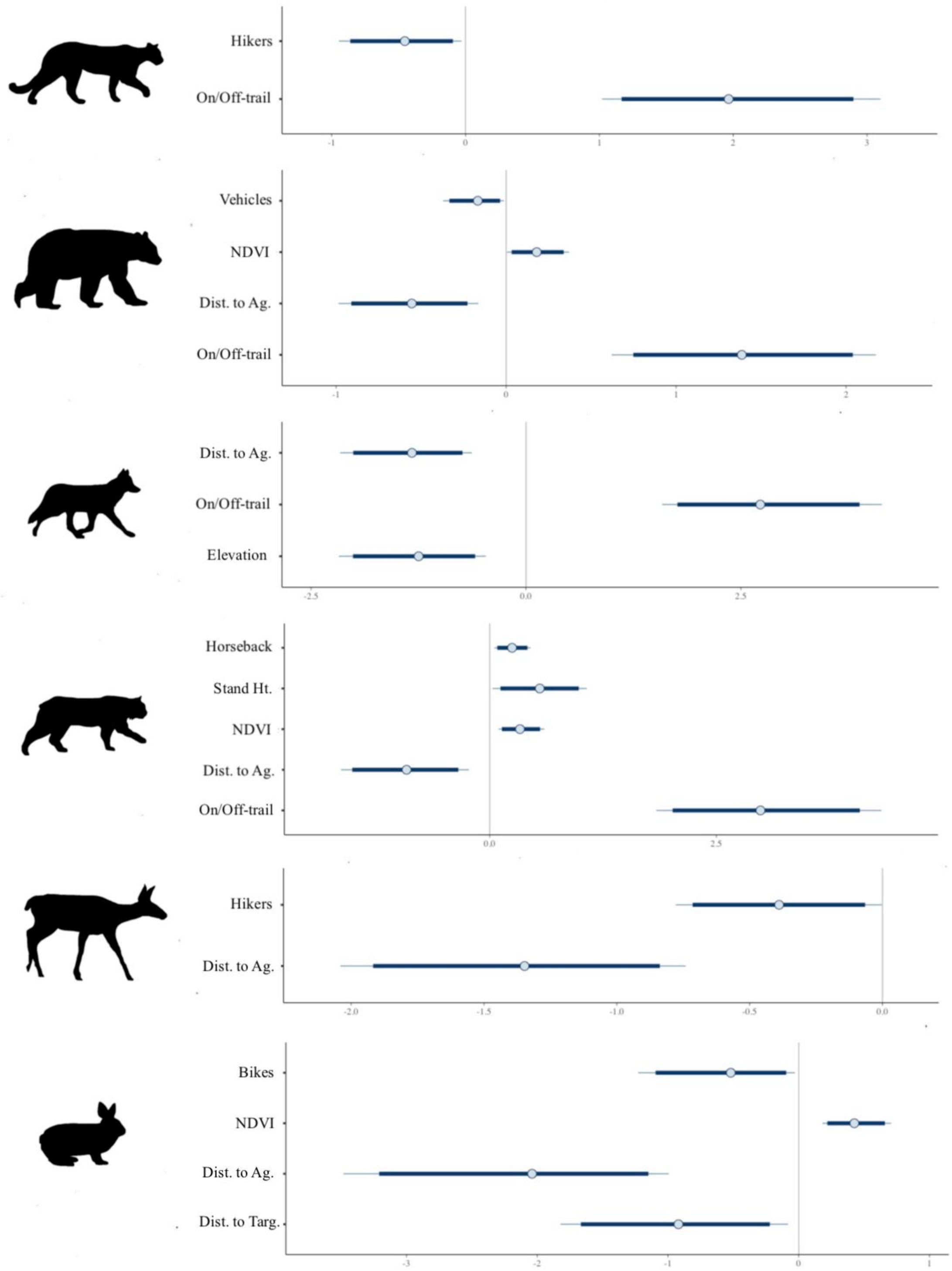


Figure 14. Significant parameter estimates from preliminary Bayesian regression models for camera trap detections (at the weekly scale) of the six focal species (from top to bottom: mountain lion (*Puma concolor*), black bear (*Ursus americanus*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), black-tailed deer (*Odocoileus hemionus*), and snowshoe hare (*Lepus americanus*)). Positive associations between wildlife occurrences and a given variable have the 95% CI bar on the right side of the dashed line at 0, while negative relationships have the CI on the left side of this line. Note that these results are subject to change pending model refinement.

South Chilcotin Mountains Provincial Park

For the sampling period covering May 2018 - September 2020, our grid of 64 motion-triggered cameras captured a wide array of species detections: 32 mammal, 32 bird, and 1 amphibian species. The most frequently detected mammal was mule deer (11,688 independent detections), while the least-frequently-detected mammal was striped skunk (n=1). Mule deer were detected at all sites, making them the most widely distributed wildlife species (Fig. 16).

Human recreational activities were also detected frequently by the camera traps. Mountain biking was the most commonly-recorded recreational human activity, with over twice as many independent detections (11,972) as hikers (Fig. 15). Hikers and mountain bikers had a greater number of independent detections than any mammal species other than mule deer.

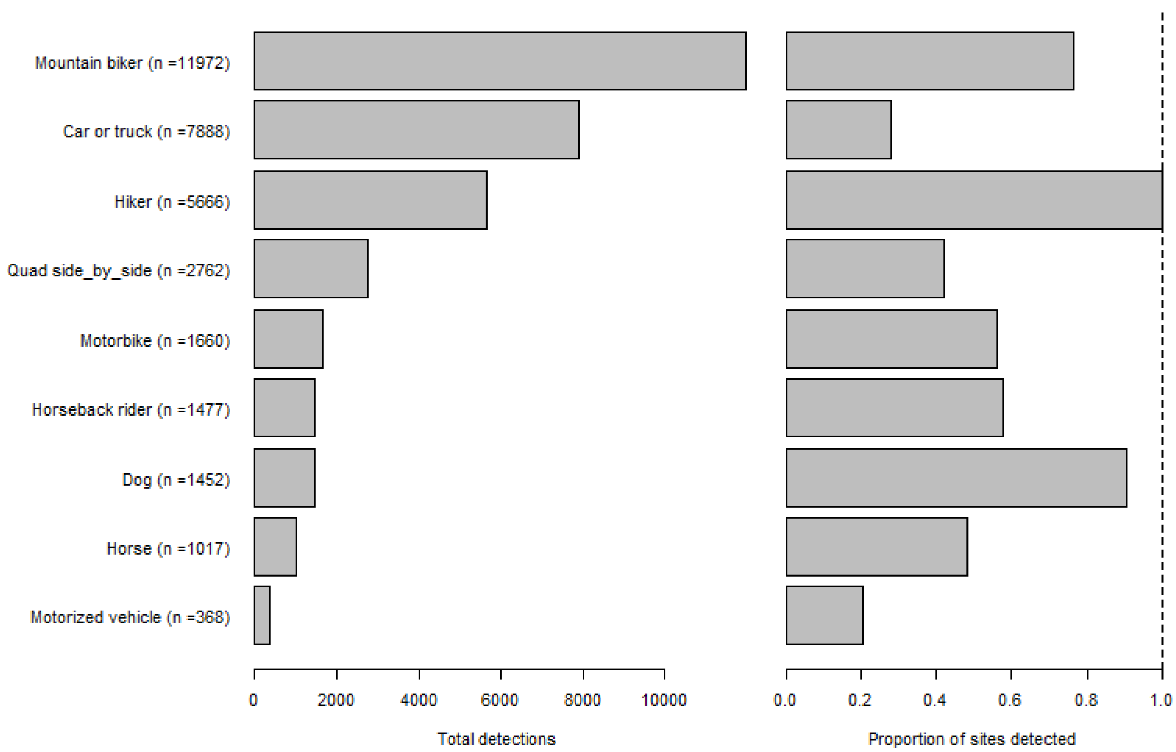


Figure 15. Independent human (and dog) detections in the South Chilcotin Mountains study area, representing 64 cameras operating from May 2018 to September 2020. An independence threshold of ten minutes between events was used. The proportion of total sites where each human activity has been detected is shown on the right.

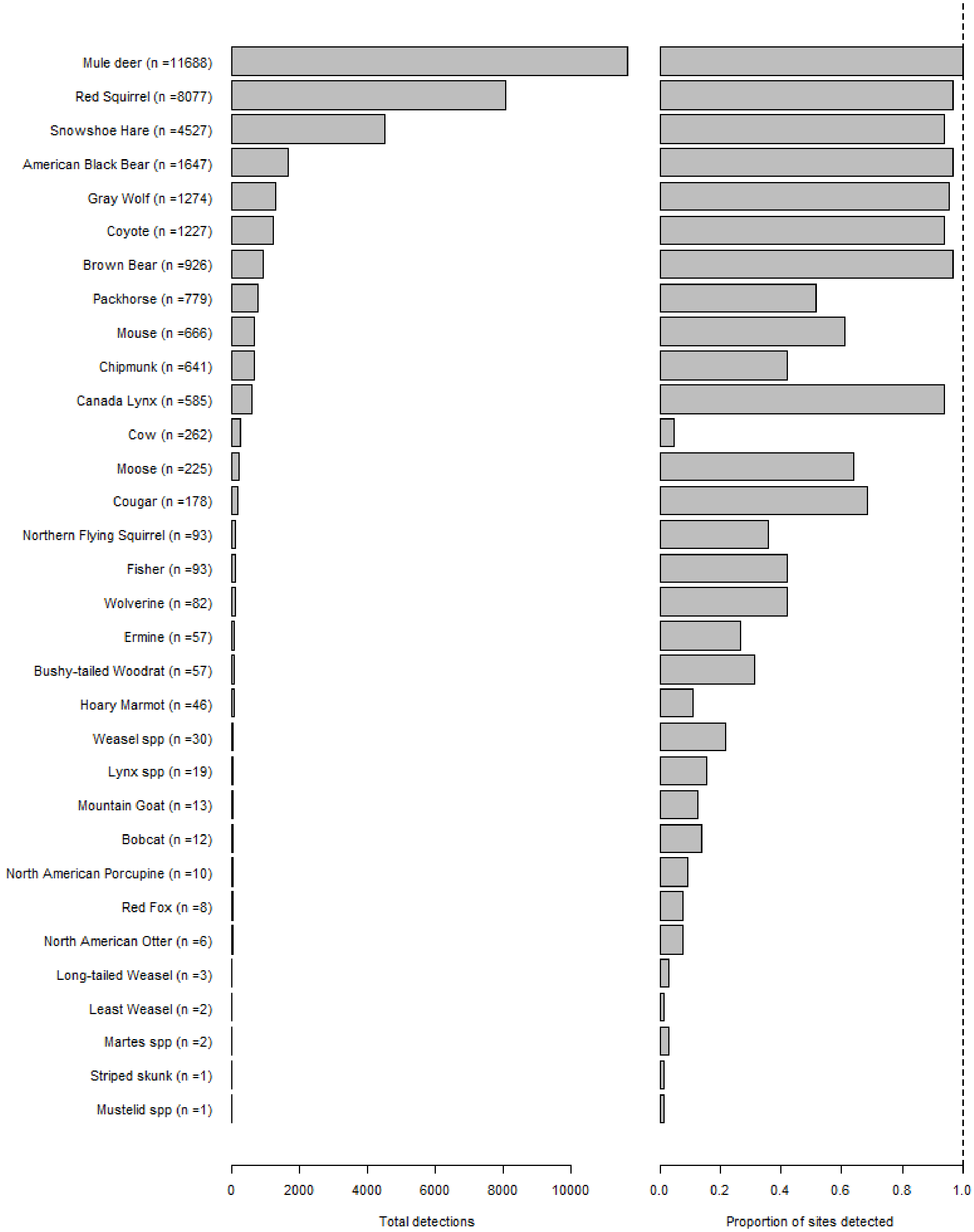


Figure 16. Independent detections of mammal species in the South Chilcotin Mountains from 64 camera stations operating from May 2018 to September 2020. An independence threshold of ten minutes between events was used. The proportion of total sites where each species has been detected is shown on the right.

We refer readers to Naidoo & Burton (2020) for the results of statistical analyses conducted on the first summer of sampling in SCM (May-August 2018). In brief, human activity did not have particularly strong or consistent negative effects on wildlife occurrences at the weekly scale. Human activity variables accounted for only 6 of the 30 statistically-significant variables, and only two of those, mountain biking for moose and grizzly bears, were negatively associated with probability of use. In contrast, environmental variables at the site level (n=8) and the larger landscape surrounding the site (n=6) accounted for half of all statistically significant variables, with temporal autocorrelation (n=7) and trail/camera characteristics (n=3) accounting for the remainder (details in Naidoo & Burton 2020). At the finer scale, all species had Avoidance-Attraction Ratio (AAR) values that were significantly greater than 1 for each recreation type, indicating some level of finer-scale trail displacement. As expected, hiking (median= 2.71) and horseback riding (median=2.38) had the lowest AAR estimates and were not statistically different from one another. In contrast to our expectation, mountain bikers (4.96), rather than motorized vehicles (4.16), had the highest AAR estimate.

Similar multispecies analyses will be undertaken in the 2020-21 project year using data collected subsequent to this initial analysis. Additionally, Dr. Naidoo and the WildCo lab are conducting analyses focused specifically on grizzly bears, including spatially explicit models estimating population density, and an analysis of the relationships between grizzly bear detections and forest harvest practices in the broader SCM landscape (the latter analysis forming part of the MSc thesis research of Chris Colton in the WildCo lab). Comparisons of the camera trap survey results with those from concurrent eDNA surveys supported by WWF-US are also described in a manuscript currently in review at *Scientific Reports.* And a separate report looking at the causal impacts of recreational trail-users on grizzly bear trail use within the SCM landscape will be submitted to BC Parks separately.

Joffre Lakes Provincial Park & Garibaldi Provincial Park

Thirty of the 39 camera stations in Joffre Lakes and Garibaldi were checked and serviced in Fall 2020. In total, these cameras collected almost 340,000 images, all of which have been processed. Almost all of these images (330,000) were collected in Garibaldi and of these, approximately 327,500 were collected at on-trail camera stations with high volumes of hikers. The 20 stations checked in Garibaldi were active for a total of 1000 camera-days, with an average of 50 camera-days per station. The 10 stations checked in Joffre Lakes resulted in a total of 677 camera-days, with cameras averaging 67.7 days per station.

Nineteen different mammal species (excluding humans and domestic dogs) were detected by camera traps in Joffre Lakes. The most commonly detected wildlife species in Joffre Lakes were Douglas squirrel (*Tamiasciurus douglasii*), mule deer (*Odocoileus hemionus*), snowshoe hare (*Lepus americanus*), bushy-tailed woodrat (*Neotoma cinerea*), and black bear (*Ursus americanus*) with 68, 36, 36, 19, and 18 independent detections, respectively (Fig. 17). Other notable wildlife species detected by the cameras were the North American porcupine (*Erethizon* *dorsatum*; 7 independent detections), American pika (*Ochotona princeps*; 6 independent detections), and wolverine (*Gulo gulo*; 1 independent detection) (Fig. 17). Despite the park closure, our cameras still collected 1126 independent detections of humans and 37 independent detections of domestic dogs, which are prohibited in the park.

In Garibaldi, 8 mammal species were detected, but only 3 species had more than 10 independent detections: snowshoe hare (*Lepus americanus*; 69 independent detections), mule deer (*Odocoileus hemionus*; 68 independent detections), and black bear (*Ursus americanus*; 40 independent detections) (Fig. 18). Some species of interest detected in low numbers include bobcat (*Lynx rufus*; 2 independent detections), cougar (*Puma concolor*; 1 independent detection), and American marten (*Martes americana*; 1 independent detection) (Fig. 18). Human detections vastly outnumbered wildlife, with 14,580 independent detections, and domestic dogs had 25 independent detections despite being prohibited in the park.

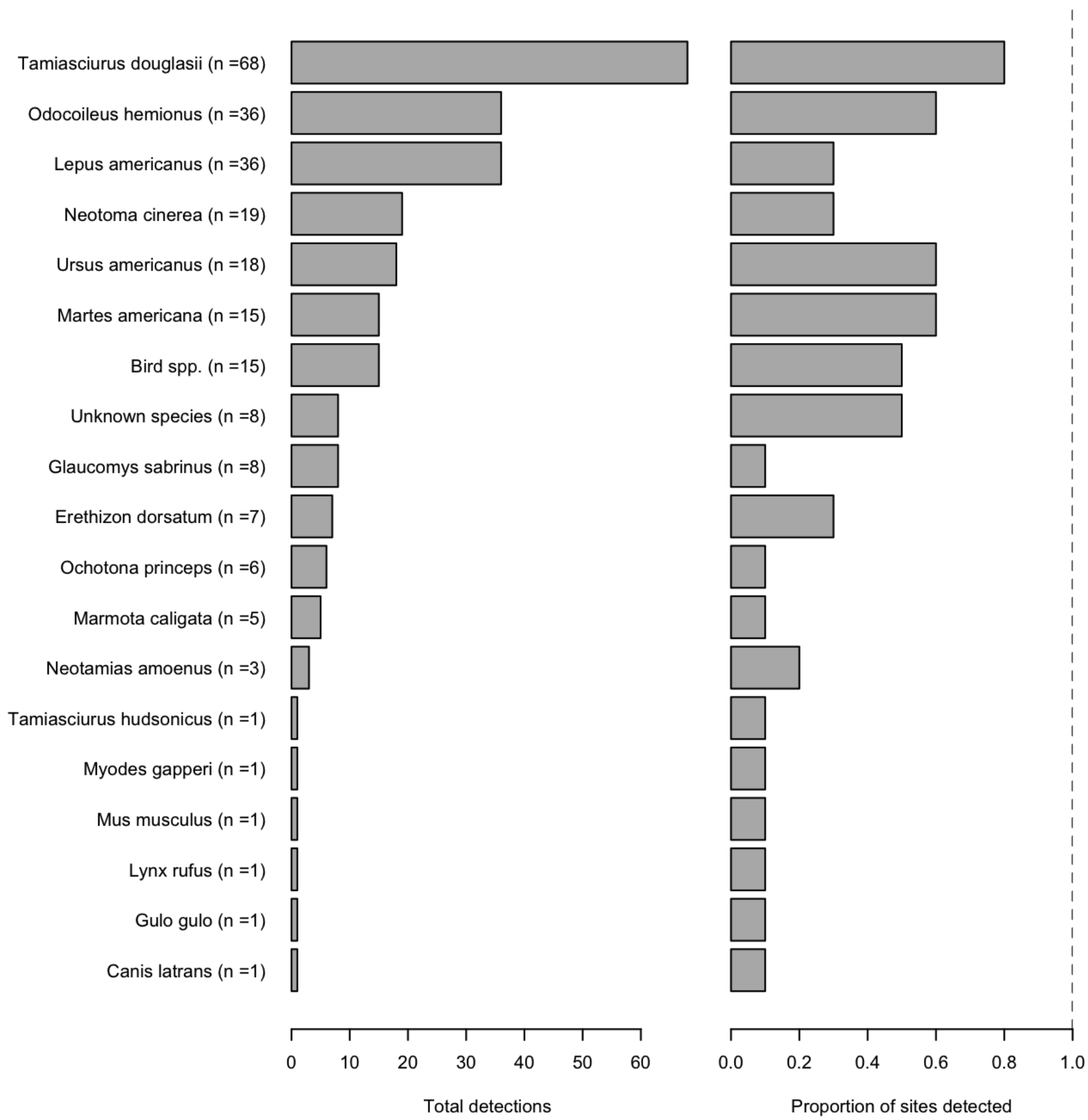


Figure 17. [*previous page*] Independent wildlife species detections in Joffre Lakes Provincial Park representing 10 cameras running for 677 total camera-days from August 3, 2020 to October 18, 2020 (left). An independence threshold of five minutes between events was used. The proportion of total sites where each species has been detected is shown on the right.

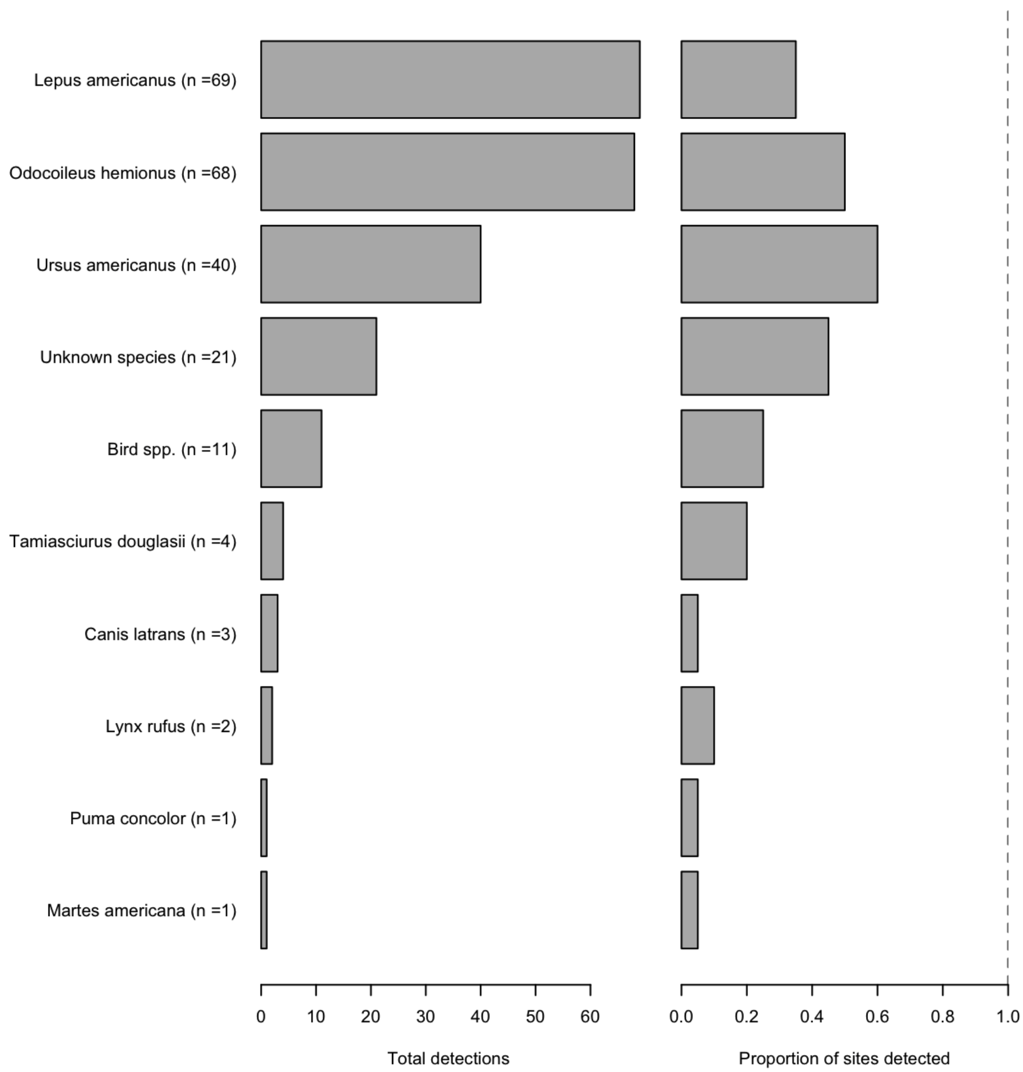


Figure 18. Independent wildlife species detections in Garibaldi Provincial Park from 20 cameras with 1000 total camera-days from August 5, 2020 to December 31, 2020 (1 camera running from October 5, 2020 to December 31, 2020). An independence threshold of five minutes between events was used. The proportion of total sites where each species has been detected is shown on the right.

Next Steps for Parks Camera Trap Surveys

We plan to continue this project through the 2021-22 year, with a primary focus on data collection, analysis and reporting for the 214 cameras currently deployed across the 5 parks. We also plan to organize meetings and/or workshops with BC Parks (and other) collaborators, in order to discuss results to date and incorporate any feedback into the upcoming field season and analytical work. Importantly, we would like to discuss longer term plans for camera trap monitoring in these and other protected areas (e.g. capacity within Parks and/or other groups to extend monitoring beyond the current MSc thesis projects). Camera traps will likely be removed this year from at least Cathedral and Golden Ears parks, unless plans are developed for a sustainable longer-term monitoring program. Potential opportunities for discussion include engagement of park staff, citizen scientists, and undergraduate student classes in supporting longer term monitoring.

Cathedral Provincial Park

In Cathedral Provincial Park, we will maintain the existing 45 CT deployments (operating since July 2019) through summer 2021, after which we plan to remove cameras with the completion of field work for Mitch Fennell's MSc thesis. The majority of cameras will have been operating continuously for a minimum of two years, with all having operated for at least one year. Data will be collected and processed as described above, and integrated into the statistical analyses that build on the preliminary modelling presented here. We expect that the resulting information will inform management decisions in the park, particularly with respect to developing a park management plan that considers the accelerating rates of human recreation in and around this protected area. We will also attempt to implement statistically rigorous spatial capture-recapture estimates of mountain goat density within Cathedral park, integrating with the ongoing mountain goat GPS collar study and providing further knowledge for park managers. Mitch Fennell will be leading the preparation of two manuscripts for peer-reviewed publication from the Cathedral surveys, along with associated presentations/communications for partners. We will also advance our analysis of phenological changes in vegetation and snow cover across the park habitats and elevation gradients, including the relationships between plant and animal phenologies and the potential links to climate change (see phenology section below).

Golden Ears Provincial Park

Michael Procko is leading the preparation of two manuscripts for peer-reviewed publication from the camera trap surveys in Golden Ears and Malcolm Knapp, with expected completion by Fall 2021. The WildCo Lab will maintain the existing 58 CT deployments until they have been operating for at least another 1 full year from the last data collection (i.e., through August 2021). At that time, we will assess the need and capacity for further data collection and processing, and the potential for integration with other camera trap sampling being conducted in the area by BC Parks (e.g. Erin Rutherford). Analyses of data collected in 2021 will be led by WildCo members.

We expect that the resulting inferences on spatial and temporal patterns within the mammal community in and around Golden Ears will provide information of use to park management, particularly with respect to understanding and managing the impacts of recreational activities. Data collected thus far have also contributed to a synthesis study linking the Golden Ears (and Cathedral) surveys to camera trap surveys in other PAs in BC and Alberta. This synthesis is led by postdoctoral researcher Alys Granados and is described below under WildCAM network development.

South Chilcotin Mountains Provincial Park

All 64 camera trap stations remain active in the SCM project, and will be revisited when conditions allow in the late spring/early summer of 2021. As described above, multispecies analyses will be updated and extended with the new data, and additional analyses are being pursued (e.g. grizzly bear population density and responses to forestry, eDNA survey comparison). In particular, WildCo graduate student Chris Colton is pursuing the use of remote sensing data to detect forest harvest cutblocks at fine spatial and temporal resolutions in order to assess how grizzly bears are responding to historical and ongoing forest harvest disturbances. We continue to seek additional funding to sustain and expand this SCM project over the long-term, and to discuss ways to effectively apply the research results with park managers, regional wildlife biologists, forestry companies, and local communities.

Joffre Lakes Provincial Park & Garibaldi Provincial Park

All cameras in Joffre Lakes and Garibaldi will be checked and serviced in the spring and summer of 2021. The data retrieved during these checks will be processed in the WildCo camera trap database. Following classification and processing of images collected in the spring, we will begin data analyses to assess how spatial temporal variation in human presence affects wildlife habitat use in each park, using the COVID-19 park closures as a case study. We will use animal detection histories to determine the number of independent detections per week for each of our focal species (e.g. *Odocoileus hemionus*, *Lepus americanus, Ursus americanus, Martes americana*) which will be used as our response variable in Bayesian GLMMs. Specifically, we will develop a series of candidate models to test the influence of park closure (a factor with two levels- open/closed), time since park closure (number of days), recreation activity (detections of humans), whether cameras are on or off trail, distance to trail head (m), and environmental variables (e.g. dominant vegetation type around the camera station, seasonality), while also controlling for variation in sampling effort across stations. Analyses will take place over the summer and fall 2021 and will be prepared for peer-reviewed publication in 2022.

Additional Research Activities

While the main focus of this project is on implementing and synthesizing the wildlife camera trap surveys across the five focal provincial park landscapes, we are also pursuing complementary research activities. Among these, we highlight here 1) monitoring of vegetation phenology using camera trap timelapse photos, and 2) integration of this project with the broader WildCAM network.

Monitoring vegetation phenology and productivity

We are exploring the use of time-lapse images from the camera traps to measure local site conditions and dynamics, such as vegetation phenology, vegetation productivity, and snow regime patterns. Phenology refers to the timing of events and phases, such as vegetation greenup and senescence (Denny et al. 2014), while productivity (typically referring to vegetation) refers to the quantity of growth or matter (Macfayden 1948). Our goal is to test hypothesized linkages between the site dynamics and wildlife habitat use, and to use this knowledge to inform predictions of, and management adaptations to, climate change. Tracking and measuring vegetation dynamics has traditionally relied on direct human observations and remote satellite methods (Zhang et al. 2003, Bolton et al. 2020). However, mounting recent evidence suggests that accurate and finer-scale understory and below-canopy measurements may require automated ground-level approaches in order to achieve spatial and temporal extents that are informative about landscape wide patterns. Camera trapping is emerging as a viable approach (McClelland et al. 2019, Siren et al. 2018), by detecting changes in relative values of ged, green, and blue color bands (i.e., RGB) over time.

Camera traps set in WildCo projects (including those covered in this report) record a daily time-lapse image at noon, to provide a consistent record of camera functionality and standardized data on the environment within the camera field of view. Daily time-lapse images provide the opportunity to explore temporally fine-scale patterns of habitat that are not possible with traditional, coarser-scaled remote sensing. We developed the methods to extract phenology and productivity signals from camera trap time-lapse images using data from WildCo's collaborative Algar Wildlife Monitoring project in northern Alberta (e.g. Tattersall et al. 2020), since the project had 4 years of continuous camera trap sampling in a highly seasonal environment (Sun et al. 2021, in review). We have been applying this approach to extract and examine phenology patterns in the BC Parks camera trap datasets. This section describes progress in developing and applying this methodology through work currently being led by postdoc Dr. Cat Sun and undergraduate student An Hoang in the WildCo lab (with previous contributions from Dr. Joanna Burgar, co-op student Taylor Justason, and undergraduate student Tom Howey).

The general process to extract understory vegetation dynamics from camera trap images involves extracting the RGB values within a region of interest (ROI) of each time-lapse image, filtering out noise and outliers, and creating indices of the red, green, and blue (RGB) color bands . For each deployment period at a camera trap site, we draw a bounding box to delineate a ROI around approximately the bottom ⅔ of a time-lapse image. The ROI bounding box is adjusted to generally exclude sky, distant landscape, and tree canopy to ensure that ROIs across sites consistently target comparable understory patterns. RGB values within the ROI are extracted and averaged. We automatically repeat this process for all time-lapse images during the deployment period, applying the same ROI. A new ROI is drawn for each deployment period to ensure the ROI consistently targets the same region despite adjustments to the viewing angle when cameras are handled for data retrieval. We use the "phenopix" package (Filippa et al. 2016) in Program R to draw ROIs and extract RGB values.

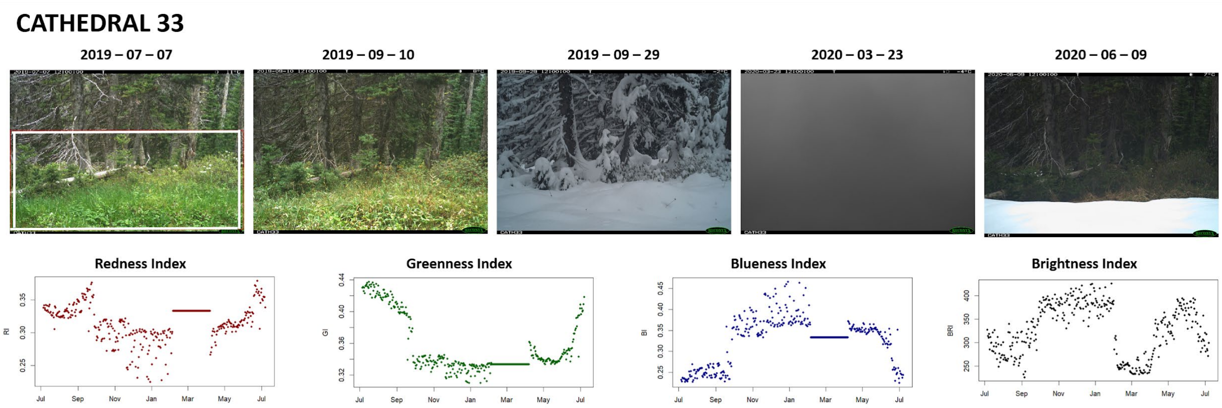


Figure 19. Time-lapse images and redness, greeness, blueness, and brightness indices extracted from all daily camera trap time-lapse images, for research site Cathedral 33. The white box in the leftmost time-lapse image delineates the region of interest for detecting understory vegetation dynamics.

Next, the time-series of daily RGB values are filtered to remove noise including poor weather conditions and low illumination. These filtered values are then used to calculate relative indices that reflect vegetation "green-up" (green index), "brown-down" (red index), and snow cycles (blue index) (Fig. 19) when plotted over time. A final step involves fitting a series of different algorithms based on thresholds and points of inflection to estimate phenologically relevant dates and derive site-specific proxies of vegetation productivity (Westgaard-Nielsen et al. 2017, Moore et al. 2016). Productivity metrics include length of season, and cumulative, maximum, and seasonality of greenness (i.e. dynamic habitat indices; Radeloff et al. 2019). To accurately estimate phenology dates and productivity metrics, camera traps should be deployed long enough to capture complete growing cycles, as exemplified by Figure 20 showing the extracted greenness index from a camera trap site in the Algar Project.

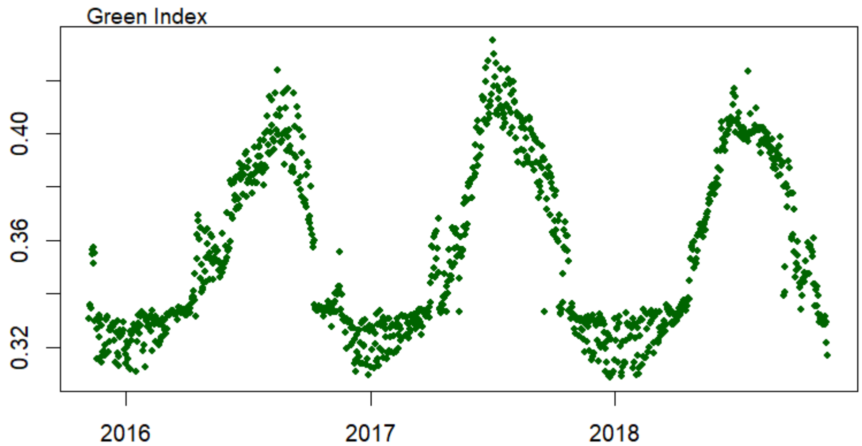


Figure 20. Daily greenness indices extracted from timelapse images taken by a camera trap at a research site in the Algar study area in northern Alberta, from November 2015 to November 2018, with peaks and troughs illustrating the detection of complete growing cycles. Similar temporal indices will be calculated for parks cameras when sufficient temporal data have been collected

Cathedral Provincial Park

We report preliminary findings on extracting phenology and productivity signals from camera traps in Cathedral Provincial Park. Sampling does not yet capture complete growing cycles, so we share results up to but not including the last step of estimating phenology dates and productivity metrics. Still, the daily filtered red, green, and blue indices serve as measures of local habitat conditions that can be related to wildlife activity.

Drawing ROIs and extracting RGB values revealed variations across sites, with implications for future methods implementation and interpretation of extracted patterns. Differences in habitat and camera viewing angle across sites necessitated variably placed ROIs in order to consistently capture understory vegetation dynamics (Fig. 21), suggesting that a completely automated process for drawing ROIs may not be appropriate. Furthermore, many camera trap research sites in Cathedral receive large amounts of snowfall that obstruct the camera view, which were detected as horizontal line segments in the time-series of extracted color indices (Fig 19). These line segments at non-zero values emphasize the importance of interpreting these indices as relative rather than absolute measures of local, site-specific habitat condition – especially if different camera trap makes and models are used at different sites.

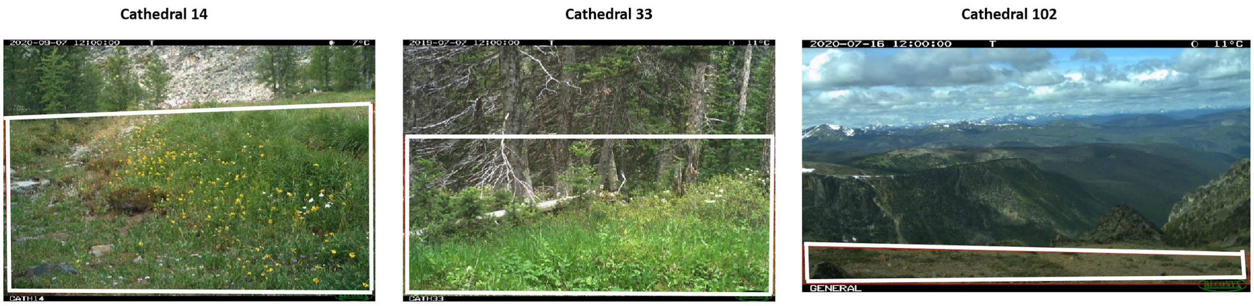


Figure 21. Variation in habitat and placement of regions of interest, delineated by white boxes, as captured by camera trap time-lapse images at three different research sites (Cathedral 14, Cathedral 33, and Cathedral 102).

Even without extracting phenological dates, differences in the timing of vegetation greening were apparent across sites. Greenup often occurred earlier at sites at lower elevation (approximately < 1500 m) compared to sites at higher elevation (Fig. 22A). This suggests that continued camera trap monitoring may be an important tool in detecting vegetation phenology changes due to climate change across elevation gradients. Greater variability at higher elevation in the timing of greenness may be due exposure to wind and variable snow cover. Furthermore, vegetation greenup at sites on hiking trails had less variable timing than at sites off hiking trails (Fig. 22B). This may be related to other factors including elevation, habitat type, and level of human activity or disturbance, that will require further investigation.

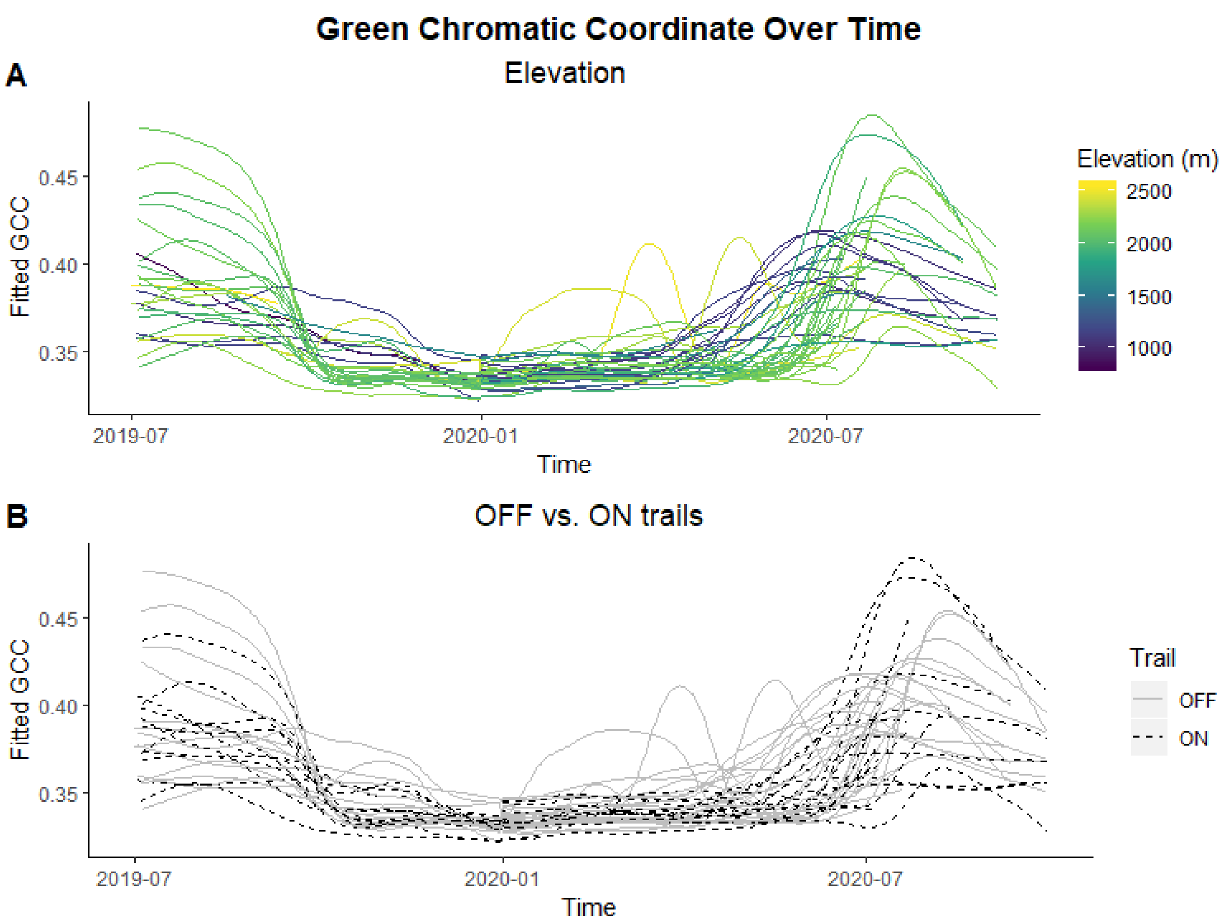


Figure 22. [*previous page*] Fitted curves of the greenness index (i.e., green chromatic coordinate, GCC) over time across all n= 45 camera trap research sites in Cathedral Provincial Park, with sites differentiated by A) elevation and B) whether research sites were off or on hiking trails.

Habitat use by mountain goats (*Oreamnos americanus*), as measured by the count of weekly independent detections, may be more related to understory vegetation productivity than to phenology. In 2020, at n=9 sites where goats were detected, the overwhelming majority of weekly detections (97%, 889 of 910) occurred after June despite vegetation greenup occurring earlier at sites at lower elevations (approximately <2000 m) (Fig. 23). The delayed detection of mountain goats on camera traps relative to the timing of understory greenup is corroborated by similar patterns with remotely-sensed NDVI at a coarser scale (biweekly, 500 m resolution). These preliminary findings raise questions about how goats and other wildlife will respond to climate change if habitat use and movements (between seasonal home ranges) do not track the timing of vegetation greenup, given that changes in phenology due to climate change can also affect productivity (Richardson et al. 2010).

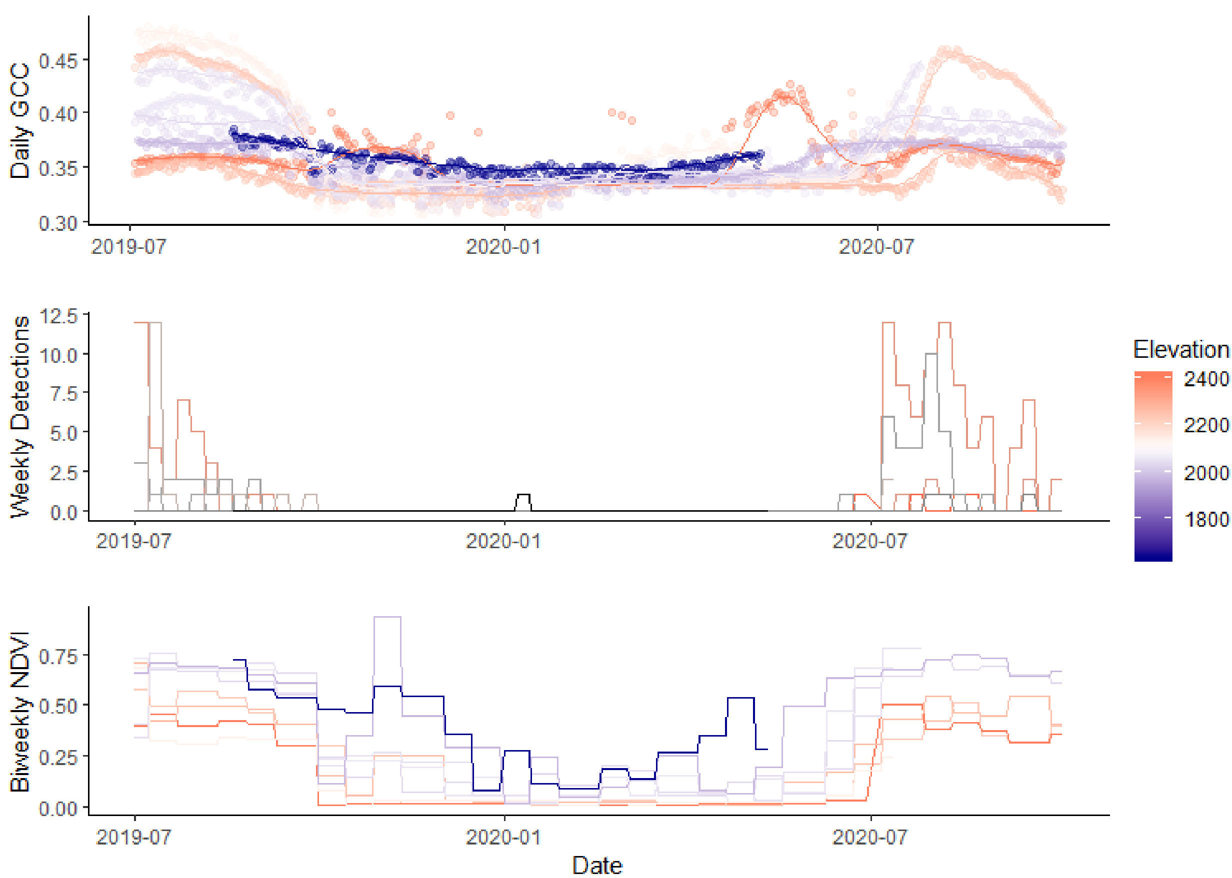


Figure 23. [*previous page*] Patterns in daily greenness indices (fitted green chromatic coordinate), weekly detections of mountain goats (*Oreamnos americanus*), and biweekly measurements of MODIS derived NDVI (500m resolution) at the n=9 camera trap research sites where mountain goats were detected in Cathedral Provincial Park.

WildCAM Network Development

The WildCo lab is playing a leading role in the development of a new camera trap network for western Canada, called the WildCAM network (short for Wildlife Cameras for Adaptive Management). The collaborative camera trap projects with BC Parks described in this report form a key part of the emerging network.

In the fall of 2019, the WildCAM website (www.wildcams.ca) was launched, providing news and updates to our growing community while also acting as a repository for camera trap-related resources such publications and reports. Over the past year, the network has grown and as of March 2021, the network has 136 members, representing 61 different projects across BC and Alberta (Fig. 24). Membership includes researchers from academia, government, non-profits, as well as citizen scientists.

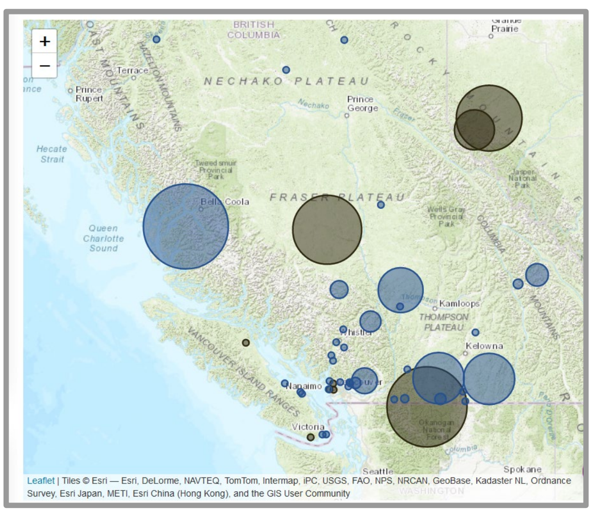


Figure 24. Locations of ongoing (blue circles) and completed (brown circles) WildCAM-affiliated projects in BC and Alberta as of March 2021. Circle sizes represent relative sampling effort among projects. Image from www.wildcams.ca/projects.

The WildCo lab, in partnership with the BC Parks Foundation, engaged postdoctoral researcher Dr. Alys Granados in January 2020 to serve as the Science Coordinator for the WildCAM network. In this role, Alys is developing and delivering science-based advice and tools for building the network. This involves reviewing and producing recommendations for camera trap survey design, data collection, and management. For example, in May 2020, we produced a protocol for setting up camera traps, which is posted on the website (www.wildcams.ca/protocols). The guide is meant to highlight some of the major considerations for camera trappers when deciding where and how to set up their camera trap array. To facilitate standardization of data collection, we also created WildCAM data sheets for use in the field during camera deployment and camera checks or retrieval. Our datasheets are consistent with metadata standards developed by Wildlife Insights and the RISC Wildlife Camera Metadata standards.

Over the past year, we explored the utility of large-scale camera networks through a case study quantifying the impacts of human recreation and habitat disturbance on mammal carnivores in BC as well as Alberta. This synthesis project includes data from 12 distinct WildCAM-affiliated projects and consists of over 800 camera trap stations (Fig. 25). Synthesizing data from multiple projects allows us to explore the utility of camera trap networks (e.g. are there benefits to pooling data from multiple sites? What are the challenges?) and ask large-scale questions about wildlife responses to human disturbance. Specifically, our findings will contribute to our understanding of the human activities compatible with human-carnivore coexistence at large spatial-scales. Datasets comprising the synthetic dataset included areas outside and within protected areas including Provincial Parks (Golden Ears, Cathedral, South Chilcotin Mountains, Skagit), Regional Parks (Minnekhada, Sea to Sea), National Parks (Jasper National Park), two Biosphere Reserves (Beaver Hills, Clayoquot Sound), Wildlife Management Units (Kootenays WMUs) and adjacent (Crown) land.

Figure 25. Location of WildCAM-affiliated projects in British Columbia and Alberta comprising our synthetic dataset for assessing the influence of recreation and land use on mammals. BC datasets comprising the synthetic dataset include 1) Clayoquot Sound Biosphere Reserve, 2) Sooke-Capital Regional District, 3) Sea to Sky area, 4) South Chilcotin Mountains Provincial Park, 5) Golden Ears Provincial Park, 6) Minnekhada Regional Park, 7) Skagit Valley Park, 8) Cathedral Provincial Park, 9) Kootenays WMUs. Alberta projects include 10) Jasper National

Park area, 11) Kananaskis Country, and 12) Beaver Hills Biosphere Reserve. BC Parks projects included in this report are noted as white circles.

For analysis of the synthetic dataset, we will assess the influence of several environmental (e.g. productivity, elevation, forest cover), anthropogenic (e.g. trail density, human detections, logging) and sampling effort on the number of independent detections of mammal carnivores in a given week (Table 5).

Table 5. Independent (predictor) variables to be used in Bayesian generalized regression models of weekly detections of wildlife species across 807 camera trap stations from 12 WildCAM-affiliated projects, including 3 WildCo - BC Parks Projects described in this report.

Variable	Description	Category
Elevation[1]	Elevation at camera station (m)	Environment
Forest[2]	% of forested habitat within a 500m radius of the camera	Environment
NDVI[3]	Normalized difference vegetation index – from MODIS imagery (500m productivity)	Environment
Hikers[4]	# of human detection events per week at each camera station	Human use
Domestic dogs[4]	# of domestic dog detection events per week at each camera station	Human use
Motorized vehicles[4]	# of detection events of of ATVs, cars, trucks, quads, etc per week at each camera station	Human use
Logging[5]	% of area logged in the 50 years before sampling within a 500m radius of the camera	Land use
Agriculture[2]	% of agricultural area habitat within a 500m radius of the camera	Land use
Urban[2]	% of urban area habitat within a 500m radius of the camera	Land use
Trail density[6,7]	Road density within a 500m radius of the camera	Human use
Road density[7]	Trail density within a 500m radius of the camera	Land use
On/off trail[4]	Variable describing camera placement	Camera set

Camera days[4]	Number of days a given camera station was active	Detectability

[1]Source: Digital Elevation Model – Province of British Columbia
[2]Source: Land Use Cover – Government of Canada
[3]Source: MODIS Satellite Product VNP13A1
[4]Source: Camera trap data
[5]Source: Harvested areas of BC– Province of British Columbia
[6]Source: Digital Road Atlas - Province of British Columbia
[7]Source: allTrails.com

Overall, the synthetic dataset consisting of 807 camera stations sampled over a range of time between 2011 up to and including 2020 and a total of 231, 467 camera trap days. Data analyses are currently ongoing and will be finished summer 2021. Across all projects, *Ursus americanus* and *Canis latrans* were the most detected carnivores while hikers were the most frequently detected recreation activity, followed by domestic dogs, motorised vehicles, and to a lesser extent, horseback riders and cyclists (Fig. 26).

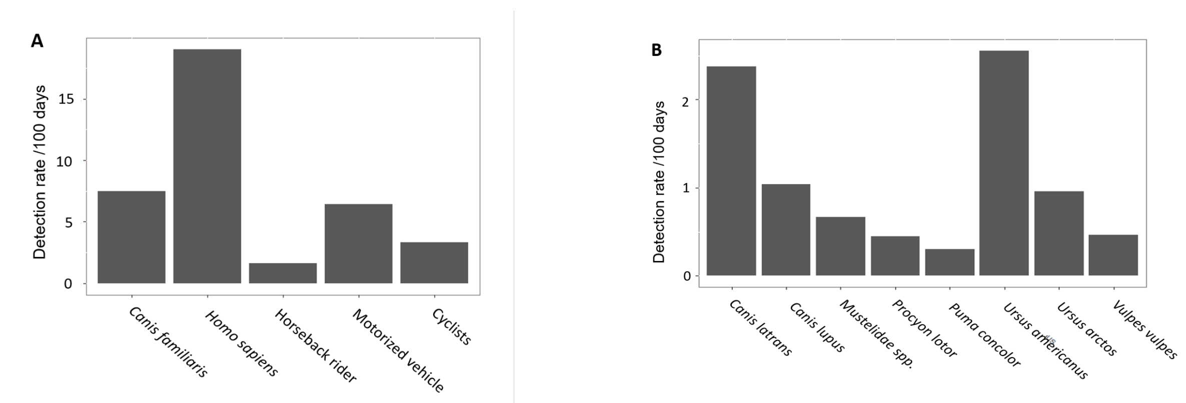


Figure 26. Overall detection rates for a) recreation activity and B) the most commonly detected carnivore species in our WildCAM synthetic dataset spanning multiple camera trap surveys in BC and Alberta.

Over the next year we will continue to expand the WildCAM network, for example, by promoting WildCAM and increasing membership through future webinars similar to those held in the fall of 2020 as part of CMIAE CredTalks, presentations at scientific conferences (e.g. upcoming virtual CMIAE camera trap conference), engagement with citizen scientists and developing partnerships with interest groups (e.g. naturalist groups, conservation NGOs). Also, a coordinator will be hired in spring 2021 to increase our outreach efforts with the camera trap community in Western Canada. Finally, we will develop new projects under WildCAM, including a planned project for summer 2021 in the South Coast in partnership with the St'at'mic First Nation and Dr. Bill Harrower from the BC FLNRORD. In this project we will use the protocols developed under WildCAM thus far, while importantly, increasing engagement with First Nations and Indigenous communities in wildlife surveys and management.

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