Wildlife Responses to Non-Motorized Recreation in the Southern Canadian Rockies: A Multi-Scale Analysis near Fernie, BC

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Complete List of Authors:	Lamb, Clayton T; University of British Columbia, Department of Biology; Biodiversity Pathways, Wildlife Science Center Chow, Emily ; Government of British Columbia, Ministry of Water, Lands, and Resource Stewardship
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1   Title: **Wildlife Responses to Non-Motorized Recreation in the Southern Canadian Rockies:**

2   **A Multi-Scale Analysis near Fernie, BC**

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4   Running head: **Fernie Rec Paper**

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6   Clayton T. Lamb[1,2*]

7   Emily Chow[3]

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10   **Affiliations**

11   [1] University of British Columbia, Department of Biology, Kelowna, BC, Canada, V1V 1V7

12   [2] Wildlife Science Center, Biodiversity Pathways, Kelowna, BC, Canada, V1V 1V7

13   [3] Ministry of Water, Lands, and Resource Stewardship, Cranbrook, BC

14   [*] Corresponding author: clayton.lamb@ubc.ca

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Data availability

The code and data to reproduce this analysis is deposited at the following github:

https://github.com/ctlamb/MtFernie_RecreationEcology

The photos and species classifications from the Fernie Trail Network data are publicly accessible

at the following links (each year of data is its own link):

https://portal.wildtrax.ca/home/camera-deployments.html?sensorId=CAM&projectId=998

https://portal.wildtrax.ca/home/camera-deployments.html?sensorId=CAM&projectId=1401

https://portal.wildtrax.ca/home/camera-deployments.html?sensorId=CAM&projectId=1971

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recreation, habitat selection, mountain bike, tourism

40   **Abstract**

41   Human outdoor recreation is expanding across natural landscapes, yet its effects on wildlife

42   remain poorly understood across spatial and temporal scales and across different contexts. We

43   assessed the responses of large mammals to non-motorized recreation near Fernie, British

44   Columbia, using a multi-scale observational approach combining data from 66 camera traps and

45   GPS telemetry from 21 grizzly bears (*Ursus arctos*). We evaluated (1) how wildlife detections

46   varied by trail type, relative to the broader landscape, and with varying levels of recreational

47   users, and (2) whether animals shifted activity to avoid peak human use, and (3) how collared

48   grizzly bear movement responded to recreation compared to other anthropogenic features. Trail

49   type, surrounding landscape, and recreational pressure significantly influenced detection

50   probabilities, but responses varied by species and scales. Elk (*Cervus canadensis*) showed the

51   strongest avoidance, with reduced presence on recreation trails (odds ratio ≈ 0.037, $p \approx 0.01$) and

52   a marked shift toward low-use periods (Δoverlap $= -0.24$). In contrast, moose (*Alces alces*) and

53   mule deer (*Odocoileus hemionus*) were more frequently detected on or near recreation trails.

54   Grizzly bears consistently avoided areas adjacent to recreation trails in GPS movement data and

55   camera detections but were detected on recreation trails more than nearby wildlife trails

56   suggesting when they do move through the trail network they do so on recreation trails. These

57   findings highlight species- and scale-dependent behavioural responses, with effects ranging from

58   strong (elk), to moderate (grizzly bears), to minimal (black bears, moose, mule deer, red fox, and

59   white-tailed deer). Our results suggest that concentrating recreation near existing developed areas

60   and during mid-day should minimize impacts on wildlife while providing important access to

61   recreation for people. Maintaining low-use zones elsewhere will be important for more sensitive

62   species. While observational studies like ours are valuable for identifying patterns and informing

63   management of rapidly changing pressures, stronger inference through experimental designs is

64   encouraged to clarify causal relationships between recreation and wildlife behavior and further

65   elucidate species- and context- dependent relationships.

66

Introduction

68   Humans have long shaped the distribution and abundance of wildlife through habitat alteration

69   and direct mortality. Road networks fragment habitat and cause vehicle collisions (Forman and

70   Alexander 1998), human settlement and persecution has reduced or eliminated species from

71   large portions of their former ranges (Laliberte and Ripple 2004). While these negative effects

72   are well documented and intensifying in many regions, it is also true that people and wildlife

73   have coexisted on Earth for millennia. Multiple examples exist where ecosystems co-evolved

74   with human interaction and have suffered when human use has been excluded, as has been the

75   case with the exclusion of cultural and prescribed fire from dry montane forests in North

76   America during the 20th century (Greene 2021). Even under contemporary pressures, there

77   remain landscapes—some densely populated—where large mammal communities persist with

78   remarkable continuity (Laliberte and Ripple 2004). This paradox underscores a central challenge

79   in conservation biology: understanding the conditions under which wildlife can persist and even

80   thrive in contemporary human-dominated environments.

81   Just as wildlife depend on access to natural habitats, humans increasingly seek those

82   same landscapes for health, well-being, and recreation. Time spent in nature has been linked to

83   improved physical and mental health, enhanced cognitive function, and greater social cohesion

84   (Bratman et al. 2019). Outdoor recreation offers the dual benefits of time in nature paired with

85   cardiovascular exercise (Thomsen et al. 2018). As participation in outdoor recreation grows, so

86   too does the spatial extent of recreational use—particularly in mountainous and forested regions.

87   This expansion raises pressing questions about how human presence influences wildlife, and

88   how these landscapes can be stewarded to sustain both biodiversity and public access. Land

89   managers, recreation planners, and policymakers are increasingly seeking science-based

90   guidance to help anticipate, mitigate, or avoid unintended impacts on sensitive species (Miller et

91   al. 2020, Jordan et al. 2025).

92   Recreation ecology—the study of recreational impacts on ecological systems—has

93   expanded rapidly to meet this need (Monz et al. 2013). Yet its findings remain mixed. Some

94   studies report strong negative effects of recreation on wildlife, such as spatial displacement,

95   increased energy expenditure, reduced reproductive success, or elevated mortality risk

96   (Wiedmann and Bleich 2014, Thompson et al. 2024, Urhan et al. 2025). Others document

97   minimal or even positive responses, including behavioral habituation (Miller et al. 2020,

98   Granados et al. 2023) or the use of human-modified areas as refuges for prey from predators or

99   hunting pressure (Berger 2007). These variable responses tend to depend on species' sensitivity,

100   landscape context, and the type, timing, and intensity of recreation (Naidoo and Burton 2020,

101   Procko et al. 2022). This heterogeneity of outcomes poses a challenge for managers: the best

102   available science is often context-dependent and difficult to generalize without appropriate

103   consideration of species, landscape, activity type, and scale.

104   Among the most informative studies are those that employ experimental or quasi-

105   experimental designs, such as before–after–control–impact (BACI) frameworks or manipulative

106   trail closures. For example, (Miller et al. 2020) conducted a BACI study around a new unpaved

107   recreational trail being built in an Appalachian protected area, focusing on responses from white-

108   tailed deer, coyotes, raccoons, and gray squirrels. Their results showed that overall species

109   decreased use of the area during trail building but returned to baseline detection levels once

110   construction was complete and humans were using the trail, albeit at low rates (1.4 visitors per

111   day). Notably, control sites helped decouple population fluctuations from experimental effects

112   that would have obscured results in even a traditional before-after experiment. Contrary to

113   Millers results, Wiedmann and Bleich (2014) assessed bighorn sheep responses to a hiking trail

114   built in western North Dakota, USA that had high rates of use. Although not stated in the paper,

115   in 2016 the trail apparently saw >15,000 users a year, or >40 people per day. They document

116   displacement, lower recruitment, population decline, and eventual abandonment of lambing areas

117   for one subpopulation of bighorn sheep. However, three other subpopulations of sheep were

118   exposed to the trail at lower intensities and with more consistent human use, and these

119   populations showed no negative effects from the trail and increased in size. Experimental

120   perturbations of elk and mule deer by recreationists at the Starkey Experimental Forest suggested

121   recreationist displaced elk by >500 meters, reduced the time elk fed or rested, and increased the

122   time they were travelling (Wisdom et al. 2018, 2018). Recreation effects on elk were greatest for

123   ATV riding, moderate from bikes, hikers, and horseback riders. Similar experiments on mule

124   deer at Starkey Experimental Forest did not produce strong effects (Wisdom 2005). Finally,

125   (Costello et al. 2013) assessed GPS collared black bear responses to the development of a non-

126   motorized trail alongside an existing road. At least 100 people were using the trail per day but

127   there was no detectable change in bear home range or frequency of crossing the corridor. Bears

128   did alter their 3rd order selection near the corridor and shifted to more nocturnal behaviour. Even

129   strong inference from experimental studies suggest recreational effects can and will vary by

130   recreational type, intensity, predictability and wildlife species.

131   Such context dependent responses to recreation are perhaps something that wildlife

132   managers will have to accept, and thus the more information that can be generated on how these

133   different contexts scale up to impact wildlife behaviour and demography at local and broader

134   scales will allow for better evidence-based management. Importantly, experimental approaches

135   can isolate causal effects but are logistically and ethically constrained, especially in high-use or

136   multi-jurisdictional areas. As a result, well-designed observational studies remain an important

137   part of knowledge generation, particularly when paired with complementary data sources such as

138   telemetry or high-resolution camera monitoring.

139   Scale is also critical to recreation ecology inquiry. Johnson's (1980) hierarchical

140   framework of habitat selection emphasizes that animals respond to their environment at multiple

141   levels: the placement of home ranges within the landscape (second-order selection), the use of

142   habitats within those home ranges (third order), and fine-scale behavioral decisions (fourth

143   order). Recreational activity can influence wildlife at all these scales. Animals may avoid regions

144   with high recreation altogether (Wiedmann and Bleich 2014), reduce use of areas near trails and

145   infrastructure within their home range (Whittington et al. 2022, Thompson et al. 2024), or shift

146   activity to less disturbed times of day (Gaynor et al. 2018, Lamb et al. 2020). Accurately

147   capturing such responses requires models and datasets that are sensitive to variation in both

148   space and time.

149   In this study, we examine how a community of large mammals responds to outdoor

150   recreation in the southern Canadian Rockies near Fernie, British Columbia. We addressed four

151   core questions: (1) Intensity of use: How do wildlife detections vary in areas of intense

152   recreational use relative to the surrounding landscape and how do different levels of recreational

153   use on trails influence detections? (2) Diel patterns: For animals present in the trail network, do

154   they adjust the timing of their trail use to minimize overlap with recreational users and how does

155   this compare to behaviour observed across the landscape? (3) Grizzly bear movement: How do

156   GPS-collared grizzly bears modify their movement and habitat selection in relation to trail

157   proximity and recreation intensity? (4) Near encounters: how common are close encounters in

158   space and time between humans and potentially dangerous animals such as bear or moose on

159   recreation trails? We hypothesized that if recreation was having strong and consistent negative

160   effects that wildlife would be detected at lower rates in areas near trails due to animals avoiding

161   the areas with high human disturbance. Within the trail network we hypothesized that wildlife

162   would avoid trails used by recreationist compared to nearby wildlife trails with low human use,

163   and that when using recreation trails, they would prefer to use recreation trails with lower

164   recreational use. We hypothesized that wildlife would temporally avoid the peak times of day

165   people are active on the trails and during these times and would avoid those times less in areas

166   with fewer people. We hypothesized that collared grizzly bears would strongly avoid the trail

167   network, and this avoidance would be similar in magnitude to other high impact disturbances

168   such as towns and the highway. Finally, we hypothesized that the overall avoidance of the

169   recreationist would mean there were few near encounters between recreationists and potentially

170   dangerous wildlife. To answer these questions, we combined multi-year camera-trap monitoring

171   integrated step selection analysis of grizzly bear telemetry. This multi-stream approach allowed

172   us to assess patterns of avoidance, co-use, and scale-dependent sensitivity to recreation activity.

173

174 **Methods**

175 *Study Area*

176 We conducted our study in the forested mountain landscape surrounding Fernie, British

177 Columbia (49.5°N, 115.1°W), a city of 6,320 residents as of the 2021 Census . Situated in the

178 Elk Valley of southeastern British Columbia, Fernie lies along the Elk River and is encircled by

179 the Rocky Mountains, including the Lizard Range and Three Sisters peaks (Figure 1). The region

180 encompasses a broad elevation gradient (900–2,400 m) and features diverse forest types,

181 including montane and subalpine coniferous stands dominated by Douglas-fir (*Pseudotsuga*

182 *menziesii*), lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), and

183 subalpine fir (*Abies lasiocarpa*). Riparian zones along the Elk River and its tributaries support

184 black cottonwood (*Populus trichocarpa*) communities.

185   Fernie is accessible via Highway 3 (Crowsnest Highway), a major east-west

186 transportation corridor traversing southern British Columbia and connecting to Alberta through

187 the Crowsnest Pass . The area supports a diverse assemblage of large mammals, including

188 grizzly bears (*Ursus arctos*), black bears (*U. americanus*), cougars (*Puma concolor*), wolves

189 (*Canis lupus*), elk (*Cervus canadensis*), and mule and white-tailed deer (*Odocoileus spp.*). A

190 dense, year-round network of recreational trails—used by hikers, bikers, backcountry skiers, and

191 motorized users—overlays this habitat, primarily on provincial Crown land but also on private

192 land accessible to the public.

193

194 *Camera Traps*

195   We deployed remote cameras (Reconyx Hyperfire 2) throughout the recreational (Rec) trail

196   network on Mount Fernie and Mount Proctor (hereafter collectively called Mount Fernie trail

197   network) (Figure 1). Cameras were set on a tree 1.5 meters above the ground and 6-10 meters

198   from the trail. Any vegetation that would interfere with detection on the trail was removed each

199   year in the spring or summer.

200   We monitored human and wildlife use on two types of trails, 1) single and double track

201   bike and hiking trails (together called Recreation trails, n=18) , and 2) adjacent wildlife trails

202   within 500 meters of trails (n=10). Cameras were programmed to take 5 photos at each detection

203   on high sensitivity, with <1 second (rapid-fire setting) between images. No delay between

204   subsequent detections were set, essentially meaning the camera took as many photos as fast as it

205   could while there was detectable movement in its' view. A timelapse photo was set to be taken at

206   12:00 pm daily to denote the period the camera was operating. The cameras were checked 2-10

207   times a year and were present year-round from May 2021- November 2024.

208   We uploaded images to WildTrax (https://wildtrax.ca/), a cloud-based camera trap data

209   management platform. The MegaDetector software (Beery et al. 2019) is automatically run

210   within WildTrax to remove high likelihood empty photos as well as humans and vehicles,

211   increasing the efficiency of downstream image processing (Fennell et al. 2022). A team of image

212   taggers from the Alberta Biodiversity Monitoring Institute manually verified species tags in each

213   image and classified images without species tags from the MegaDetector. For each image the

214   number of each wildlife species present in the image was recorded. We did not count the number

215   of humans present in each image due to the volume of photos, and rather just tagged to the type

216   of human use- bike, vehicle, off-road vehicle, heavy machinery, or human (typically a hiker or

217   runner). Initially we classified domestic dogs along with hikers and bikers on the trails. Dogs

218   were present at high rates, and we didn't expect that there would be sufficient variation in dog

219   absence or presence with recreationists to assess dog effects, thus we stopped tagging dogs in

220   2022 to reduce costs and do not conduct any analyses on domestic dogs. Off leash dogs were

221   common.

222   In addition to the camera traps specifically deployed for this project, we also used

223   cameras from neighbouring projects near Fernie to gain a broader landscape perspective (Figure

224   1). These cameras were dispersed through the Elk and adjacent river valleys as well as high

225   elevation areas. While these cameras were deployed on a variety of trail types, we only used the

226   cameras deployed on wildlife trails. We broke these landscape-level cameras into two groups.

227   The "landscape-valley" group was within 25 km of Fernie and in similar habitats to the Fernie

228   recreation cameras (n=21), which were typically Interior Cedar Hemlock or Montane Spruce

229   zones. The landscape-valley cameras were in areas that also had highways, railways, towns, and

230   resource roads but less recreational use than the Fernie trail network and thus provided a

231   comparison with insight into the additive effect of the trail network on wildlife detections and

232   behaviour. The second group, "landscape-remote", were in more remote and higher elevation

233   habitats than the Fernie trail network (n=17). Because the habitat of the landscape-remote

234   cameras was not as comparable with the Fernie trail network we used these cameras for temporal

235   (diel) comparisons only but not intensity of use. All cameras were Reconyx, although a variety

236   of Reconyx models were used (HP2X, Hyperfire PC600-900). We included the camera model in

237   our models to account for detectability differences. Details on these landscape-level camera

238   projects can be found in the following publications (Granados et al. 2023, Lamb 2025a, 2025b,

239   Lamb et al. 2025), Figure 1).

240

Camera Statistical Analysis

242   From the classified images, we created several datasets for the following analyses. We subset the

243   camera data to the period between May 1 and October 31 each year to focus on the snow-free

244   season, when wildlife were consistently present across the landscape. This period also

245   corresponded with peak non-motorized recreational activity on the Fernie trail network. During

246   the winter months many migratory ungulates left the area and bears were hibernating (Lamb et

247   al. 2022, Poole et al. 2024). Recreation use was low in winter on most trails except those

248   groomed for winter biking, walking, or cross-country skiing. We considered an alpha level of

249   0.10 for statistical analysis of the camera due to small sample sizes.

250   *Intensity of use*—We generated a detection dataset by collapsing consecutive photos of the same

251   species into single detection events if separated by less than ten minutes. This approach likely

252   underestimates the true number of recreationists detected as many individuals or groups may

253   pass in 10-minute window but aligns with the tagging protocol of the landscape-level cameras

254   allowing for comparison among projects. These detections were compiled for each species at

255   each camera. We assessed how average monthly detection rates varied by location (Recreation

256   trails and wildlife trails in the Fernie trail network and the Landscape-valley cameras outside the

257   Fernie trail network) using generalized linear mixed models. To account for the abundance of

258   months with no detections, we used a hurdle-model approach where we first modelled presence-

259   absence using a binomial model with logit link for each species per month and then a second

260   model where animals were detected using a truncated Poisson distribution to model the detection

261   rate (relative abundance). For each model we included random intercepts for camera model,

262   month, year, and camera ID. We also assessed if additional environmental variables were

263   appropriate to include to remove environmental variation between the camera projects that could

264   interfere with our comparisons. For each species we compared whether inclusion of indices of

265   habitat productivity (annual precipitation or summer enhanced vegetation index) improved the fit

266   of data to the model via Akaikes Information Criteria (AIC, Akaike (1973)) . In cases where

267   these covariates improved model fit, we included the covariates in their final model models.

268   Within the Fernie trail network, we assessed how wildlife detection rates were influenced

269   by the number of recreational users on the recreation trails. We conducted this analysis at a

270   weekly interval to detect finer-scale responses of wildlife to changing recreation pressure. To

271   account for finer differences between trail locations we included measures of canopy cover,

272   slope, summer enhanced vegetation index, and distance to a building for each camera. We used

273   the hurdle model structure as above to model presence and then relative abundance based on the

274   number of recreational users on the trails. We included random effects for week of the year, year,

275   and camera ID. No random effect for camera model was included because the cameras were all

276   the same model in this analysis.

277   *Diel patterns*–In addition to comparing detection rates across space, we analyzed temporal

278   variation in response to human recreation by summarizing daily diel overlap between people and

279   wildlife across trail types. We assessed diel patterns using detection histograms and calculated

280   coefficients of temporal overlap (Δ) to quantify behavioral displacement of wildlife from people

281   on recreation trails, adjacent wildlife trails, and the wildlife trails across the broader landscape.

282   People were primarily detected on recreational trails and thus we compared the use of wildlife

283   during this period of high human use on the recreation trails to assess if animals not facing this

284   same level of human use still avoid these times or not.

285   *Near encounters*–To quantify how often large mammals were detected soon before or after

286   recreationists, we paired every biker and hiker detection on single-track trails with all detections

287   of black bears, grizzly bears, or moose at the same camera. We selected these animals as

288   they are the primary species that can be dangerous to people and were frequently detected in the

289   trail network. We then kept only the closest-in-time wildlife detection for each species and

290   recreation event. We calculated the time difference in minutes and summarized how often

291   wildlife detections occurred within 30 minutes and within 5 minutes of people. We visualized

292   these "near encounters" by species and recreation type.

293

294   *Collared Grizzly Bears*

295   Grizzly bears were collared throughout the Elk Valley between 2016-2024 as part of a study to

296   assess population demography (Lamb et al. 2023). Although the study goal was not to assess

297   recreational impacts on bear behaviour, we are able to leverage these data as part of our multi-

298   lines of inference approach given the abundance of grizzly bear telemetry around Fernie. Full

299   details on the grizzly bear capture and handling and relevant permits are summarized in (Lamb et

300   al. 2023). Briefly, the bears we considered here were collared with Vectronics Vertex Lite GPS

301   collars programmed to take locations every 2 hours during the active season for grizzly bears

302   (April to December). The data was transmitted via Iridium satellite. We collared all age and sex

303   classes except animals <2 years of age due to challenges fitting collars to these rapidly growing

304   young bears. For this analysis we used location data for bears with at least 50 locations within 10

305   km of Fernie between May 1-October 31 across years.

306   *Grizzly Bear Integrated Step Selection Analysis*

307   We used integrated step selection analysis (iSSA) to evaluate how large mammals respond to

308   human recreation and habitat features in the Fernie region of British Columbia (Avgar et al.

309   2016). Step selection functions were implemented using conditional Poisson regression with

310   random effects, which is mathematically equivalent to conditional logistic regression but enables

311   more flexible estimation of random slopes and intercepts using generalized linear mixed models

312   (GLMMs) (Muff et al. 2020).

313   For each GPS-collared animal, observed steps were paired with a set of ten random

314   available steps drawn from the empirical step length and turn angle distribution, forming

315   matched strata of one "used" and ten "available" steps. We then fit iSSA models using the

316   glmmTMB package (v1.1.7) in R, with a binary response variable (where 1 = used step and 0 =

317   available), family = poisson, and a random intercept for each stratum to condition the analysis

318   within each matched set.

319   The fixed effect's structure included habitat covariates (e.g., land cover type, elevation,

320   summer greenness [EVI]), topographic complexity (TRI), and several measures of anthropogenic

321   influence, including distance to trail, highway, and rural development, as well as semipermeable

322   barrier effects. Movement covariates included step length (log-transformed), turn angle (cosine),

323   and their interaction (e.g., cos_ta:log_sl_km) to capture behavioral state transitions. We also

324   included habitat-by-movement interactions (e.g., cos_ta:dist_to_trail) to allow for context-

325   dependent movement decisions.

326   To account for variation in selection across individuals and seasons, we included random

327   slopes by individual ((0 + covariate | id)) for key habitat, movement, and barrier variables, and a

328   random slope for elevation by month to account for seasonal effects ((0 + elevation_end |

329   month)). All continuous covariates were standardized prior to modeling to facilitate convergence

330   and comparability of coefficients.

331   We used a candidate model approach to evaluate how outdoor recreation and

332   environmental covariates influenced step selection by wildlife. We began with a core set of

333   ecological and movement covariates and iteratively added disturbance and barrier terms to

334   construct biologically plausible models. Each candidate model was evaluated using AIC and the

335   top model was selected based on parsimony and fit.

336   To assess model stability and performance, we examined predicted values to ensure no

337   extreme or implausible outputs and checked for convergence warnings. Due to the structure of

338   iSSA data—particularly the large number of strata and design-imposed zeros—we did not use

339   residual simulation tools such as DHARMa, which are known to perform poorly under these

340   conditions.

341

342   **Results**

343   *Camera Traps*

344 Cameras operated in the Fernie trail network for 13, 698 trap nights between May 1, 2021, and

345 October 31, 2024, and captured 1,739,387 images. After removing empty images and classifying

346 unique detections (images 10 minutes apart) there were 98,499 detections. Of these detections,

347 88,558 were of people, 43 of domestic species, and 9,451 were of wildlife (Table 1). Mountain

348 bikers were the most detected recreational group on the cameras. White-tailed and mule deer

349 were the most detected wildlife. Several species were detected at low rates (<30 detections) such

350 as bobcats, badgers, wolverine, and a mountain goat and were not used in subsequent analyses

351 due to their rarity. We focus our analyses on 7 large/medium mammal species with > 30

352 detections each (white-tailed deer, mule deer, elk, red fox, moose, black bear, and grizzly bear).

353

354 *Table 1. Summary of detections by species at Fernie Trail Network cameras between May and*

355 *October each year between 2021-2024*

Group	Species	Sites	Detections	Hit rate per 100 days
Human	bike	19	73346	535.5
Human	human	28	14666	107.1
Human	all terrain vehicle	8	286	2.1
Human	vehicle	5	242	1.8
Human	heavy equipment	2	18	0.1
Wild	white-tailed deer	28	3611	32.6
Wild	mule deer	27	2008	17.9
Wild	elk	27	1382	13.4
Wild	red fox	22	908	6.7

Wild	moose	26	670	5.7
Wild	black bear	28	464	3.8
Wild	deer	24	141	1.1
Wild	grizzly bear	20	101	1
Wild	snowshoe hare	7	85	0.6
Wild	gray wolf	11	22	0.2
Wild	cougar	9	14	0.1
Wild	bird	9	13	0.1
Wild	coyote	8	10	0.1
Wild	porcupine	6	7	0.1

356

357   *Camera Statistical Analysis*

358   *Intensity of use*— Across species, trail type and its' surrounding habitat influenced detection

359   probabilities and relative abundance, but effects varied by species and by model component

360   (presence vs. abundance). Trail contrasts were assessed both between the Mt. Fernie trail

361   network and the broader valley, and within the trail network (wildlife vs. recreation trails, Figure

362   2).

363   Humans and bikers were overwhelmingly detected on recreation trails. Presence and

364   abundance (given presence) were significantly higher in the Mt. Fernie trail network compared to

365   Landscape-valley sites (human presence Odds Ratio (OR) >120, $p < 0.001$; abundance ratio >8,

366   $p < 0.001$, although bike model struggled with convergence due to near zero bikes detected at

367   Landscape-valley sites). Within the trail network, detections were strongly concentrated on

368   recreation trails (presence OR>55, p < 0.001; abundance ratio >626, p < 0.001).

369   Black bears presence was higher within the trail network overall compared to Landscape-

370   valley sites (OR ≈ 3.6, p ≈ 0.022) and showed significantly higher presence on wildlife trails

371   within the trail network compared to Landscape-valley sites (OR ≈ 4.7, p ≈ 0.016). Black bear

372   abundance did not differ significantly across contexts when present. Elk occurred more

373   frequently in Landscape-valley sites than in the Mt. Fernie trail network (OR ≈ 26.7, p ≈ 0.013).

374   Within the trail network, they were more likely to occur on wildlife trails than Recreation trails

375   (OR ≈ 2.6, p ≈ 0.065), consistent with the near-zero detections on recreation trails. Grizzly bears

376   were detected infrequently, but trail type affected their probability of occurrence. Abundance

377   was lower on the Mt Fernie trail network than Landscape-valley sites (abundance ratio ≈ 0.45, p

378   ≈ 0.06), but presence appeared unaffected. Within the Mt Fernie trail network, Grizzly bear

379   presence was higher on recreation trails than wildlife trails (OR ≈ 4.7, p ≈ 0.001).

380   Moose showed the opposite pattern. Both presence and abundance were significantly

381   higher in the trail network compared to Landscape-valley sites (presence OR ≈ 59.9, p < 0.001;

382   abundance ratio ≈ 3.2, p ≈ 0.014). Moose were most often detected on recreation trails, but

383   differences between recreation and wildlife trails within the trail network were not significant.

384   Mule deer followed a similar trend to moose. Presence and relative abundance was higher on

385   recreation trails than wildlife trails within the Mt Fernie trail network (presence OR ≈ 3.2, p <

386   0.015; abundance ratio >1.8, p ≈ 0.07). Landscape-level differences in mule deer detections

387   between the Mt Fernie trail network and Landscape-valley sites were not notable.

388   Red foxes were significantly more likely to occur in the Mt Fernie trail network than in

389   the Landscape-valley sites (presence OR ≈ 16.4, p <0.001) and were more abundant on

390   recreation trails than on wildlife trails (abundance ratio ≈ 3.7, p ≈ 0.005), leading to the highest

391   expected detections on recreation trails. White-tailed deer showed somewhat higher detection

392   rates at Landscape-valley sites than the Mt Fernie trail, but none of the presence or abundance

393   contrasts reached statistical significance. Cougars and gray wolves were rarely detected, and

394   models generally did not converge for these species. We did not consider either species in

395   subsequent analyses.

396   Species varied in their responses to local recreation activity on single-track trails, but the

397   strength and direction of effects differed by species and model component (presence vs.

398   abundance, Figure 3). Elk showed the strongest evidence of recreation avoidance: both the

399   probability of occurrence (β ≈ −0.37, p ≈ 0.002) and expected abundance (β ≈ −0.15, p ≈ 0.038)

400   declined significantly with higher recreation use — a stronger effect than any local habitat

401   variable in the model.

402   In contrast, mule deer and moose showed positive associations with recreation activity.

403   Mule deer were more frequently detected in areas with greater recreation use, with positive

404   effects on both presence (β ≈ 0.25, p ≈ 0.069) and relative abundance (β ≈ 0.14, p ≈ 0.036),

405   although these effects were moderate in size. Moose also showed a significant increase in

406   relative abundance with higher recreation levels (β ≈ +0.32, p ≈ 0.009), but presence was not

407   significantly affected (β ≈ +0.11, p = 0.48).

408   Red fox, black bear, white-tailed deer, and grizzly bear showed no clear relationship with

409   local recreation levels. For these species, both presence and abundance estimates were small and

410   statistically non-significant (p > 0.1), indicating little to no consistent response to trail use

411   intensity.

412   *Diel patterns*— Hikers and bikers were active almost entirely during daylight hours on single-

413   track trails, with detections peaking from about 9 AM to 8 PM. All wildlife species showed

414   strongly crepuscular or nocturnal activity overall, with lower detections during these core

415   human-use periods (Figure 4).

416   The overlap estimates reflect how closely each wildlife species' daily activity on

417   recreation trails, wildlife trails, landscape-valley, and landscape-remote coincides with the peak

418   periods of recreation use on recreation trails, hereafter called the recreation period (Figure 5). In

419   this analysis we incorporate the Landscape-remote cameras, which capture animal behaviour in

420   higher elevation areas with much lower human pressure than the other areas and perhaps serve as

421   a comparison for behavior that is less impacted by people. Black bears had moderately lower diel

422   overlap with recreation periods on recreation trails (mean ≈ 0.62) than on adjacent wildlife trails

423   (0.74; $\Delta = -0.13$, $p < 0.10$). However, overlap did not differ significantly between recreation

424   trails and landscape-valley or landscape-remote sites. Elk exhibited clear diel avoidance: overlap

425   on recreation trails (0.28) was significantly lower than on adjacent wildlife trails (0.40),

426   landscape-valley sites (0.31), and especially landscape-remote sites (0.51). The greatest contrast

427   was between recreation trails and landscape-remote sites ($\Delta \approx -0.24$, $p < 0.10$), indicating strong

428   temporal shifts away from human-dominated periods on busy trails. Grizzly bears showed

429   moderate diel differences, with significantly lower overlap on recreation trails (0.44) than in

430   landscape-remote areas (0.62; $\Delta \approx -0.15$, $p < 0.10$). Overlap on recreation trails vs. landscape-

431   valley sites was slightly higher (Δ ≈ 0.12) but not statistically significant, and no estimate was

432   available for wildlife trails due to too few detections.

433   Moose showed minimal diel variation across contexts. Overlap estimates ranged from

434   0.43 (recreation trail) to 0.50 (landscape-remote), with only a small difference between

435   recreation trails and remote sites (Δ ≈ –0.07, $p < 0.10$), suggesting modest temporal avoidance of

436   peak human use. Mule deer had broadly consistent overlap across locations but showed

437   significantly lower overlap at landscape-remote sites (0.44) compared to recreation trails (0.51; Δ

438   ≈ -0.09, $p < 0.10$). Slight differences from recreation to wildlife trails (Δ ≈ –0.03) or landscape-

439   valley (Δ ≈ –0.01) were not significant.

440   Red foxes exhibited the strongest diel shift: overlap was much lower on recreation trails

441   (0.18) than on wildlife trails (0.41; Δ ≈ –0.25, $p < 0.10$) and valley sites (0.41; Δ ≈ –0.23, $p <$

442   0.10), consistent with strong temporal avoidance of human activity in high-use areas.

443   Comparisons with landscape-remote sites were not possible due to too few detections. White-

444   tailed deer showed slightly lower diel overlap in landscape-valley and remote contexts (≈0.40–

445   0.44) compared to recreation trails (0.53), with significantly higher overlap on recreation trails

446   vs. landscape-valley (Δ ≈ 0.13, $p < 0.10$) and vs. landscape-remote sites (Δ ≈ 0.08, $p < 0.10$).

447   This pattern suggests a tolerance of daytime human activity.

448   *Near encounters–* Across all recreation trail detections, only a small fraction of recreation events

449   were associated with close-in-time wildlife detections. For black bears and moose, about 0.1% of

450   recreation events had a wildlife detection within 30 minutes (149 and 148 cases respectively),

451   and around 0.02% fell within just 5 minutes. Grizzly bears showed even lower overlap, with only

452   0.015% of recreation events within 30 minutes (19 cases) and fewer than 1 in 1000 within 5

453   minutes (1 case). Histograms show that most close calls clustered within 5–30 minutes, with no

454   strong bias toward bikers or hikers for any species (Figure 6).

455

456   *Collared Grizzly Bears*

457   After sub-setting to the focal area around Fernie and the desired seasonal window we retained

458   19,489 GPS collar locations from 21 grizzly bears between June 2017 and October 2024. An

459   average of 928 locations per bear were collected within the focal area, which ranged from 61-

460   3,012 locations across all 21 bears.

461   *Grizzly Bear Integrated Step Selection Analysis*

462   A suite of candidate iSSA models was compared using AIC to evaluate drivers of wildlife

463   movement. The best-supported model included trail distance, town distance, and highway effects

464   (AIC = 394,212), outperforming all alternatives by ≥34 AIC units. This suggests that the

465   combined influence of multiple anthropogenic features best explains movement behavior, with

466   trails emerging as particularly influential (Figure 7).

467   Among fixed effects, animals selected areas with higher summer greenness (EVI $\beta = 0.44$, $p <$

468   0.001) and avoided steep elevation gains (Δelev $\beta = -0.37$, $p < 0.001$). Distance to trails

469   significantly increased selection ($\beta = 0.088$, $p = 0.016$), indicating avoidance of trail-adjacent

470   areas. Crossing trails further reduced selection ($\beta = -0.23$, $p < 0.001$), an effect of smaller

471   magnitude to barrier effects from highways ($\beta = -0.50$) and rivers ($\beta = -0.68$). Trail-related

472   avoidance was notable but generally weaker than town and highway effects. Step–trail

473   interactions revealed that animals took longer steps when closer to trails ($\beta = -0.044$, $p < 0.001$),

474   suggesting faster movement near recreation infrastructure. Random slopes revealed substantial

475   individual variation, particularly for barrier responses.
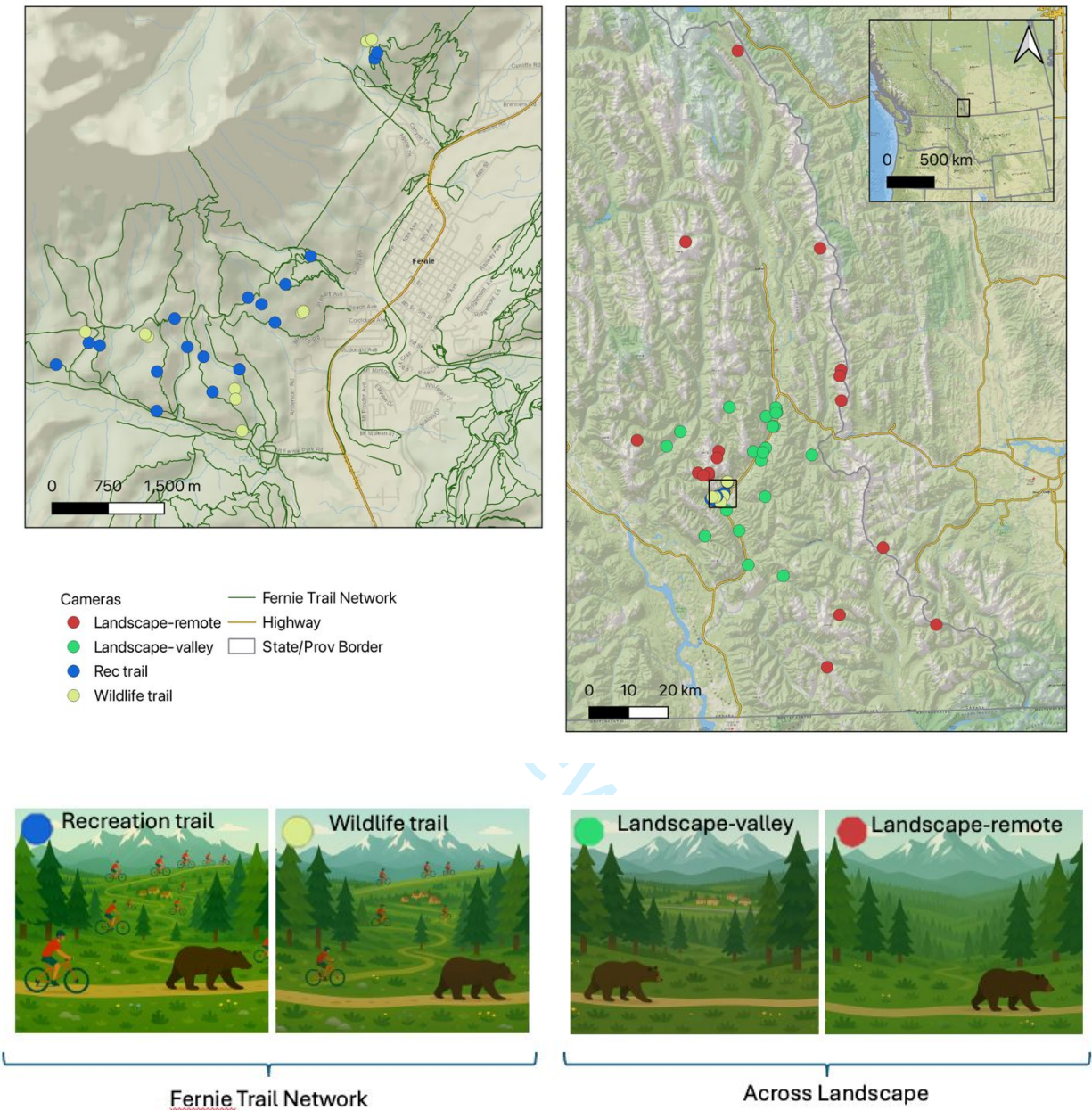

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479   *Figure 1. Map of study area near Fernie, BC, Canada in the southern Canadian Rockies. The*

480   *Fernie trail network was assessed west and north of Fernie BC on the slopes of Mount Fernie*

481   *and Mount Proctor with cameras on wildlife trails and recreation trails. Landscape-level*

482   *comparisons across these habitat contexts were made with ancillary data from neighboring*

483   *camera projects where landscape-valley were in similar habitats and a multi-use landscape to*

484   *the Fernie trail network cameras but with less overall non-motorized recreation pressure.*

485   *Landscape-remote were on wildlife trails in areas with lower levels of human pressures*

486   *compared to the other cameras but were also in different habitats (often higher elevation) and*

487   *not thus intensity of use at these cameras were not as directly comparable to other cameras.*

488   *Landscape-remote cameras were also on wildlife trails and used as a baseline for diel patterns*
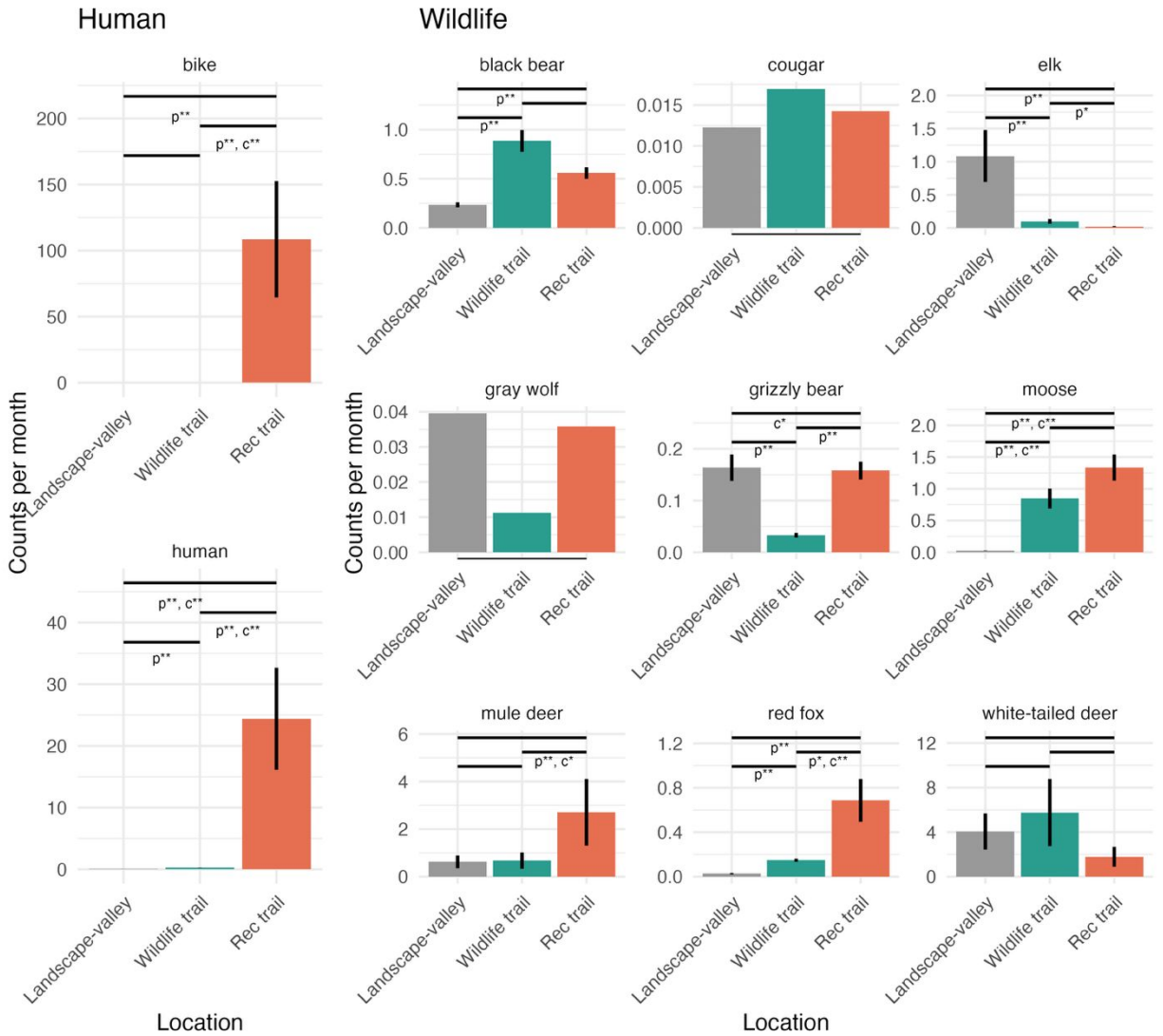
489   *in wilder areas.*

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Figure 2. Intensity of use (monthly detection rate) assessments for human and wildlife groups

across three zones. Results are predictions from a GLMM, and statistical significance shown as

* for p<0.1 and ** for p<0.05 for presence (p) and relative abundance counts (c) under the

applicable bar. Horizontal Bars indicate comparison between groups. The horizontal bar

spanning the full width is a combined comparison between landscape-valley and the Mt Fernie

trail network (i.e., wildlife and recreation trails pooled). Cougar and gray wolf did not have

sufficient detections for model convergence and were excluded from subsequent analyses.
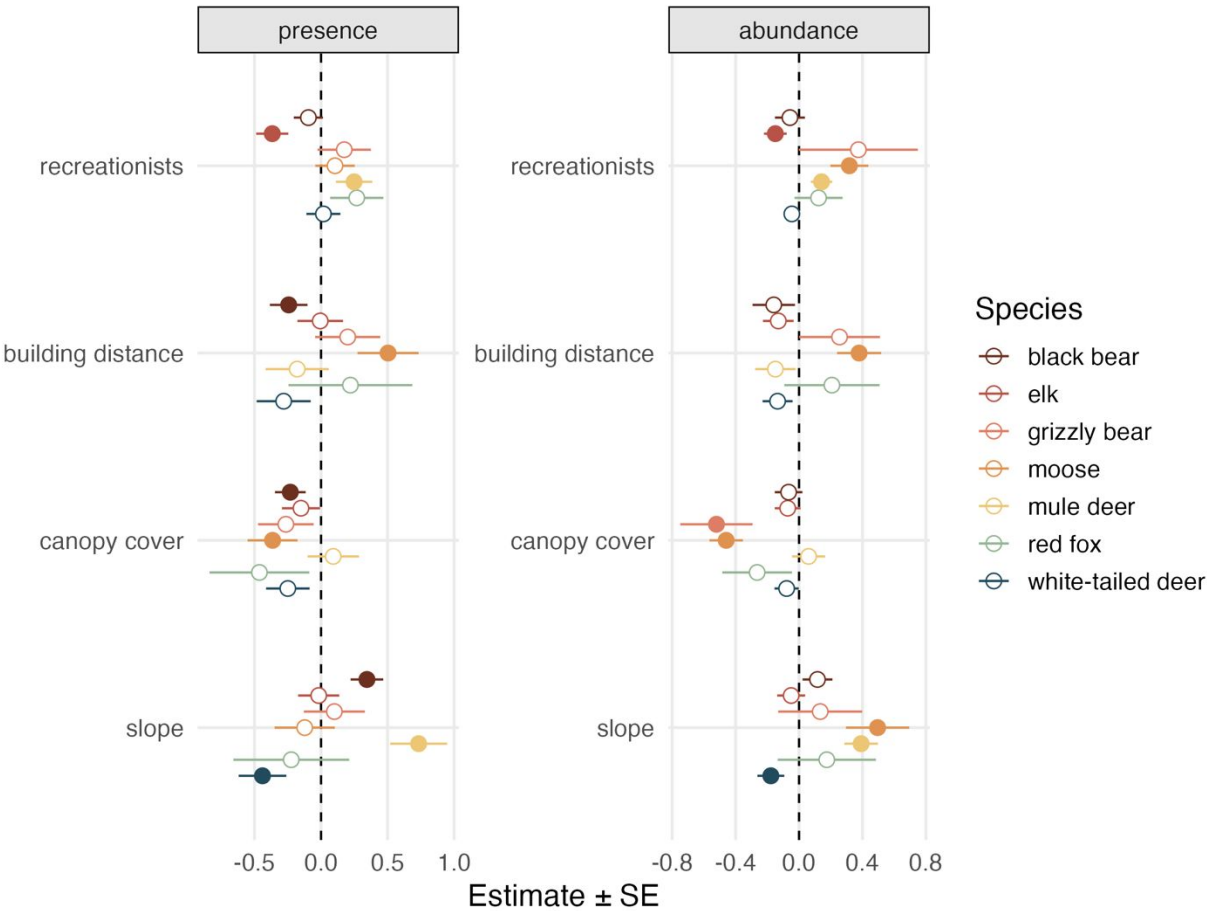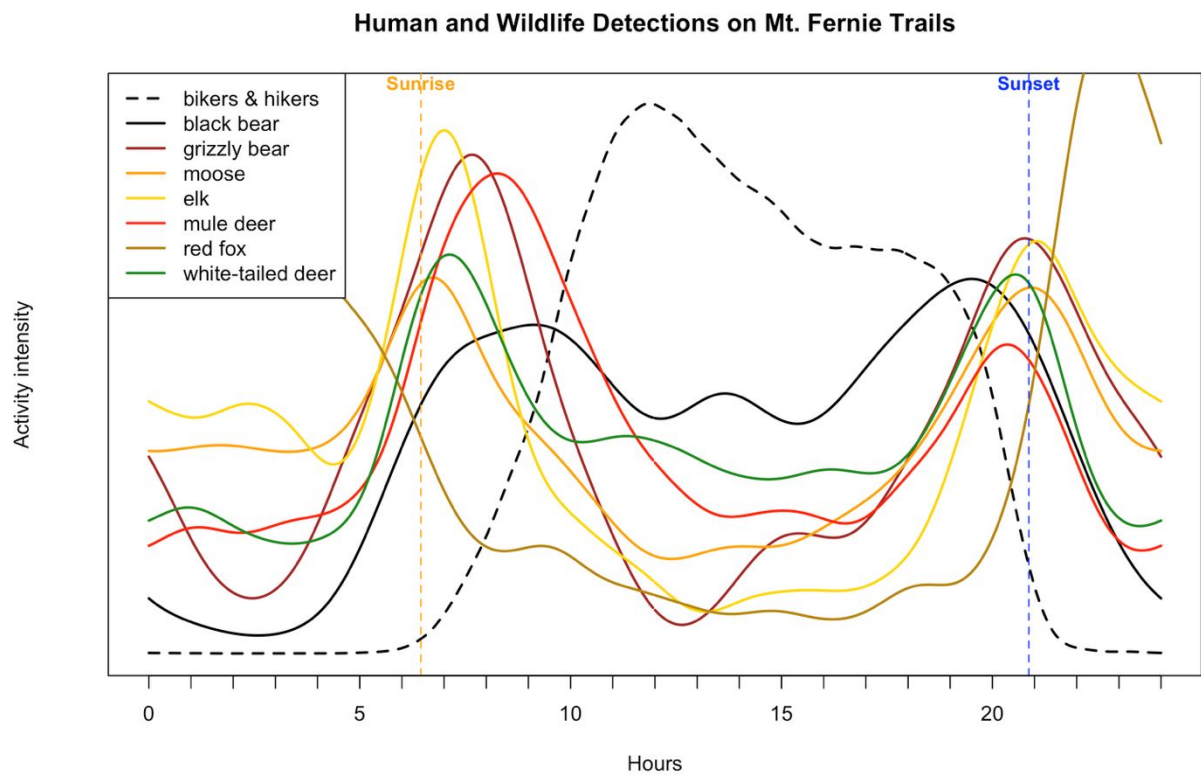
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Figure 3. Influence of the number of recreationists on wildlife detections by species on

recreation trails in the Fernie trail network. Ancillary habitat variables included to control for

additional variation and compare magnitude of response. Filled dots signify statistical

significance at p<0.1.

Human and Wildlife Detections on Mt. Fernie Trails

Figure 4. Diel patterns of wildlife and human recreation on recreation trails in the Fernie trail network.
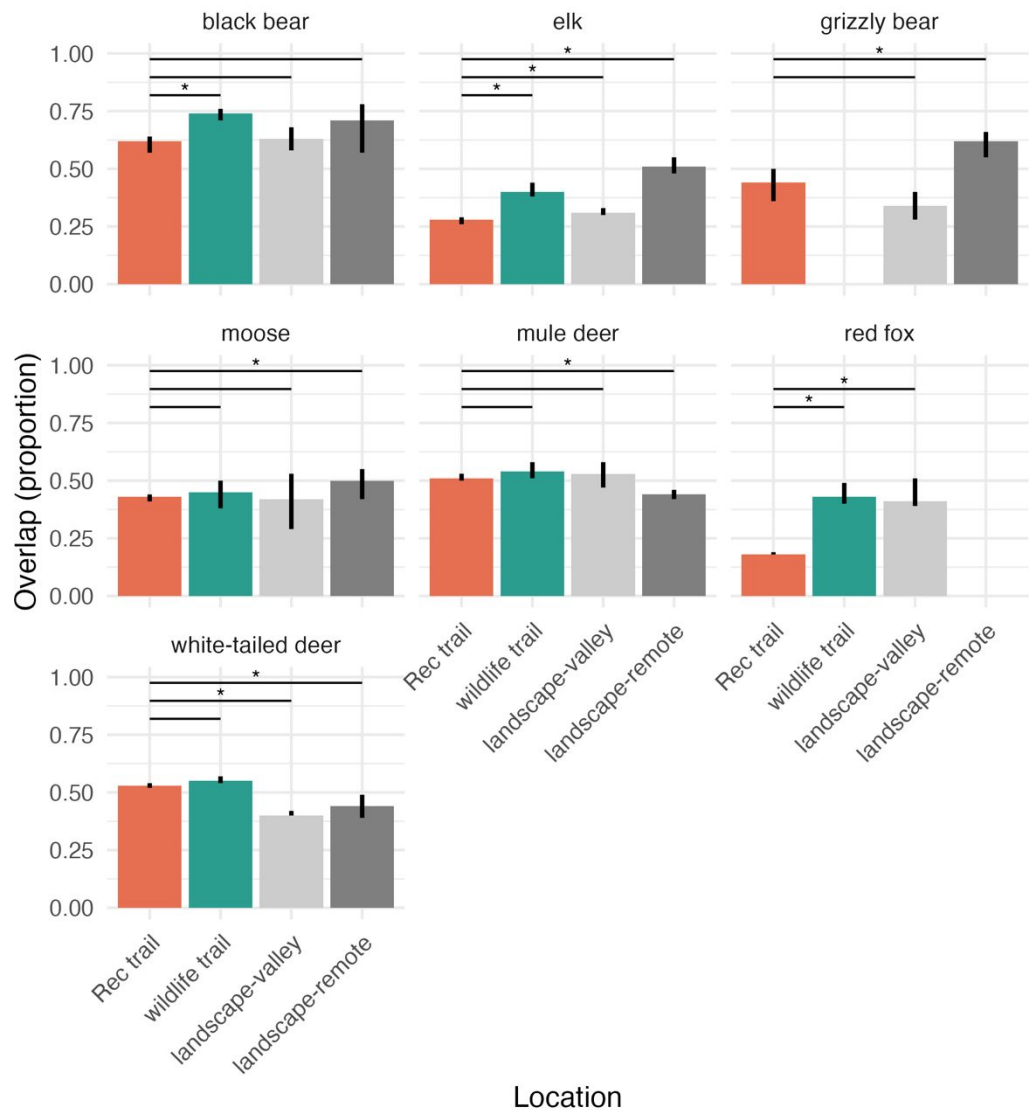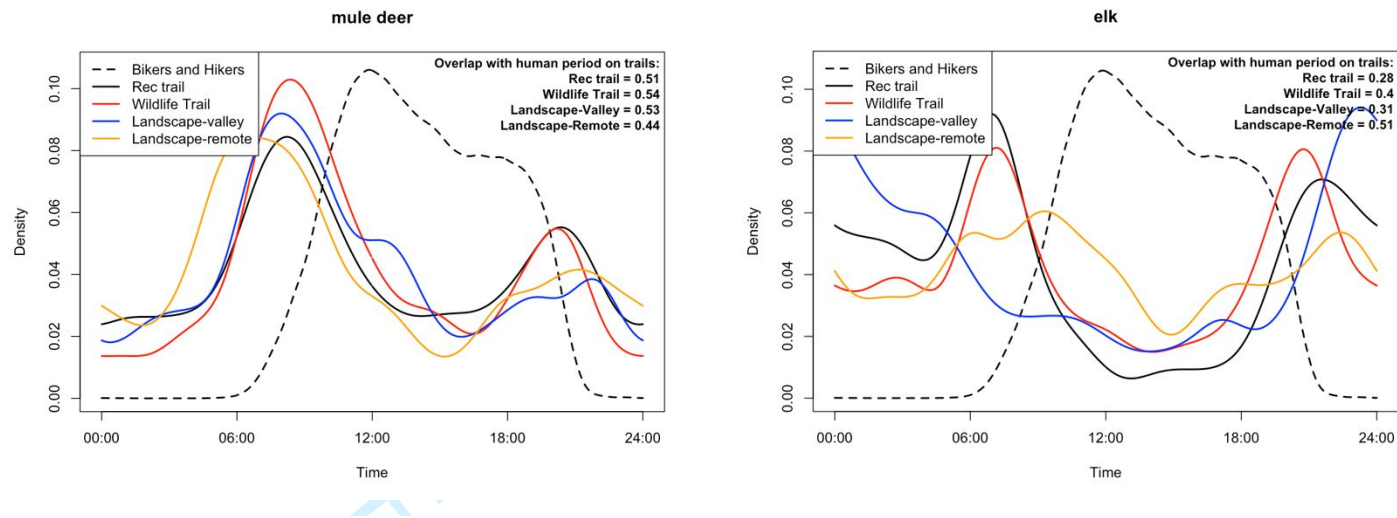
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516   *Figure 5. top left) Comparison of recreation, wildlife, and larger landscape diel patterns for*

517   *mule deer which show little diel changes across habitat context, top right) Comparison of*

518   *recreation, wildlife, and larger landscape diel patterns for elk that show more daytime activity in*

519   *remote areas, bottom) average overlap with peak recreation time from recreation trails between*

520   *trail types for all species and areas.*

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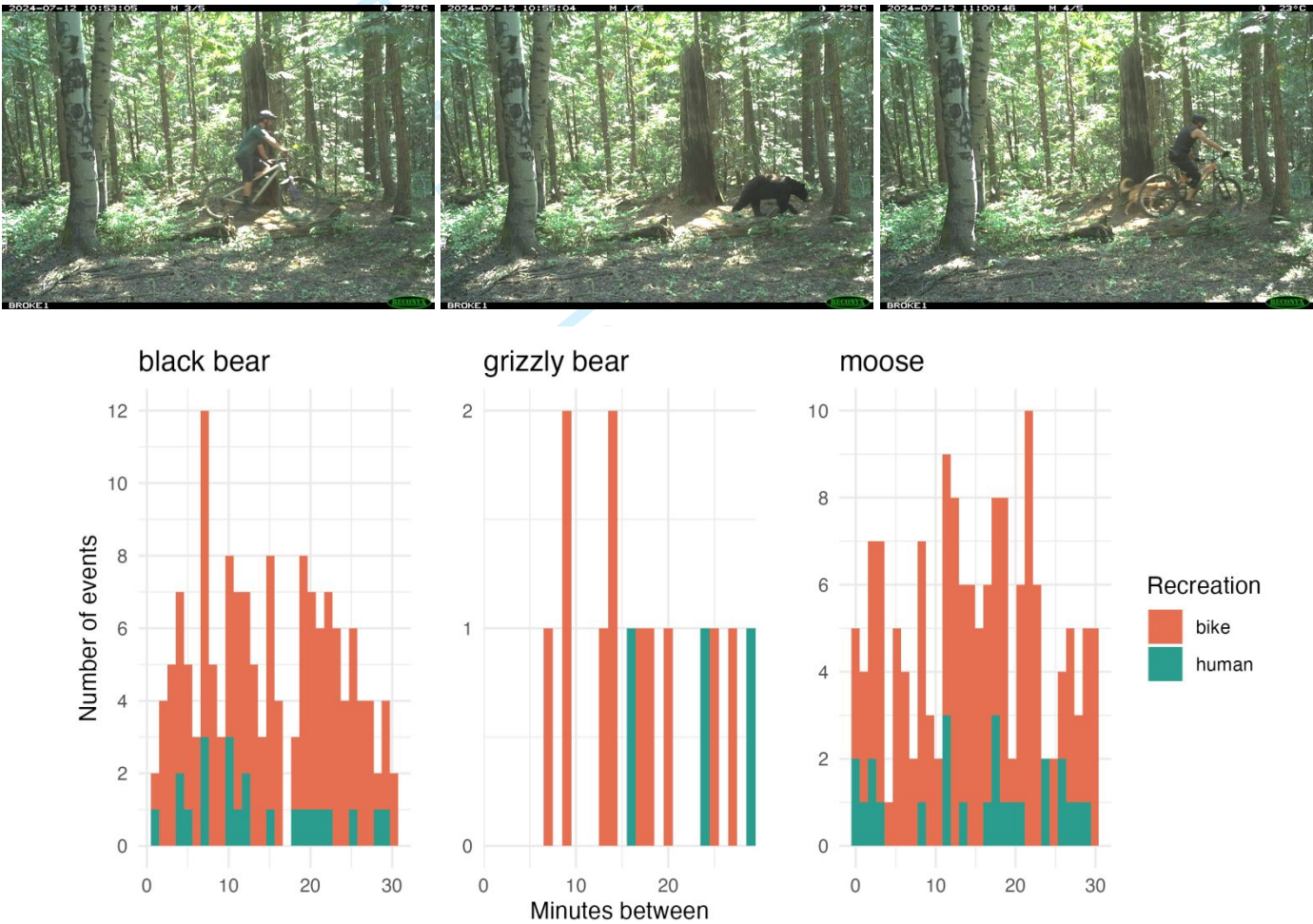524

525

526   *Figure 6. Near encounters between recreationists and three species of wildlife that can be*

527   *dangerous to people. top) Example sequence showing bikers detected 2 minutes before and 5*

528   *minutes after a black bear on a single-track trail, and bottom) histogram of minutes between*

529   *recreationists and select wildlife species between 2021-2024.*

530

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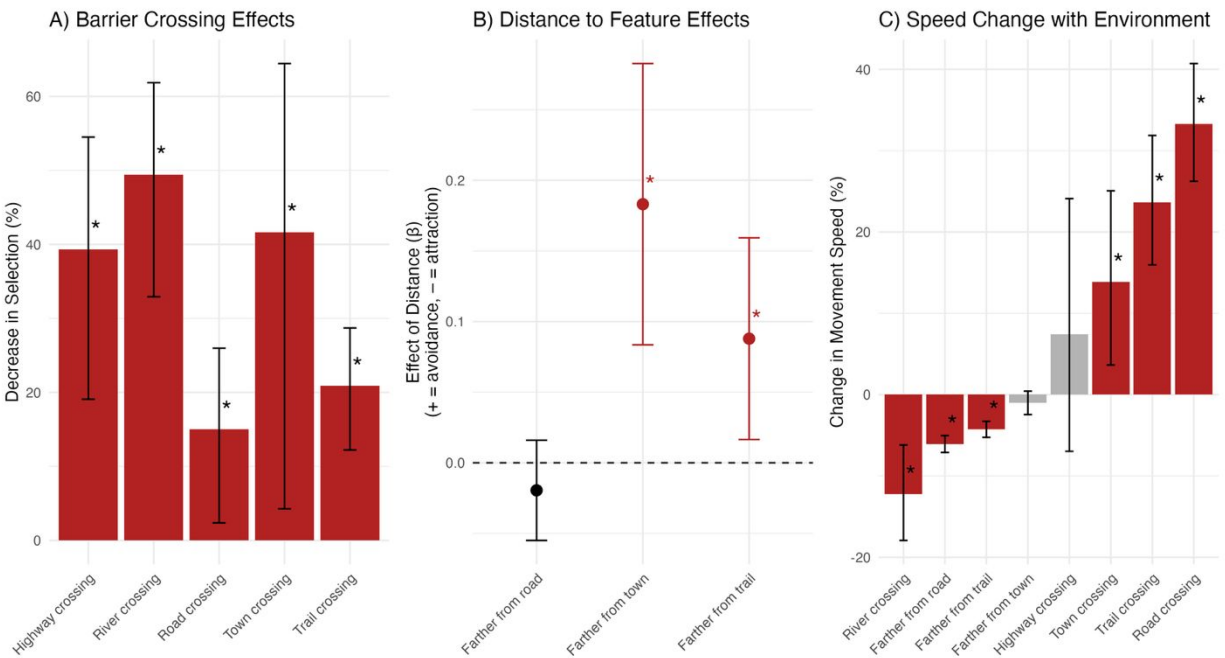532   *Figure 7. Integrated step selection results for grizzly bears near Fernie, BC. Response to human*

533   *features shown A)decrease in selection for crossing various human features, B) effect of*

534   *distance to human features. Note highway not included here due to covariance with distance to*

535   *town, and C) change in movement speed in various contexts.*

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539

540   *Table 2. Summary of recreation effects across scales and species.*

Selection Order	3rd			4th	
Species	*Response to trail network at landscape scale*	*Fine scale use of trails vs nearby wildlife trail*	*Use of single-track trails with increasing recreational pressure*	*diel patterns on trails when people are active*	**Overall effect**
Black bear	selection	neutral	neutral	avoidance	Landscape selection, avoidance/coexistenc
Elk	avoidance	avoidance	avoidance	avoidance	Landscape avoidance
Grizzly bear	avoidance	selection	neutral	avoidance	Landscape avoidance
Moose	selection	neutral	selection	avoidance	Landscape selection,
Mule deer	selection	neutral	selection	neutral	Landscape selection,
Red fox	selection	selection	neutral	avoidance	Landscape selection,
White-tailed deer	neutral	neutral	neutral	selection	Landscape neutral, fin

541

542

Discussion

544   Our study revealed that large mammal responses to non-motorized recreation in the Southern

545   Canadian Rockies varied considerably among species, spatial scales, and behavioral metrics. Elk

546   and grizzly bears showed avoidance of recreation at landscape and trail scales, whereas black

547   bear, moose, mule deer, white-tailed deer, and red fox exhibited tolerance or behavioral

548   adaptations such as diel shifts in activity. The goal of our study was to add to the growing body

549   of literature on wildlife responses to recreational pressure and provide wildlife managers with

550   locally relevant information to inform decisions, given previous research documented substantial

551   species and context-specific responses to recreation (e.g., (Naidoo and Burton 2020, Miller et al.

552   2020, Procko et al. 2022, Granados et al. 2023, Jordan et al. 2025)).

553   Overall, our hypothesis of strong and negative responses to recreation across species was

554   rejected. Instead, and perhaps inconvenient for management, we observed variable and scale-

555   dependent responses in several species. Elk, for example, exhibited avoidance of recreational

556   areas at both broad (third order) and fine (fourth order) scales, suggesting that recreation may

557   displace individuals from otherwise suitable habitat. Grizzly bears showed moderate landscape-

558   scale avoidance of trail networks in GPS and camera data but appeared to select for recreational

559   trails rather than wildlife trails as travel corridors when moving through the trail network. In

560   contrast, red foxes did not show strong spatial avoidance but shifted their activity patterns to

561   avoid humans temporally. It is likely that landscape-scale avoidance may be more indicative of

562   demographic consequences such as reduced abundance due to loss of habitat, whereas diel

563   behavioral shifts may reflect a more flexible, potentially less costly strategy of coexistence.

564   The variation in responses among species likely reflects both intrinsic traits, such as body

565   size, trophic position, and anti-predator strategies, and extrinsic factors including recreation

566   intensity, trail design, and predictability of human presence. Conceptual frameworks such as the

567   "landscape of fear" (Brown et al. 1999), "risk-disturbance hypothesis" (Frid and Dill 2002), and

568   the "human shield hypothesis" (Berger 2007) have been proposed to explain these patterns. The

569   landscape of fear framework suggests that animals perceive and respond to spatial variation in

570   predation risk, often avoiding areas they associate with danger—even if those areas contain

571   valuable resources (Brown et al. 1999). Building on this, the risk-disturbance hypothesis posits

572   that wildlife treat human disturbance as a form of predation risk, leading to anti-predator

573   behaviors such as avoidance, increased vigilance, or altered activity patterns in areas used by

574   people (Frid and Dill 2002). Because some wildlife avoid people, the human shield hypothesis

575   proposes that some prey species may benefit from human presence by using areas near people as

576   refuges from natural predators, who themselves avoid humans (Berger 2007). Empirical results

577   provide mixed support for these hypotheses in explaining the variation among species and scales

578   in response to recreation. Multi-species analyses often show some species had positive responses

579   to recreation (Naidoo and Burton 2020, Procko et al. 2022, Fennell et al. 2023, Granados et al.

580   2023), suggesting the risk-disturbance hypothesis does not explain recreation effects as whole.

581   Support for the landscape of fear and human shield also remain mixed with cases of predator and

582   prey selecting for recreation trails (Granados et al. 2023), but others showing some support for

583   avoidance of recreation trails by large predators and selection by prey (Procko et al. 2022,

584   Fennell et al. 2023).

585   Our findings provide additional insights. Prey species showed mixed responses to

586   recreation with clear avoidance by elk and selection by mule deer and moose, suggesting that

587   there is not widespread support for the landscape of fear or risk-disturbance hypotheses. We had

588   limited data to fully assess the human shield hypothesis, however the one large predator, grizzly

589   bear, that we had sufficient data for did appear to avoid the area due to recreation pressure.

590   Limited data on cougar and wolves reduced our ability to assess the response of the full large

591   predator community but the anectodical evidence we had showed cougars detected at similar

592   levels within the trail network compared to the surrounding landscape and perhaps some

593   avoidance by wolves. Regardless, because the primary prey of these large carnivores did not

594   show consistent selection or avoidance of the area and thus the human shield hypothesis is not an

595   explanation for the responses of all species in the Fernie trail network.

596   The response of elk to recreation was among the most consistent and negative of all

597   species in our study. Elk were significantly less likely to occur within the trail network compared

598   to the broader landscape, and within the trail network, they were less likely to use trails than

599   adjacent off-trail areas. When using recreation trails, elk were more likely to use trails with fewer

600 recreational users—the only species with this response. These multiple lines of evidence suggest

601 that recreation may displace elk from otherwise suitable habitat, consistent with other studies

602 showing elk sensitivity to human activity (e.g., Procko et al. 2024, Jordan et al. 2025). Elk

603 avoided daytime periods on recreation trails more than they do in remote areas and wildlife trails

604 within the Fernie trail network. However, elk generally had low use of daytime periods on

605 recreational trails, wildlife trails, and the landscape-valley cameras compared to landscape-

606 remote cameras suggesting the avoidance of daytime on the recreation trails may not solely be

607 due to recreation effects and may be a response to additional human pressures such as towns,

608 roads, or hunting pressure. Overall the strong response of elk to recreation in our study and

609 others seems to juxtapose with concurrent observations of elk becoming a nuisance in human-

610 dominated areas such as agricultural fields and even in towns (Wilmers and Levi 2013, Guthrie

611 2020, Rutherford et al. 2025r). Resolving this juxtaposition was not a focus of our study but

612 clearly demonstrates the multiple competing pressures that elk are responding to in a multi-use

613 landscape. In the case of agricultural conflicts, the reduced prevalence of hunters and predators

614 on working ranches paired with productive forage results in dense congregations of elk. Clearly

615 human presence thus does not always produce negative responses in elk, and when human

616 presence also provides productive habitat and mortality reduction elk can be found in great

617 numbers. There are other examples where elk congregate near people and disturbance such as

618 open pit coal mines in the Elk Valley where hunters and predators are likely fewer and patches of

619 reclaimed areas can temporarily provide nutrient dense food (Poole et al. 2024). Indeed elk do

620 appear to show a functional response in selection for human footprint that depends on the level

621 of human footprint they are continually exposed to suggesting habituation and synanthropy

622 (Gaynor et al. 2025). Elk likely avoid recreation trails because the trade-off of being disturbed by

623   recreationists is not offset by benefits such as better forage and there is not sufficient predator or

624   hunter avoidance of these areas. One prediction from this would be that if recreational use was

625   more intense in the Fernie trail network and as a result predators avoided the area more, and

626   forage was increased through habitat restoration, then elk may have reduced or positive

627   responses. Such a prediction would require testing, and such increased recreational intensity

628   would continue to come with trade-offs for other species and recreationist.

629   Grizzly bears displayed a complex response to non-motorized recreation. At a broad

630   scale, GPS data indicated moderate avoidance of the Mt. Fernie trail network relative to the

631   surrounding valley landscape. Within the network, however, camera data showed grizzly bears

632   were more likely to use recreation trails than adjacent wildlife trails, but overall, the use of the

633   trails within the Mt Fernie network (wildlife and recreation trails) was lower than the

634   surrounding landscape. This apparent selection for recreation trails compared to wildlife trails

635   within the trail network may reflect efficient travel along predictable corridors, which is

636   consistent with the step selection analysis that shows bears moving faster when using the trail

637   network. The overall low detection rates within the trail network and moderate avoidance of

638   high-use zones suggest that trail use by grizzly bears is limited to periods or areas with lower

639   human activity. This dual pattern of broad-scale avoidance and localized, functional trail use is

640   consistent with a risk-management strategy in which bears minimize overlap with people while

641   exploiting the linear features for movement when safe to do so. Similar to elk, grizzly bears were

642   more nocturnal within the Fernie trail network and landscape-valley trails than the landscape-

643   remote cameras suggesting human effects beyond just recreation are causing bears to alter their

644   behaviour. The iSSA analysis provides important context of bears' response to other competing

645   human pressures. While bears avoided the trail network, they more strongly avoided settled areas

646   such as the area around the town of Fernie, thus the effects detected from cameras within the

647   Fernie trail network must be considered with cumulative effects of additional pressures of the

648   town, highway, and roads in mind. Bears avoided crossing the recreation trails and resource

649   roads, but not nearly as much as they avoided crossing the town, or highway.

650   From a management perspective, our results indicated that non-motorized recreation can

651   influence wildlife habitat use and behavior, but effects were species- and context-specific. It is

652   our perspective that overall, the behavioural effects of recreation were moderate to low for the

653   species we considered, especially considering the currently compact footprint of the trail network

654   relative to the surrounding landscape. Of the species considered, elk and grizzly bear were the

655   primary species that showed negative effects, with elk showing the most consistent and strong

656   responses. Mitigating the negative effects to elk and grizzly bear could be accomplished by

657   concentrating recreation in high-use, predictable areas such as those around existing towns. Such

658   an approach reduces the spatial extent of disturbance because the towns themselves already have

659   a buffer of impacts around them and provides low use refugia for more sensitive species in the

660   areas outside the concentrated recreation areas. Seasonal or spatial closures may be warranted in

661   areas that overlap with key habitats or during vulnerable periods such as bighorn sheep lambing

662   areas or bear dens. To protect the nocturnal and crepuscular periods that wildlife often begin to

663   use as pressure increases during the day it is recommended to concentrate recreation pressure

664   during the daylight hours between 10 am and 7 pm. The very low rate of near encounters

665   between recreationists and wildlife, particularly large carnivores, suggests that current patterns of

666   recreation do not pose a high risk of conflict, though proactive measures such as signage,

667   concentrating use during the day, and education remain important. The animals within the Fernie

668   trail network are often avoiding human recreation at some scale, likely to reduce any negative

669   effects on themselves, so seeing as the animals are doing what they can to coexist with recreation

670   it's important for recreationists to do what they can to coexist with wildlife.

671   While it is well documented that time in nature is good for people, the effects of

672   recreation on wildlife continues to be an evolving area of research that struggles to find

673   consistently strong effects across contexts and species. There is also substantial variation in the

674   perspectives of the public and recreationists on the effects of recreation on wildlife, which ranges

675   from benign to substantial impacts. Recreationists commonly perceive any negative

676   environmental impacts as the fault of other recreation types and rarely their preferred type of

677   recreation (i.e., hikers blame mountain bikers and horseback riders, and vice versa, (Taylor and

678   Knight 2003)). In a landscape of murky results, polarized stakeholders, and increasing

679   recreational pressure, landscape managers are clearly left in a challenging position. Some of the

680   challenge in finding consistent effects of recreation may be a result of layers of ecological

681   complexity that result in true context-dependency or could be a result of generally small true

682   effect sizes and confounding variables creating variable results. Our study relied on

683   observational data, which limits our ability to infer causality. Although we used a multi-scale

684   design and integrated data from camera traps and GPS telemetry, confounding factors such as

685   habitat quality, habituation, topography, and detectability can never be perfectly accounted for.

686   As noted by others (e.g., Jordan et al. 2025), stronger inference requires experimental

687   approaches, such as Before-After-Control-Impact (BACI) designs, temporary trail closures, or

688   controlled recreation manipulations. While such studies present logistical and ethical challenges,

689   they are critical for establishing causal links between recreation and wildlife responses and for

690   identifying thresholds of acceptable use. We encourage land managers, trail alliances, and

691   researchers to collaborate to set up BACI experiments prior to new trails being built. Such an

692   experiment would ideally have multiple years of before and after data and include measurements

693   directly on the trail and nearby within the buffer of potential recreation effects (100-500 m).

694   Such an approach would provide strong evidence of the effect of recreation on wildlife.

695   Replicating these experiments across gradients of recreation disturbance such as new trails

696   within existing networks and those within a less disturbed landscape, as well as across differing

697   recreation use volumes would eventually provide the critical information to assess the context-

698   dependent nature of recreation.

699   In conclusion, non-motorized recreation influences wildlife behavior and space use in

700   complex, scale-dependent ways. Some species demonstrate behavioral plasticity that may

701   facilitate coexistence, while others appear more sensitive to human presence and may be

702   displaced from preferred habitats. Managing recreation to maintain predictable use patterns,

703   minimize trail proliferation, and retain undisturbed refugia will be essential to support diverse

704   wildlife communities in multi-use landscapes. Future experimental and demographic studies will

705   further help quantify the long-term impacts of recreation and to inform adaptive management

706   strategies.

707

708

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714 the Fernie Trails Alliance for comments on an earlier version of this paper. Thanks to Troy

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716

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