Ya Ha Tinda Elk Project

Annual Report 2018 - 2019

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PERMITS

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DISCLAIMER

This progress report contains preliminary data from ongoing academic research directed by the University of Alberta and University of Montana that will form portions of graduate student theses and scientific publications. Results and opinions presented herein are therefore considered preliminary and to be interpreted with caution, and are subject to revision.

EXECUTIVE SUMMARY

This report summarizes activities from the long-term studies of the Ya Ha Tinda (YHT) elk population up to June 1, 2019, focusing from June 1 2017 – June 1 2019. The report also includes summaries of 5 graduate and undergraduate student projects including 1) bull elk ecology, 2) parasitology of migratory and resident elk, 3) winter behavioral observations, and 4) Remote camera-based research on i) predator-prey spatiotemporal dynamics, and, ii) estimating calf:cow ratio's using remote cameras. We also summarize scientific and public communication in the last 2 years.

Based on aerial winter counts, the Ya Ha Tinda elk population appears to have stabilized near ~400-500 in winter of 2018/19. Counts in winter 2018 indicated a minimum count of 371 elk, and 390 elk in 2019 winter. Recruitment rates in winter of 2018 and 2019 were near our long-term average of ~ 20%, again confirming our apparent long-term stabilization around ~ 400-500 elk. Up until 2014, there have been no consistent differences in survival or recruitment rates of migrant and western elk. However, part of the stabilization of the elk population may be driven by higher calf survival of the relatively new phenomenon of migratory elk that migrate to the Dogrib burn and Wildhorse Creek areas. Recently completed PhD research by Jodi Berg confirms higher elk calf survival of these eastern migrants, suggesting continued population shifts eastward are likely.

In winter of 2017 and 2018, 39 and 20 adult female elk were free-range darted and radiocollared from horseback. Pregnancy rates were high in 2018, 92%, but low in 2019, 70%. This is amongst the lowest pregnancy rate reported in our ~ 19 years, and suggests lower recruitment should be expected in Spring 2020. The cause of adult female mortalities detected in the reporting period (n=19) were very similar to long-term trends from ~ 150 mortalities detected since 2001. Mortality is essentially evenly split amongst all combined human caused mortality (bow, rifle, poaching, legal first nation – combined ~ 22%), wolf predation (20%) and grizzly bear predation (19%). However, cougar predation has increased in recent years and now represents 10% of known mortality for adult female elk. The timing of mortality has not changed and peaks in late winter early spring months for female elk.

We continue to monitor long-term migratory behavior, dynamics, and shifts. Results suggest continued modest declines in migration at Ya Ha Tinda. In 2017, 39% of radiocollared animals migrated, whereas in 2018, 30% migrated. In contrast, nearly 70% of the Ya Ha Tinda population is now classified as resident, remaining near the Ya Ha Tinda winter range year-round. Low but steady numbers of radiocollared elk continue to migrate west and south into Banff National Park. But there has been growth in the numbers of radiocollared elk migrating east to provincial lands near the Dogrib burn.

University of Montana PhD student began studying bull elk ecology and population dynamics with the radiocollaring of 32 bull elk in Jan of 2018, and 29 in Jan 2019. Our goals are to understand bull elk spatial migration ecology, habitat selection and bull elk demography, survival and harvest vulnerability. Ultimately, the goal is to develop an integrated population model for use in evaluating effects of harvest regulations on bull elk population dynamics in our system and beyond. Preliminary results show that bull elk displayed earlier, but similar spring migration dynamics as female elk, but very different movements in the fall. Average age of harvested bull elk was 5 years in the limited entry 6-point antler-point-restriction WMU's and 3 years in the general permit 3-point antler-point-restriction WMUs. So far 8 bull elk have been harvested. Significant additional funding for the bull elk component of the Ya Ha Tinda elk project was generously provided by Safari Club International Foundation, Rocky Mountain Elk Foundation, Alberta Conservation Association and the Ministers Special License Funding in Alberta through Alberta Fish and Game Association.

We evaluated differences in migratory and resident elk at Ya Ha Tinda as part of Jacky Normandeau's MS research project at University of Alberta. Samples collected from elk during the summer of 2017 and 2018 showed that eastern migrant elk had an average parasite prevalence of 66% where residents and Banff migrants had an average prevalence of 31% and 42% respectively. *F. magna* intensity was significantly higher in 2018 ($p = 0.008$) and in eastern migrant elk ($p < 0.001$). These results highlight both the importance of wildlife health monitoring, and differences in exposure of resident and migrant elk to different parasite prevalence levels.

Masters student Maddie Trottier (University of Alberta) is examining fine-scale differences between migratory strategies (eastern, western) and resident elk during winter. Maddie is contrasting behavior of migrant (eastern and western) and resident elk in the winters of 2018-2020 to determine differences in space use, grouping interactions, foraging behavior, and vigilance. Preliminary analysis of elk cohesion indicates that western migrants are less cohesive among themselves and with elk in other migratory groups, whereas resident and eastern elk tend to be associated with individuals in their own migratory group and with each other. In winter 2017 and 2018, residents showed the lowest vigilance.

Undergraduate researcher Mateen Hessami (U. Montana) tested whether remote cameras could provide estimates of calf:cow ratio's to compare to traditional methods in 2018. Mateen developed Royle-Nichols' (2003) occupancy models that estimated the abundance of calf and cow elk during 5 time periods in 2018 from May – September. Estimated calf:cow ratio's closely matched ground observations of calf:cow ratios, with the exception of the early spring period when elk calves were often missed by ground crews, but, not by remote camera's. The correlation between ground and camera-based estimates of calf:cow ratio was ~ $r=0.5$, indicating that remote cameras have great promise to contribute demographic information to agency monitoring protocols. Future work will compare calf:cow estimates obtained in 2016 and 2017 to Jodi Berg's neonate elk calf survival estimates.

MS student Mitch Flowers examined fine-scale predator avoidance by elk using remote camera's deployed in the intensive area surrounding Ya Ha Tinda grasslands. Mitch measured return times of elk to remote camera sites as a function of predator activity at each and adjacent camera sites in a time-to-event modeling framework. During summer, return times of elk were related to the amount of edge habitat surrounding the site as well as the occurrence of wolves, grizzlies, and cougars. Elk took longer to return to sites with higher wolf and cougar activity, but not for grizzly bear activity. Thus, fine scale behavioral avoidance may influence observed neonate and adult female survival rates in our population.

Finally, during the reporting period, we published 10 scientific papers, many with Parks Canada and Alberta Environment coauthors. We also completed 3 graduate theses at the University of Alberta, and 1 Undergraduate thesis at the University of Montana. We currently have 5 graduate students, 1PhD, and 4 MS students in progress. Our students and PI's presented 12 presentations at regional, national and international conferences, and published two websites.

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1.0 ELK POPULATION DEMOGRAPHY, AND MOVEMENT

1.1 Introduction

The Ya Ha Tinda Elk project is now amongst the longest running elk research project in the world. Initiated in 2000, the Ya Ha Tinda elk project is the result of a collaboration between University of Alberta, University of Montana, Parks Canada, and Alberta Environment and Parks, Fish and Wildlife Division. While early studies in the late 1970's and early 1980's lead by Dr. Luigi Morgantini laid the foundation for our latter studies (Morgantini and Hudson 1988), there was a ~ 20-year gap in active research on Alberta's most important elk population. Initiated at first because of questions regarding the changing migratory dynamics of the migratory Ya Ha Tinda elk population, the project has since evolved into North America's longest running wild, free-ranging elk research projects focused on fundamental and applied research.

The Ya Ha Tinda is one of Alberta's most pristine montane rough fescue winter ranges which provides the habitat foundation for one of Canada's most iconic and largest elk populations (Morgantini 1995). The Ya Ha Tinda elk population is also a transboundary system, with annual elk migratory cycles that have spanned two provinces (elk have migrated into Yoho National Park, British Columbia), two land management regimes including Banff National Park, Provincial Forest Land Use Zones, and Provincial multiple use zones. Ya Ha Tinda is also managed as a premier bull elk harvest area that provides much sought-after hunting opportunities to residents and guided hunters alike (Fig. 1). Meaning mountain prairie in the Stoney Sioux language, Ya Ha Tinda has long been important to First Nation communities for hunting and traditional land use practices. And the region is also home to recovered populations of grizzly bears, wolves, and other large mammal predator-prey species, including for the first time in over a century – Plains bison. In this transboundary setting, our long-term research has contributed directly to enhancing interagency cooperation and management of this important elk population. Furthermore, our research

Figure 1. No. 8 Typical
Hunter: Clarence Brown
Score: 419 5/8
Panther River, AB

has helped train over 20 graduate students who now work across western Canada and the United States managing similar wildlife populations in positions with State, Provincial and Federal natural resource agencies, Universities and private industry.

Our broad research goals have been to understand the changing migratory behavior of elk and predator-prey dynamics within this transboundary, montane system. Fundamental research on behavioral ecology of elk, foraging ecology, and predator-prey dynamics have provided the firm foundation to understand applied questions such as the effects of prescribed and natural fire, differing management policies in our transboundary setting, salvage logging, and harvest of both elk and large carnivores in the region. Our long-term research has also provided supporting science for Parks Canada's Plains bison reintroduction program, long-term caribou recovery planning by Parks Canada, and environmental assessments and evaluation of prescribed fire programs in Parks and Alberta lands.

1.1.2 Review of Previous Studies

Our long-term studies have documented dramatic changes in migratory behavior and population dynamics arising from this complex landscape of gradients in carnivore densities, habitat productivity, and differences in land management practices. Over the last 30-40 years migrant to resident ratios have substantially decreased from 12:1 (1977-1987, (Morgantini and Hudson 1988)), 3:1 in the early 2000's (Hebblewhite et al. 2006), to more recently a ratio closer to 1:1 (Berg 2019). Early studies in the 2000's demonstrated that migratory elk moving west into BNP experienced much higher forage quality which translated to higher calf 8-month old weights and higher pregnancy rates (Hebblewhite et al. 2008). Yet western migrants also experienced reduced predation risk from wolves, but higher risk from grizzly bear predation (Hebblewhite and Merrill 2007, MacAulay 2019). Resident elk remaining year-round near Ya Ha Tinda, in contrast, experienced lower forage quality, but, compensated for this by reducing predation risk by seeking out fine-scale predation risk refugia surrounding human development at the Ya Ha Tinda (Hebblewhite and Merrill 2009, Robinson et al. 2010). Commensurate with these shifts in the migratory dynamics of this population have been correspondingly significant population shifts and changes (Hebblewhite et al. 2006, Killeen et al. 2015, Berg 2019).

In the last decade, a new migratory strategy has emerged with female elk now undertaking an eastward migration into Provincial multiple use lands in and adjacent to the 2001 Dogrib fire (Killeen et al. 2015). Long-term research revealed individual elk are making density-dependent switches in migratory behavior, evidently to seek out these new beneficial areas (Eggeman et al. 2016). In 2013 – 2017, we lead a neonate calf survival research component to understand spatial variation in calf survival (Berg 2019). Calf survival and cow:calf ratios have indicated that calf survival of elk migrating east on to industrial forest experienced higher calf survival. In January 2019, Jodi Berg defended her PhD thesis on elk calf survival, and her thesis details are provided in our publications section below. This new migratory behavior has seemingly stabilized the Ya Ha Tinda elk population, which has fluctuated between 400 – 600 elk now for almost a decade. Our long-term predator-prey research shows, however, that this stabilization is not likely a result of wolf or grizzly bear predation stabilizing the population at low density (Hebblewhite et al. 2018). Instead, our research suggests that migratory behavior itself may be providing escape from low densities (Hebblewhite et al. 2018).

1.1.2 New and Ongoing Studies

This new shift to eastern summer ranges have exposed the elk population to a wider gradient in predation risk by non-human and human predation alike. As a result, in 2014, we expanded our predator-prey monitoring with two new research areas; predator scat monitoring, and, using remote camera's. In 2019, Kara MacAulay, MS student at University of Alberta, defended her MS thesis on spatial predation risk for elk using spatial analyses of multi-species predator scat (MacAulay 2019). Second, we expanded our remote camera network that integrates with Parks Canada regional camera trap monitoring system. This allows us to monitor multiple large carnivores and predator-prey dynamics, the focus of Mitch Flowers ongoing MS research at University of Alberta. Secondly, University of Montana Undergraduate student Mateen Hessami completed his Undergraduate thesis in 2019 that focused on estimating calf:cow ratio's from remote camera's around the Ya Ha Tinda ranch, that we report on here. Furthermore, MS student Jacky Normandeau (University of Alberta) is in her final year completing new research on parasitology differences as well between resident and migratory elk that have important population implications as well. Finally, to fill a long-term gap in our knowledge of the Ya Ha Tinda system with direct management implications for elk harvest management, University of Montana PhD student Hans Martin initiated a new research component on understanding bull elk ecology, survival, and management at Ya Ha Tinda.

1.2 Progress Report Objectives

Following this overview and brief summary of past and ongoing studies, this report summarizes research activities from April 1, 2017 to April 1, 2019 including:

(1) Long-term monitoring of the YHT elk herd movements, population size and trends.
(2) Bull elk research (Hans Martin)
(3) Parasitology research (Jacky Normandeau)
(4) Winter behavioral observations of migratory elk (Maddie Trottier).
(5) Camera trapping research results including;
  a) Predator-prey interactions from remote camera data (Mitch Flowers)
  b) Evaluating remote camera's utility to estimate calf:cow ratio's (Mateen Hessami)

2.0 Population Monitoring

Here we report on population monitoring results for the Ya Ha Tinda elk herd, from 2001 to the present based on ground counts, aerial counts, and summaries of radiotelemetry monitoring of mortality, migrations, and demography. Methods follow general population survey methods described in (Morgantini and Hudson 1988, Hebblewhite et al. 2006).

2.1 Ground Counts

The highest minimum winter ground counts of the Ya Ha Tinda elk population were conducted when the majority of animals were joined together in one large group on Ya Ha Tinda ranch grasslands (Table 1). We feel confident these counts represent the majority of the cow-calf herd because all radio-collared females were present in the group, and no other large groups of elk were present on the ranch grasslands when these counts were made. However, as we note below in our new bull elk research component, aerial surveys vastly under-represent bull elk numbers because of the spatial separation and denser cover in which bull elk occur, limiting observations from aerial surveys. Our new bull elk research component will address this challenge by developing an integrated population model that explicitly estimates total population size including the underrepresented bull elk component.

Table 1. Highest minimum population counts of elk herd obtained from the ground in late winter (1 February to 30 April, 2001 - 2019) at Ya Ha Tinda, Alberta, Canada. Biological year refers to 2001/2002, for example.

Biological Year	Number of Observations	Minimum Count
2001	83	700
2002	178	748
2003	69	616
2004	38	948
2005	62	609
2006	32	620
2007	29	300
2008	28	450
2009	14	400
2010	20	325
2011	6	279
2012	22	335
2013	16	387
2014	14	358
2015	21	355
2016	21	357
2017	36	390
2018	56	371

2.2 Aerial Surveys

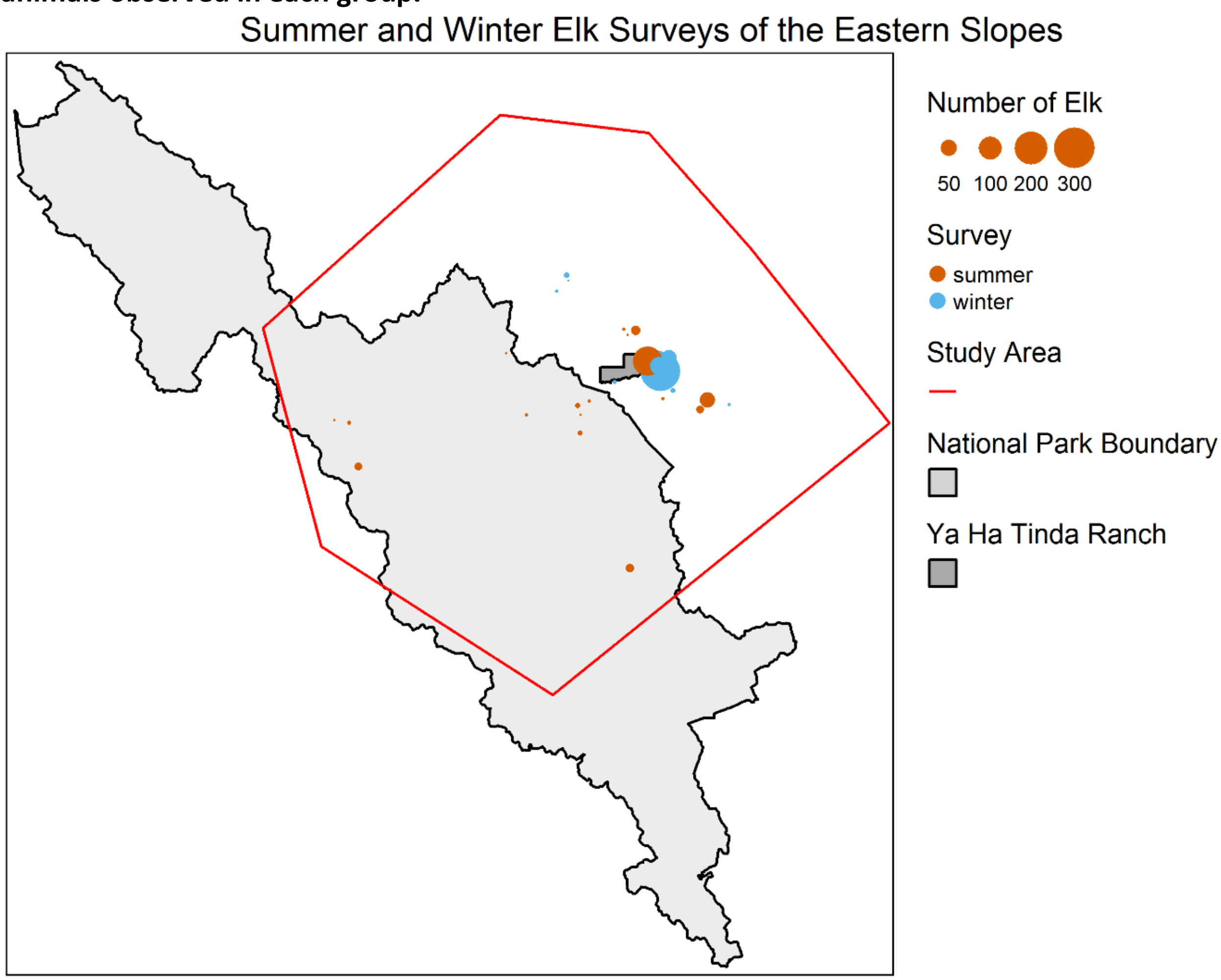
Summer

Parks Canada, Alberta Environment and Parks, and University of Montana Staff conducted a summer survey in 2017 on July 13-14th (Fig. 1) No summer aerial surveys were conducted in 2016 or 2018. During summer surveys, we surveyed all alpine and subalpine summer elk ranges and key winter ranges identified by Morgantini and Hudson (1988). Telemetry data from both early and late periods confirmed no major summer ranges were missed during surveys (Morgantini and Hudson 1988, Hebblewhite and Morgantini 2003, Spaedtke 2007). We photographed large herds (e.g., > 50) for counting. We recorded group size, general group composition (male, female, mixed), activity, and GPS location. A total of 279 elk were counted during the survey (similar to 2007 where 232 elk were recorded). A total of 47 elk were observed within Banff National Park, 58 in the eastern portion of the study area, and 174 were seen on the winter range on or near the Ya Ha Tinda Ranch.

Winter

We flew winter aerial surveys 1–2 days after heavy snowfalls during the morning (0800–1200 hours) on sunny or flat-light days during January or February to maximize sightability of elk (Allen et al. 2008). Surveys were conducted by Parks Canada (Blair Fyten) in winter 2017/18, but not 2018/19. Otherwise, methods followed those described by Hebblewhite et al. (2006). In winter 2017/2018, a total of 416 elk (including 357 in the single large cow-calf group and 57 bulls) were counted during the aerial survey. Given the importance of the aerial survey data in understanding population trends in the long-term perspective in this population (Hebblewhite et al. 2006), we recommend aerial surveys continue to be coordinated between Alberta Environment and Parks Canada each winter.

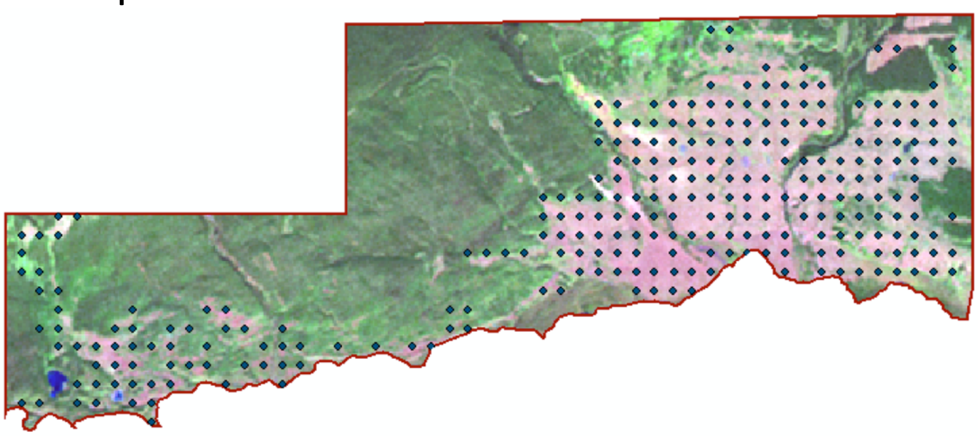
Figure 1. Survey results from summer 2017 and winter 2017/2018 including the number of animals observed in each group.



2. 3 Pellet Plot Surveys

We also continued long-term pellet counts in the grassland (<60% canopy cover; Fig. 2) of the Ya Ha Tinda and forested and shrubby regions adjacent to the grasslands to provide a within-season assessment of ungulate grazing pressure and relative abundance and distribution. Spring pellet counts were conducted during May and represent winter use of the ranch. Fall counts occurred during September and represent summer use. Plots were 25 m^2 and located in a systematic grid at 250-m intervals across the grasslands. Pellet groups were defined as containing at least 8 pellets and counted if >50% of the group was within the plot. Ungulate species recorded included elk, deer (*Odocoileus virginiana, O. hemonius*), horse (*Equus*), and moose (*Alces alces).* Color, weathering, and shape of pellets were used to determine pellet species and age. Elk pellets deposited in the winter had a squared bullet shape, while summer pellets transition to a soft coalesced or disc form. Deer pellets were similar but smaller, typically under 1 cm in length. Black pellets were considered recently deposited, whereas grey or white color indicated pellets deposited last season or even a year earlier.

Figure 2. Pellet plot locations at the Ya Ha Tinda Grasslands.



Results indicate a continued decline in winter use by elk on the Ya Ha Tinda grasslands to 1.04 pellet groups counted (SD =2.04) in 2018/19 compared to a high of 3.94 in 2001/02. Conversely, pellet group counts during the summer have been relatively steady over time, especially for the past ~ 5 years, with 0.52 pellet groups/plot (SD = 0.88) in Fall 2018 (Fig. 3). Moreover, deer pellet densities have remained similarly relatively constant for the last decade, and similar between summer and winter (Fig. 3).

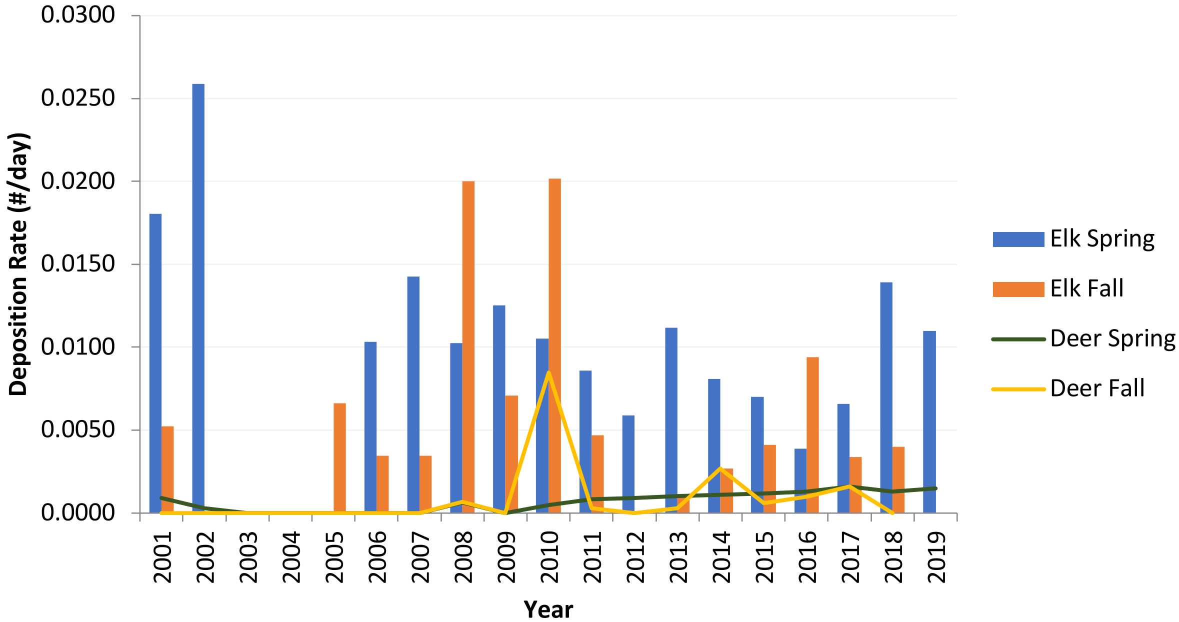


Fig. 3. Changes in deposition rates (#/day) averaged across plots surveyed every year (*n* = 29) over time from winter 2000/01 to winter 2018/19; pellet groups counts were conducted at the Ya Ha Tinda ranch, Alberta, Canada. Note that spring refers to winter use, and fall refers to ungulate use over the summer. Also, not all plots were completed in Fall of 2018.

Table 2. Number of plots sampled, and minimum, maximum, mean, and standard deviation of elk pellet groups counted, and deposition rates (#/day) observed during winter and summer elk pellet surveys at the Ya Ha Tinda ranch, Alberta, Canada.

Season	Year	n	Min	Max	Mean	S.D.	No./Day	S.D.
Summer	2000	275	0	8	0.57	1.07		
Summer	2001	277	0	10	0.42	1.03	0.003	0.008
Summer	2005	37	0	3	0.78	1.00	0.008	0.010
Summer	2006	37	0	2	0.38	0.59	0.003	0.005
Summer	2007	45	0	3	0.31	0.67	0.003	0.006
Summer	2008	367	0	10	1.08	1.69	0.011	0.017
Summer	2009	325	0	8	0.84	1.32	0.006	0.009
Summer	2010	379	0	18	1.39	2.28	0.011	0.019
Summer	2011	356	0	6	0.43	0.89	0.004	0.008
Summer	2012	382	0	2	0.08	0.32	0.001	0.002
Summer	2013	366	0	5	0.23	0.63	0.002	0.005
Summer	2014	374	0	8	0.28	0.79	0.002	0.007
Summer	2015	376	0	9	0.52	1.08	0.004	0.009
Summer	2016	377	0	9	0.37	1.02	0.003	0.009
Summer	2017	152	0	7	0.41	0.89	0.003	0.001

Summer	2018	78	0	4	0.52	0.88	0.004	0.006
Winter	2000/01	270	0	24	3.01	3.33	0.013	0.014
Winter	2001/02	272	0	21	3.94	2.60	0.017	0.018
Winter	2004/05	37	0	16	3.76	3.12	n/a	n/a
Winter	2005/06	38	0	14	2.74	3.36	0.011	0.013
Winter	2006/07	46	0	16	2.85	3.48	0.011	0.014
Winter	2007/08	120	0	16	1.47	2.31	0.007	0.011
Winter	2008/09	356	0	25	1.70	2.55	0.008	0.011
Winter	2009/10	359	0	16	1.37	2.09	0.006	0.010
Winter	2010/11	356	0	19	1.15	2.11	0.005	0.008
Winter	2011/12	357	0	16	0.90	1.80	0.004	0.001
Winter	2012/13	378	0	21	0.95	1.67	0.004	0.009
Winter	2013/14	358	0	22	0.63	2.01	0.003	0.009
Winter	2014/15	372	0	12	0.78	1.86	0.003	0.008
Winter	2015/16	375	0	12	0.752	1.52	0.003	0.006
Winter	2016/17	375	0	7	0.54	1.18	0.002	0.005
Winter	2017/18	593	0	19	1.57	2.80	0.007	0.003
Winter	2018/19	393	0	15	1.04	2.04	0.005	0.009

2.3 Adult Elk Capture and Handling 2018 & 2019

In February and March, 2018 and 2019, a total of 59 adult female elk were free-range darted and immobilized (Fig. 4). Thirty-nine of the elk were recaptures from previous years and 20 new elk were collared in both years. In 2018, we captured 39 female elk, of which 12 were new individuals. In 2019, we captured 20 females, again of which 8 were new individuals. All female elk were fitted with Globalstar or Iridium GPS collars scheduled to take fixes every 6-13 hrs. Hair and blood samples were taken from all elk and body condition and chest girths were measured. The animals were kept on oxygen during the immobilization and vitals were monitored. Blood samples were sent to Biotracking, inc. for pregnancy analysis using BioPRYN's placental Pregnancy-Specific Protein B test (PSPB, see below). All elk that were captured for the first time were ear-tagged in both ears and a vestigial canine tooth was removed for aging after blocking the nerve

Fig. 4. Parks Canada and research staff chemically immobilizing elk on horseback to capture adult female elk and estimate pregnancy rates.

with Lidocaine following our approved animal handling protocols. As a result of winter capture efforts, the YHT elk herd entered spring 2018 and 2019 with 63 and 59 collared females respectively (approximately 26-28% of the total adult female population), in the herd.

1.4 Adult Elk Telemetry

We have monitored a total of 406 unique collared adult female elk from 2002 - 2019 in the YHT herd. On average, we have had 82 adult female elk radio-collared per year, with 62 VHF collars/year and 20 GPS collars/year, with a range of 4 - 46 GPS collars deployed in any one year (Table 3). Because some elk wear both GPS and VHF collars at different times during their monitoring, the total numbers of unique VHF and GPS-collared elk are not independent (Table 3). On average, individual elk are collared for a duration of 3.1 years. From VHF-collared elk, we have obtained an average of 20 (range: 9 - 55) VHF locations/elk/year. For the GPS-collared elk, we have collected an average of 4,696 locations/elk, and 1,620,308 GPS locations in total.

Starting in 2017 we began only deploying GPS collars on elk to reduce flight time in relocating migrant elk, assist in fecal sample collection, and decrease the time it takes to locate elk mortalities. These GPS collars collect ~2 locations per day (1 location / 13 hours) providing sufficient location data for monitoring migration and habitat selection but with a lifespan comparable to that of a VHF collar (5-7 years).

Fig. 5. Locating migratory elk using radio telemetry.

Table 3. Summary radio-telemetry table for VHF and GPS-collared elk from 2001 to 2019 in the Ya Ha Tinda elk herd, Alberta, Canada. The table shows total number of adult female elk collared/year, number and average number of VHF/GPS locations/individual elk, and total number of locations. Note that the total number of unique VHF and GPS-collared elk do not add up because some elk wear both kinds of collars, and because individual elk occur in multiple years (3 on average).

Year	# Elk Collared	Total VHF Locs.	Total # VHF-collared	Mean VHF Locs./Elk	Total # GPS-collared	Total GPS Locs.	Mean GPS Locs./Elk
2002	41	2,045	37	55	4	11,192	2,798
2003	81	2,858	73	39	8	36,342	4,543
2004	99	1,891	74	26	25	88,152	3,526
2005	92	983	81	12	11	51,498	4,682
2006	113	1,392	99	14	14	126,342	9,024
2007	103	872	94	9	9	86,926	9,658
2008	81	1,027	81	13	0	0	0
2009	108	1,339	101	13	7	27,157	3,880
2010	97	936	91	10	6	40,542	6,757
2011	87	988	81	12	6	17,651	2,942
2012	63	547	60	9	3	2,749	916
2013	77	1,673	55	30	22	138,745	6,307
2014	77	1,267	47	27	30	212,780	7,093
2015	74	419	49	9	25	178,770	7,151
2016	76	671	30	22	48	412,799	6,580
2017	75	781	28	9	47	151,427	3,222
2018	75	1664	25	17	50	37,236	745
2019	60	574	15	7	45	-	-
Average	82	1,218	62	19	20	95,312	4,696
Totals	1,479	21,927	1,121	333	360	1,620,308	79,824

2.4 Elk Demography

2.4.1 Adult Mortality

A major goal of our long-term research has been assessment of cause-specific mortality of adult (and neonate collared) elk. Cause-specific mortality is critical to assess predator-prey dynamics, density-dependent predation by specific carnivores, and to understand drivers of long-term changes in migratory elk dynamics. Mortality signals from radio-collars were detected using ground and aerial telemetry, and were investigated from the ground or via helicopter as quickly as possible. Since 2016, the average time to investigate kill sites was 6 days (SE=1.7), not significantly different from our long-term time-to-investigation of 5.5 days (Hebblewhite and Merrill 2011, Hebblewhite et al. 2018).

Over the entire duration of the project, we have investigated 154 mortalities of radiocollared female elk (Fig. 6). Of known-caused mortalities, human-caused mortality from all hunting combined (bow harvest, rifle, poaching, and legal First Nation) was the dominant cause of mortality. Wolves were the second leading cause, followed by grizzly bear and cougar (Fig. 6). Considering only the mortality data collected on collared females in the reporting period (2017 – 2018), we located 19 new adult female mortalities during this period (Fig. 7). Overall trends in the cause of adult female mortality have remained the same, with human harvest and wolf-caused mortality being the highest cause of known mortality (Fig. 6, 7).

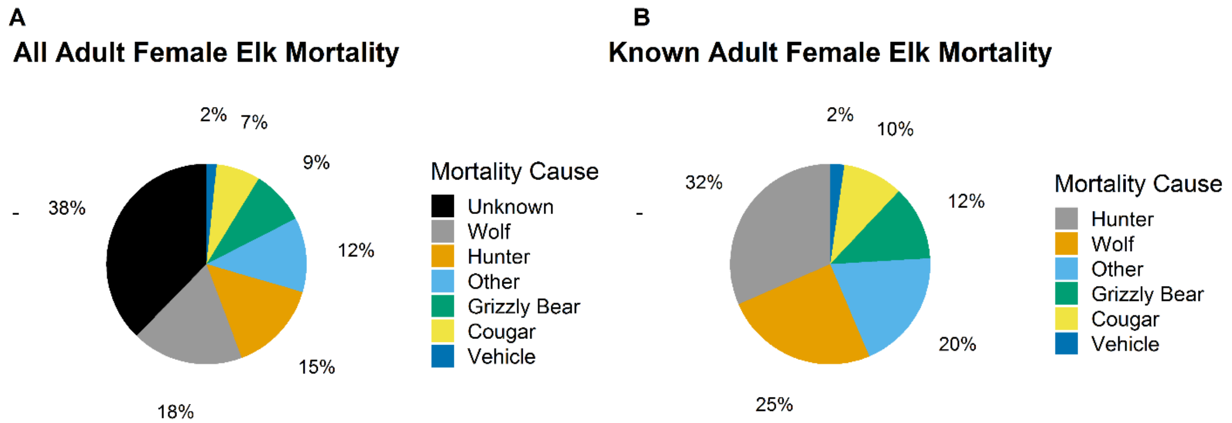


Fig. 6. Mortality causes for radio-collared adult female elk (*n* = 154) from 2002 – April 2019 in the Ya Ha Tinda elk population, Alberta, Canada. (A) Shows all mortalities, including unknowns (*n* = 183), and (B) shows only known-causes of mortality (*n* = 114).

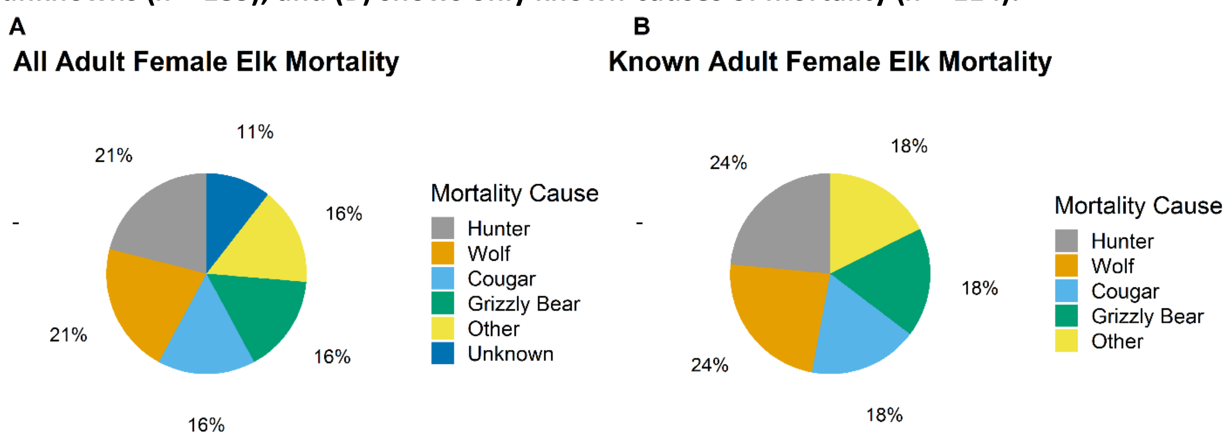


Fig. 7. Mortality causes for radio-collared adult female elk (*n* = 19) from 2017 –April 2019 in the Ya Ha Tinda elk population, Alberta, Canada. (A) Shows all mortalities, including unknowns (*n* = 19), and (B) shows only known-causes of mortality (*n* = 17).

2.4.2 Winter Calf:Cow Ratios

For all observations of groups of collared, tagged, and/or un-collared elk, we recorded time, date, location, and the numbers of tagged elk in the herd, whenever possible. We followed the criteria (Smith and McDonald 2002) to sex- and age-classify elk in groups to obtain demographic data. Although we attempted to classify yearling females in the field, this practice is not recommended except by skilled observers at very close range, as body size of yearling females is variable and there is considerable risk of misclassification (Smith and MacDonald 2002). Therefore, we included any of the classified yearling females in the adult female total. Observations were made from a distance to avoid disturbing the elk (on average 30-100 m from horseback, and 100-500 m from the ground or truck). Here, we examine trends in recruitment from 2001 – 2018 by examining the calf:cow ratio in late winter (1 Feb. – 30 Apr.; Table 5, Fig. 6). We follow statistical methods of Hebblewhite (2006, Appendix 1B). We calculated the standard error in Y_{ij} assuming errors were binomially distributed following (Czaplewski et al. 1983).

In the reporting period, spring recruitment rates were very close to the long-term average (Table 5, Figure 8). In 2017, we observed 0.196 (SE = 0.007) calves:100 cows, slightly lower than the 0.239 calves: 100 cows (SE= 0.005) observed in 2018 (Table 5, Fig. 8)

Table 5. Cow:calf ratio data in late winter (1 Feb. to 30 Apr.), Ya Ha Tinda elk herd, Alberta, Canada. Adult female total includes female yearlings.

Year	Total # Classified	# of Groups	ADF Total	YOY Total	Cow:calf	SE
2002	1942	20	1362	188	0.138	0.009
2003	6296	70	5490	493	0.09	0.004
2004	4381	35	3563	533	0.15	0.006
2005	229	10	183	19	0.104	0.021
2006	2144	19	1552	347	0.224	0.01
2007	2316	14	1909	346	0.181	0.008
2008	--	--	--	--		
2009	1568	13	1310	222	0.169	0.01
2010	454	6	348	86	0.247	0.021
2011	1035	13	813	90	0.111	0.01
2012	545	2	524	18	0.034	0.008
2013	568	2	506	57	0.113	0.013
2014	2832	14	2106	643	0.305	0.009
2015	1198	9	914	142	0.155	0.011
2016	2063	17	1643	279	0.17	0.008
2017	3335	37	2797	548	0.196	0.007
2018	7631	56	6163	1471	0.239	0.005
Average	2240	42	1902	344	0.18	0.01

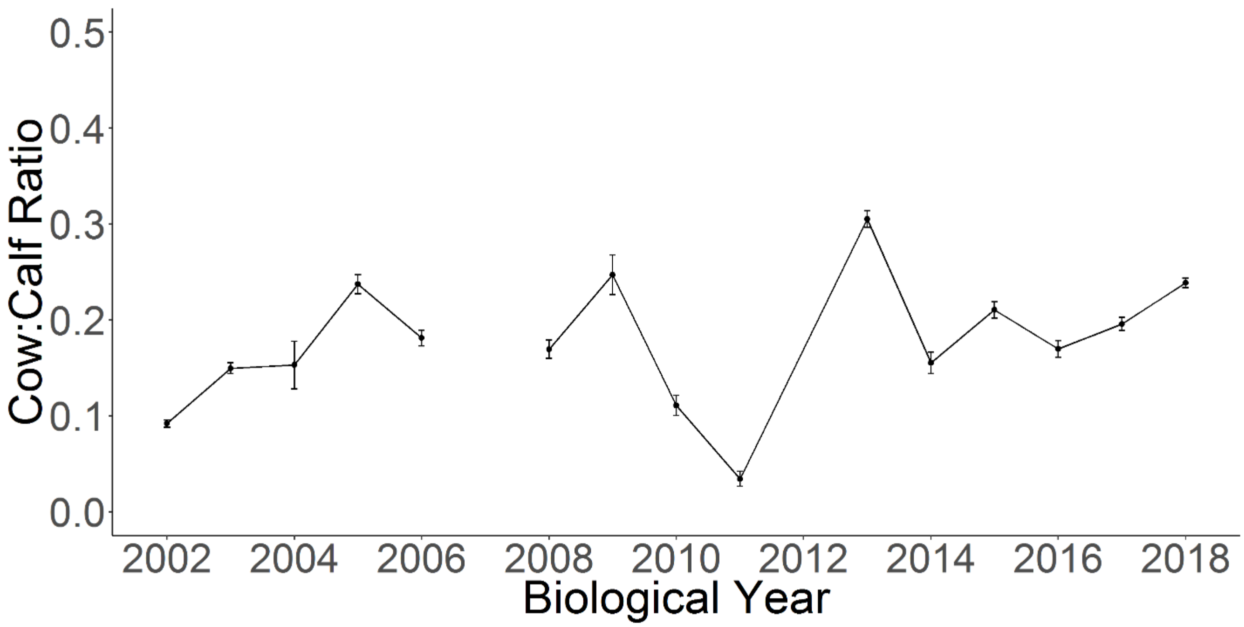


Fig. 8. Calf:cow ratio data in late winter (1 Feb. – 30 Apr.) from 2002 - 2018 for the Ya Ha Tinda elk herd, Alberta, Canada. Adult female total includes female yearlings.

1.5.3 Pregnancy Rates

In March, 2018, 36 female elk that were tested for Pregnancy Specific Protein B (PSPB) were pregnant; 3 elk were not pregnant. The pregnancy rate was 92% (Table 8). In March, 2019, 14 of 20 elk (70%) that tested were pregnant. With the exception of 2018/19, pregnancy rates appear to have increased over the past decade, perhaps consistent with reduced density and reduced competition for forage. Future analyses by the current PhD student, Hans Martin, will test for these changes.

Table 8. Pregnancy rates in late winter across all years except 2007 and 2010 for the Ya Ha Tinda elk herd, Alberta, Canada.

Year	# Pregnant	Total Sample	% Total
2002	23	35	0.657
2003	39	47	0.83
2004	41	49	0.837
2005	29	30	0.967
2006	20	26	0.769
2007	N/A		
2008	23	40	0.575
2009	40	42	0.952
2010	N/A		
2011	14	16	0.875
2012	N/A		
2013	21	23	0.913
2014	47	48	0.979
2015	60	64	0.938
2016	44	46	0.957
2017	17	18	0.944
2018	36	39	0.923
2019	14	20	0.700
Total	**468**	**543**	
Average	**32**	**37**	**0.858**

2.6 Migration

2.6.1 Classifying Migrants and Residents

We classified individual behavior as migrant or resident using the Net Squared Displacement (NSD) method (Bunnefeld et al. 2011, Borger and Fryxell 2012, Spitz 2015) combined with post-hoc spatial rules and visual confirmation in a GIS. NSD measures the cumulative squared displacement from the starting location. We fit linear and non-linear movement models to NSD for each individual in each year (hereafter referred to as elk-years) for migrant, mixed migrant, resident, nomad and disperser behavior (Bunnefeld et al. 2011, Spitz et al. 2017) The best movement model was then selected using AIC_c.

Because there were no mixed migrants or nomads in our population these models were excluded from comparisons. Most elk classified as dispersers were re-classified as migrants because in almost all cases the dispersal movement model was the best fitting because the elk either died or lost its collar during migration or while on its summer range. All model fitting was carried out using the R package *MigrateR* (Spitz et al. 2015)(Spitz 2015) developed in part using Ya Ha Tinda elk data. GPS data was resampled to 1 location per day at random. For VHF data, we attempted to use the NSD method but this was only successful for 222 VHF elk-years due to small sample sizes. Remaining VHF elk-years were classified visually using a GIS.

Because of the misclassification of residents as migrants in cases of summer range expansion we used a post-hoc spatial constraint to ensure correct classification in these cases. For an individual to be considered resident it had to remain within 10 km of the winter range during summer. Some individuals also showed short duration ‘exploratory movements’ which we did not consider true migratory behavior. To account for these cases, we considered an individual to be migratory only if it used seasonal ranges for a minimum of 30 days.

Our results suggest continued modest declines in the proportion of elk that migrate at Ya Ha Tinda (Fig. 9, Table 9). In 2017, 39% of the radiocollared sample migrated, whereas in 2018, 30% displayed migratory behavior. Major trends in migratory travel routes are similar to those reported by (Killeen et al. 2015) with stability in the numbers of GPS radiocollared elk migrating west and south into Banff National Park (Table 9), and in the numbers of radiocollared elk migrating east to provincial lands near the Dogrib burn (Table 9). Nearly 70% of the Ya Ha Tinda population is now classified as resident, remaining near the Ya Ha Tinda winter range year-round, and this is consistent with long-term trends since about 2011.

Table 9. The total number of female elk tracked using GPS collars in each year, with their classification as western, southern, northern, or eastern migrants or residents. Note that the total tracked does not necessarily match the total collared (Table 4) because not enough locations were recorded to determine migratory status for every animal. The total percentages of elk that were migrant or resident in each year are also shown.

	Total	Migratory Status					Migrant	Resident
Year	**Tracked**	**West**	**South**	**North**	**East**	**Resident**	**%**	**%**
2002	3	2	0	0	0	1	66.7	33.3
2003	7	4	2	0	0	1	85.7	14.3
2004	16	3	3	5	0	5	68.8	31.2
2005	7	1	0	0	0	6	14.3	85.7
2006	9	2	0	2	0	5	44.4	55.6
2007	8	0	0	1	0	7	12.5	87.5
2008	0	0	0	0	0	0	-	-
2009	7	0	0	0	0	7	0	100
2010	7	0	0	0	1	6	14.3	85.7
2011	3	0	0	0	1	2	33.3	66.7
2012	0	0	0	0	0	0	-	-
2013	19	1	1	0	3	14	26.3	73.7
2014	28	4	0	0	7	17	39.3	60.7
2015	25	3	3	0	6	13	48	52
2016	47	3	3	1	13	27	42.6	57.4
2017	44	3	3	0	11	27	38.6	61.4
2018	40	3	3	0	6	28	30.0	70.0
Total	**135**	**18**	**9**	**8**	**18**	**82**	**37.7**	**62.3**

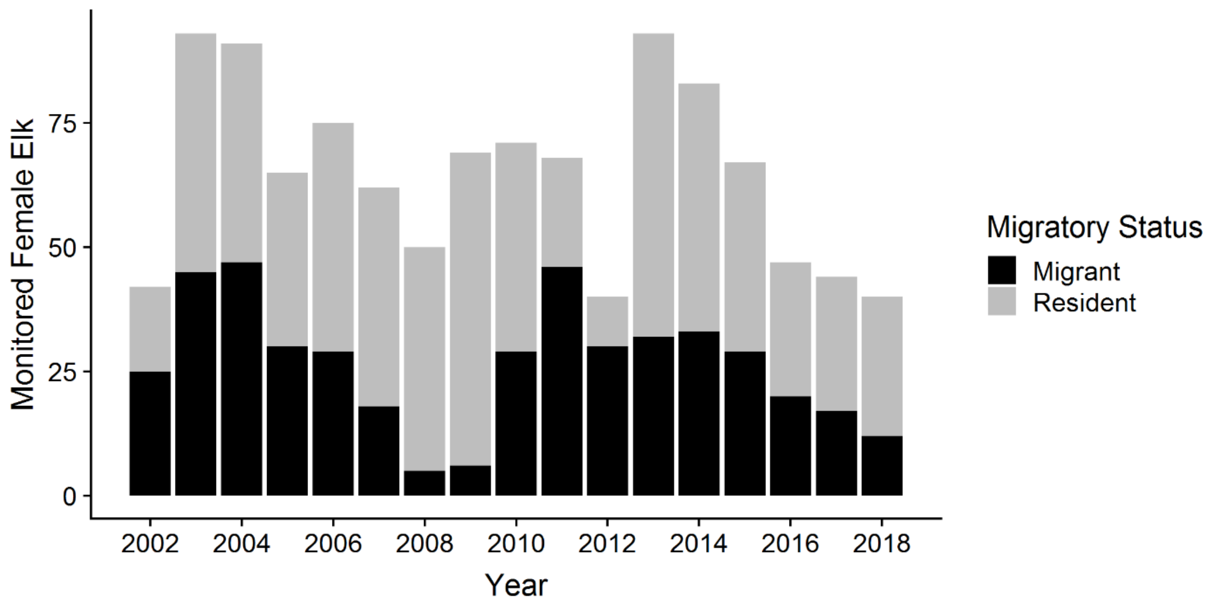


Fig. 9. The numbers of elk classified as migrant or resident in each year, including both GPS-collared and VHF-collared individuals.

3.0 BULL ELK RECRUITMENT, SURVIVAL, AND HARVEST

Hans Martin (PhD Candidate, University of Montana)

Most ungulate studies (the Ya Ha Tinda Elk Study included) focus on the female component of the population due to their direct link to population growth. However, male ungulates are an important source of food for carnivores (Huggard 1993, Metz et al. 2012) and provide viewing opportunity desired by park visitors. Moreover, the Ya Ha Tinda – like many elk populations – provide important elk harvest opportunities for resident and non-resident hunters alike focusing on the bull elk component of the population. As mentioned, the Ya Ha Tinda is amongst one of Alberta's premier trophy bull elk regions, producing one of Canada's largest bull elk ever harvested.

Thus, the goal of this component of the Ya Ha Tinda elk project is to understand bull elk ecology in a partially migratory population and how predation, hunting, and migration affect the number and size of bull elk in a population. We have three main objectives of this multi-year project: 1) determine migratory movements of bull elk in the Ya Ha Tinda herd; 2) determine cause-specific mortality, survival, age structure, and trophy potential of bull elk in the Ya Ha Tinda elk herd; 3) develop an integrated population model based on our long-term female data that includes bull elk population dynamics and migration. Our bull elk component is proposed to take 3 full biological years, with radiocollaring in January 2018 – 2020.

OBJECTIVE 1: *Determine migratory behaviour and spatial distribution of bull elk in the Ya Ha Tinda elk herd.*

GPS locations from the first winter and summer provide a glimpse into the spatial distribution and migratory patterns of bull elk in the Ya Ha Tinda population. All the collared bull elk wintered on the Ya Ha Tinda Ranch and within 10 km surrounding the Ranch on provincial lands. In spring 2018, we observed migratory behavior beginning in late April as bulls began to move east into the industrial forest lands and west into Banff National Park. As of 31

July 2018, 19 (63%) of the collared bulls migrated into Banff National park, 6 (20%) remained as residents on the winter range, and 5 (16%) migrated east into provincial land (Fig. 11).

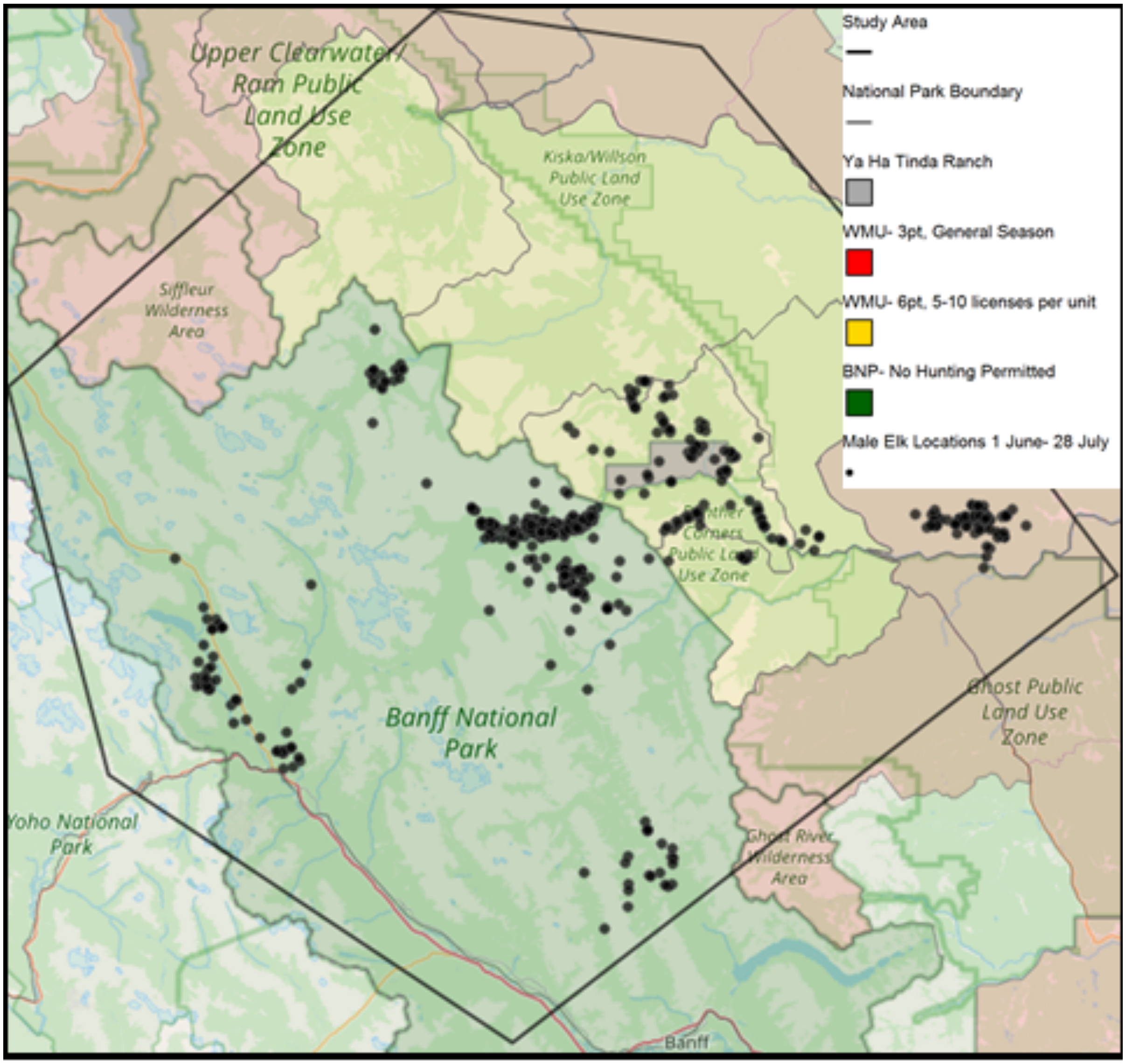


Figure 11. Summer (1 June- 28 July) locations of bull elk collared on the Ya Ha Tinda winter range (n=30). The bulls are currently distributed across a range of harvest regulations with 19 (63%) of the collared bull migrating to the west, 6 (20%) remained as residents on the winter range, and 5 (16%) migration to the east. Different hunting zone regulations are shown in beige/red, yellow, and green.

OBJECTIVE 2: *Determine cause-specific mortality, survival, age structure, and trophy potential of bull elk in the Ya Ha Tinda elk herd*

In January 2018 and 2019, we successfully collared 61 adult (>2.5 years old) bull elk using aerial darting (32 in 2018, 29 in 2019). The elk were fit with Lotek LifecyclePro and Vectronics Survey GPS collars that transmit location data every 13 hours. We measured body condition, extracted a vestigial canine for aging, and scored antlers following Safari Club

International's (SCI) guidelines. During the 2019 captures, the average antler score was 190 inches, lower than 2018 (average score 218 inches), with the largest bull elk scoring 275 inches. Aging of the bulls collared in 2018 indicated that the age-structure of the bull elk population is skewed toward younger age-classes and no bulls collared in 2018 were over 4 years of age (Fig. 10).

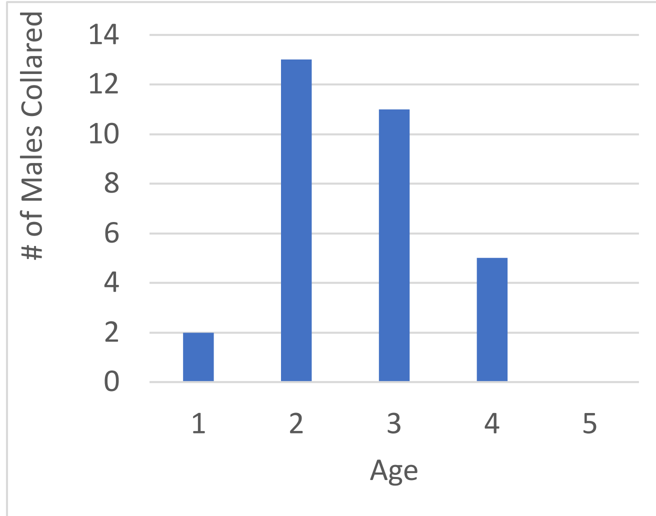


Figure 10. The age distribution determined by tooth histology of bull elk collared in the Ya Ha Tinda in 2018.

During the 2018 capture season, we used a combination of fixed and expandable length collars. Prior to hunting season, 4 of the expandable collars ripped leaving 28 collared individuals. Of these 28 individuals, 8 were harvested during the 2018 season and in February 2019, one bull died from malnutrition. Hunters harvested 6 collared bulls from WMU 418 with an average age of 5 (range 3.5-5.5) and average antler score of 298 inches (range 271-324) and two 3.5-year-old bulls were harvested in WMU 316 and WMU 318 scoring 192 and 234 inches respectively. We worked with Alberta Environment and Parks to develop a hunter information pamphlet and survey to obtain age and antler size of harvested bulls in the surrounding WMUs and communicate the project's objectives to the public. Two of the surveys were returned after the hunting season from hunters who harvested uncollared bulls. A research technician contacted hunters at local campgrounds to assist hunters and facilitate data collection from bulls harvested.

We predict that harvest vulnerability would vary between the three migratory segments of the population. Five of the eastern migrants were within wildlife management units (WMUs 316 and 318) with unlimited hunting on the general Alberta elk tag and a 3-point regulation on bull harvest. Of these 5 bulls, 2 were harvested. The 6 bulls harvested within WMU 418 spent the summer within Banff National Park. Two of these bulls migrated over 65 km in September before being harvested in WMU 418. None of the resident bulls in WMU 418 were harvested, although this may have been because they did not meet the minimum antler-point

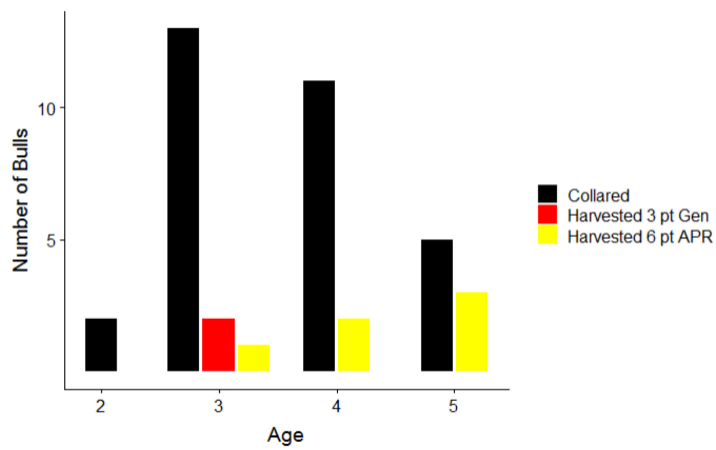


Figure 12. Six-point antler point restriction limits harvest of younger age class bulls but high vulnerability results in a young-age structure Black represents collared bulls available for harvest by age class. Red represents the number of bulls harvested in 3-pt general WMUs 318 and 316 and yellow represents bulls harvested in the 6-pt APR WMU 418.

restriction during the 2018 hunting season. Despite 6-point regulations and limited entry quotas to limit bull elk vulnerability, the age distribution of the bull elk population remains skewed toward younger age classes (Fig. 12).

OBJECTIVE 3: *Develop Bayesian Integrated Population Models that includes bull elk population dynamics and migration to predict population sizes and harvest under different harvest regimes and management actions.*

We will develop an IPM that includes bull elk population dynamics and migration in year 3 of this project, once we have obtained sufficient amounts of survival and migratory data from collared bull elk. However, to date, we have made progress in developing the mark-re-sight calf survival component of the integrated population model, adult female survival component, and population count components. These initial steps are critical in the development of the model and provide a foundation onto which we can overlay bull elk survival and migration to fulfill this objective.

Future Work

The first two years of bull elk collaring were a success, and we have 1 more year of bull collaring in January 2020. After which we will monitor the survival, migration, and habitat selection of collared bulls for an additional year. The project is on target for the continued monitoring of sufficient sample sizes of adult male and female elk in the population. This should provide us with about 150 bull elk-years of data assuming a 60% survival rate. We anticipate project completion for this graduate project in Fall 2020.

4.0 Are There Differences in Parasite Exposure in a Partially Migratory Elk Population?

Jacalyn Normandeau (MS Student, University of Alberta), Dr. Susan Kutz (Collaborator, University of Calgary)

Many studies of ungulate populations focus on forage-predation interactions, but parasites can be as important in affecting mortality especially as an indirect cause (M.J. et al. 2015, Mysterud et al. 2016). Parasites affect host body condition, reproduction and survival in ungulates, but the interaction between migration and parasite infection is not well understood (Pybus et al. 2015). From preliminary fieldwork in 2017, we found that elk at the Ya Ha Tinda (YHT), Alberta were infected with giant liver fluke (*Fascioloides magna*) which can have potential health implications and mortality. Here, we compared *F. magna* prevalence and intensity among migration strategies in 2017-2018. We predicted that (1) elk migrating into Banff National Park would have lower *F. magna* infection than resident elk because they have high quality forage and are not concentrated in summer, whereas (2) elk that migrated east of YHT would have higher fluke infection than both Banff migrants and residents because they are concentrated in human-mediated refuges and may have lower forage quality making them more susceptible to parasite infections (L. et al. 2016). We also collected samples from collared elk in spring of 2018 to relate to habitat use in the summer of 2017 to determine factors potentially increasing *F. magna* exposure.

During spring and summer 2017 and 2018, we radiotracked collared elk in each of the 3 migration strategies at 6-week intervals (n=3 times) from May-August with the goal of collecting ~30 fresh samples/segment/interval (Fig. 13). We collected fresh samples from unknown elk after observed elk groups had moved away or from game trails following telemetry of collared elk. We also collected pellet samples from individual elk on the winter range during March and April of 2018 to compare their *F. magna* egg excretion to summer

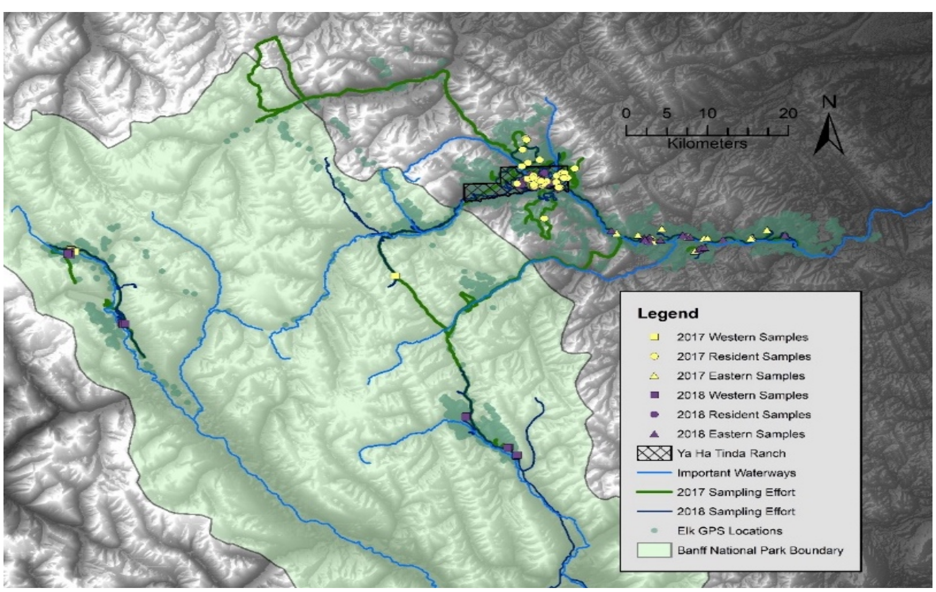


Figure 13. A map of the study site including the Ya Ha Tinda Ranch, Banff National Park, and allopatric elk summer ranges with locations of samples collected in 2017 shown in yellow and 2018 shown in purple.

habitat use. We collected 3 pellet groups from known, radiocollared individuals for a total of 39 individuals. We created Brownian Bridge utilization distributions for each elk using GPS data from May to October 2017 to weight covariates including total elk use of the landscape, elevation, and wetland presence/absence by individual elk use. We used a negative binomial model with a nested random effect of pellet group and individual to determine which factors were influencing *F. magna* egg output.

Samples collected from elk during the summer of 2017 and 2018 showed that eastern migrants had significantly higher fluke prevalence than Banff migrants and residents using a logistic regression ($p = 0.001$). Across all years and seasons eastern migrant elk had an average prevalence of 66% where residents and Banff migrants had an average prevalence of 31% and 42% respectively (Figure 14). *F. magna* intensity was significantly higher in 2018 ($p = 0.008$) and in eastern migrant elk ($p < 0.001$) according to a negative binomial model. Analysis of individual elk use from May 2017 - October 2017 and *F. magna* egg output in spring of 2018 showed that the top model using AICc model selection had a significant effect of migration strategy where residents had lower *F. magna* egg output than eastern and Banff migrants and wetlands increased *F. magna* egg output significantly. The second-best supported model showed the same trends with an added non-significant positive effect of elk use of the landscape.

Wetland exposure is critical to *F. magna* transmission because of the need for snail secondary hosts but it is interesting to note that according to the top model, high elk use of the landscape is not needed for high exposure to *F. magna*. This suggests that other species besides elk may be contributing to *F. magna* presence on the landscape including deer and that suitability of wetland habitats for *F. magna* snail secondary hosts may be higher in eastern areas. Higher *F. magna* prevalence and intensity in eastern migrant elk could have health implications for elk using the new eastern migration strategy if these elk have higher *F. magna* infection consistently over the coming years. The next component of the study will add another year of collared elk fecal samples collected in spring of 2019 to relate to habitat use in the summer of 2018.

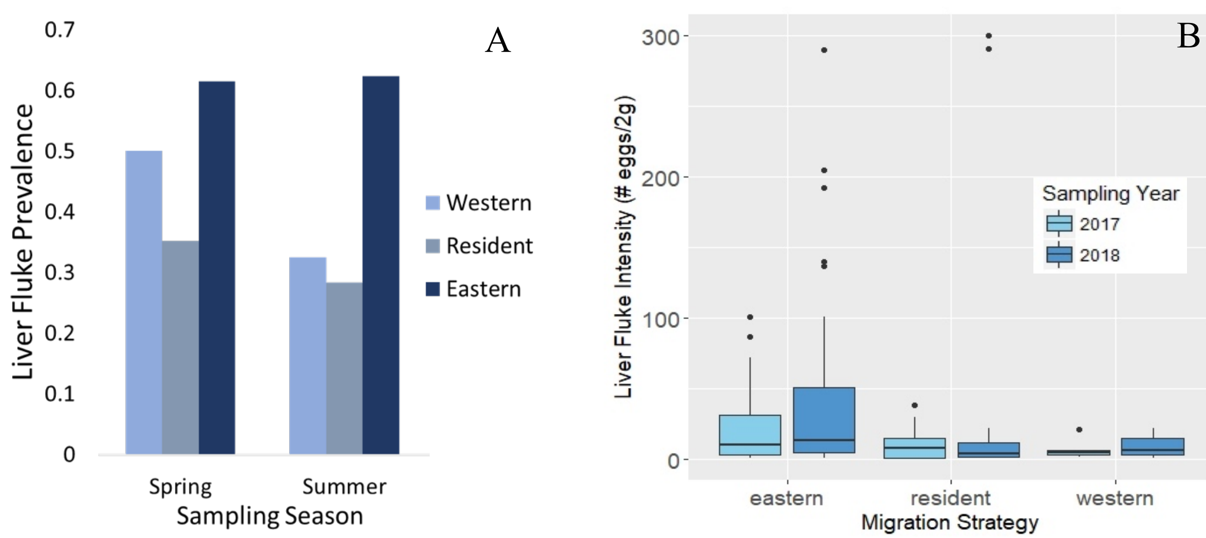


Figure 14. (A) Fluke prevalence (infected animals/all animals sampled) and (B) fluke intensity (number of eggs/2g of feces) detected in each elk migrant strategy separated by sampling period.

5.0 Winter Behavioral Observations

Madeline Trottier (MS Student, University of Alberta).

In our studies to date, we have focused on explaining trade-offs in elk habitat selection related to forage and predation on allopatric summer ranges. In contrast, less effort has been devoted to understanding interactions among elk that follow different migratory tactics in winter. (Robinson et al. 2010) reported high overlap in space, forage and exposure to predation risk amongst migrant and resident elk during daytime in winter. However, at night when wolves moved onto the grasslands, predation risk for resident increased more than western migrant elk. Further, migrant elk showed less group cohesion and more foraging interference, occurred in smaller group sizes, had higher vigilance in response to humans (but not wolves), and were poorer at multitasking, i.e., being vigilant and chewing (Robinson and Merrill 2013). As a result, it was hypothesized that foraging cost to migrant elk in winter may have partially offset the foraging benefits of migration in summer, particularly in years of high snow when elk foraging rate was encounter limited (Robinson and Merrill 2012).

With the recent increase in elk migrating to summer on industrial forests east of the Ya Ha Tinda, there may be altered interactions in winter among animals of different migratory tactics. Eastern migrant elk, which leave the winter range 3-4 weeks earlier than western migrants, may benefit from earlier forage green up at low elevation during calving and from low predation risk due to high human activity associated with timber harvest, energy development, and recreational use (Berg 2019). If eastern migrants habituate to humans in summer, in winter they may remain in areas near human infrastructure where they benefit from a human-based predation refuge, increasing competition among residents and eastern migrants. Alternatively, eastern migrants may not tolerate human activities during summer, and in winter avoid areas of human activity, show high vigilance to humans, and be less able to multitask like western migrants. Further, it is unknown how eastern migrants interact directly with western migrants and residents in forming cohesive groups, which may affect their predation risk and elk survival.

In my Masters research, I am contrasting behavior of migrant (eastern and western) and resident elk in the winters of 2018-2020 to determine their differences in space use, grouping interactions, foraging behavior, and vigilance. We hypothesized that in winter, compared to other elk groups eastern migrants will differ in range use, have smaller and less cohesive winter groups, experience higher foraging interference, and show more vigilance for predators and humans than resident elk, and are less effective at multi-tasking. To date, we have completed two (2018, 2019) field seasons of direct observations. We present preliminary analyses of data from winter 2018.

5.1 Methods

Elk spatial distribution

We used locations of GPS-collared elk in each migratory tactic (n= ~4-26 elk/tactic; Table 10) to determine home range overlap and habitat selection for each migratory tactic in winter using volume of intersection of kernel home ranges, and resources selection functions. Habitat selection assessed using within-home range selection analyses. Analysis of these data have not yet been begun.

Table 10. Number of elk and number of behavioral observations collected during winter 2018 (February 2-26) and winter 2019 (January 14-April 4) for each migratory tactic, as well as number of GPS-collared elk and number of collar relocations for each strategy.

Winter	Migratory Tactic	No. Focal Elk	No. of Direct Observations	No. GPS-Collared Elk	Total GPS Relocations
2018	Eastern	11	30	5	5839
	Western	10	32	4	3619
	Resident	18	53	10	11 824
	Total	39	115	19	21 282
2019	Eastern	6	37	6	2528
	Western	8	49	6	2547
	Resident	16	97	28	10 574
	Total	30	183	40	15 649

Group cohesion

We used GPS movement data from 1 December 2017 - 13 March 2018 from 19 individuals (resident n = 10; western n = 4; eastern n = 5) collected at a two-hour fix rate. We used a spatial criterion of 50 m and a temporal criterion of 15 minutes to identify an association event of a pair (dyad) of elk during this period, producing a matrix of the frequency of times the locations of dyads of all collared elk met the above criteria. The cohesion among groups was then quantified using a Jaccard index, which reflects the frequency of time elk were found together compared to their total observations.

Foraging and vigilance observations

During February 2018 and January - April 4 2019, we located GPS-collared female elk randomly using telemetry and observed focal animals using a spotting scope from 80-1100m for 3-20 minutes (Table 1). Location, group size, time spent feeding (head down, grazing), number of bites, and number of steps, seconds of vigilance (head up, looking around), and pawing (moving snow using front foot) were recorded. We also recorded conspecific interactions, position of the individual in the herd (center or periphery), density of elk around the focal (within 1, 5, and 10 elk-lengths; elk length ~1.8m). Observations were terminated if the elk moved out of view, bedded down, or became aware of the observer. Conspecific interactions were classed as aggressive, submissive, or neutral based on the behavior of the focal elk to conspecifics. A peripheral location was defined as an individual being the first elk to be encountered as a wolf group approached. Behaviours were dictated into a handheld recording device and post-processed in program JWatcher™. Environmental variables collected at the time of observation included air temperature, snow depth and cover, distance to human infrastructure and timber, wolf presence indicated by fresh scat, tracks, howling or sightings within 2 km of the elk group. Within ~1-2 days, biomass samples were clipped in 2 0.25-m^2 quadrats from an ungrazed area within 5 m of the center of each individual's foraging path.

5.2 Preliminary Results

Preliminary analysis of elk cohesion indicates that western migrants are less cohesive among themselves and with elk in other migratory groups, whereas resident and eastern elk tend to be associated with individuals in their own migratory group and with each other (Fig. 15).

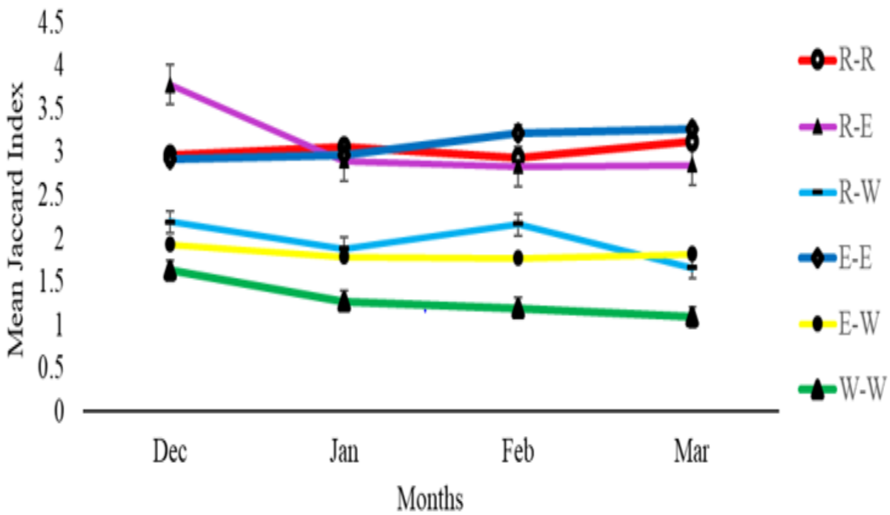


Fig 5. Mean (+SE) Jaccard index of groups observed between December 2017-March 2018 by dyad of migratory tactic (R= resident, W= western migrant, E= eastern migrant.

A total of 298 observations were made on focal animals of each migration strategy with an average length of observation period of 15.4 hrs ± 0.1 in 2018 and 34 hrs ± 0.07 in 2019. In both years, residents showed the lowest vigilance (Fig. 16), but this difference occurred between tactics only in 2019 (P = 0.046, df = 2, Kruskal-Wallis χ^2 = 6.67, Dunn's multiple comparison test, P< 0.01). Preliminary data analysis from 2018 only indicated that position within the group had the greatest effect on vigilance, with elk on the periphery being more vigilant ($\bar{x}$ = 121.58 ± 47.72) than when in the center ($\bar{x}$ = 48.06 ± 7.80). This was consistent across elk in different migratory tactics.

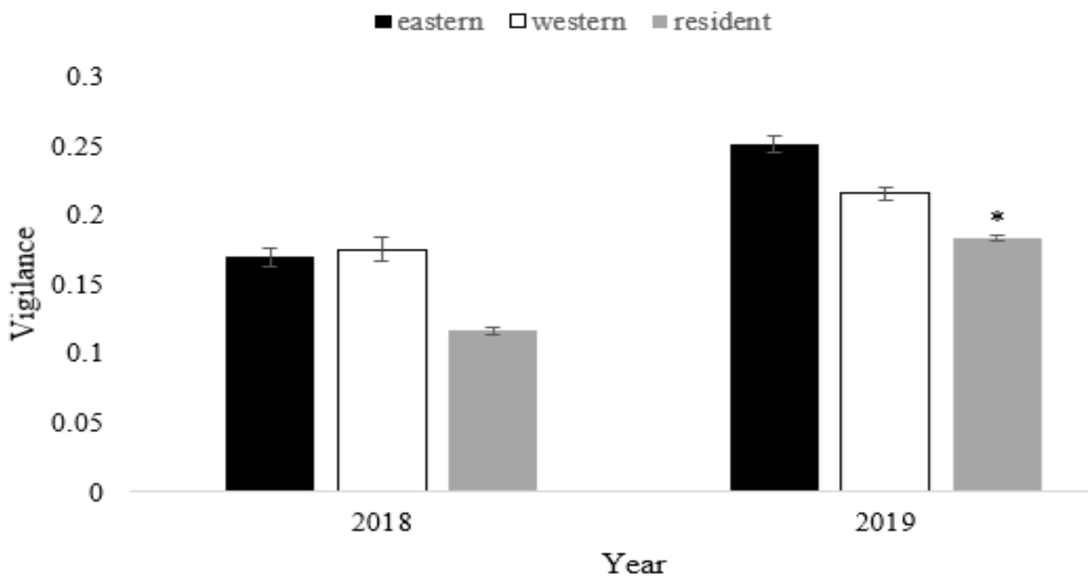


Fig 16. Mean (±SD) proportion of time spent vigilance during foraging in eastern, western, and resident elk in 2018 and 2019. * indicates different (*P*<0.05) between migratory tactic within years.

Future Work

Additional field work is planned for winter 2020. During summer of 2019, we will continue preliminary data analysis and modeling of factors influencing vigilance using data from both 2018 and 2019. This will continue over the next 2 years as part of an MSc project that is expected to be completed in December 2020.

6.0 MONITORING PREDATOR AND PREY USING REMOTE CAMERA TRAPS

6.1 Background

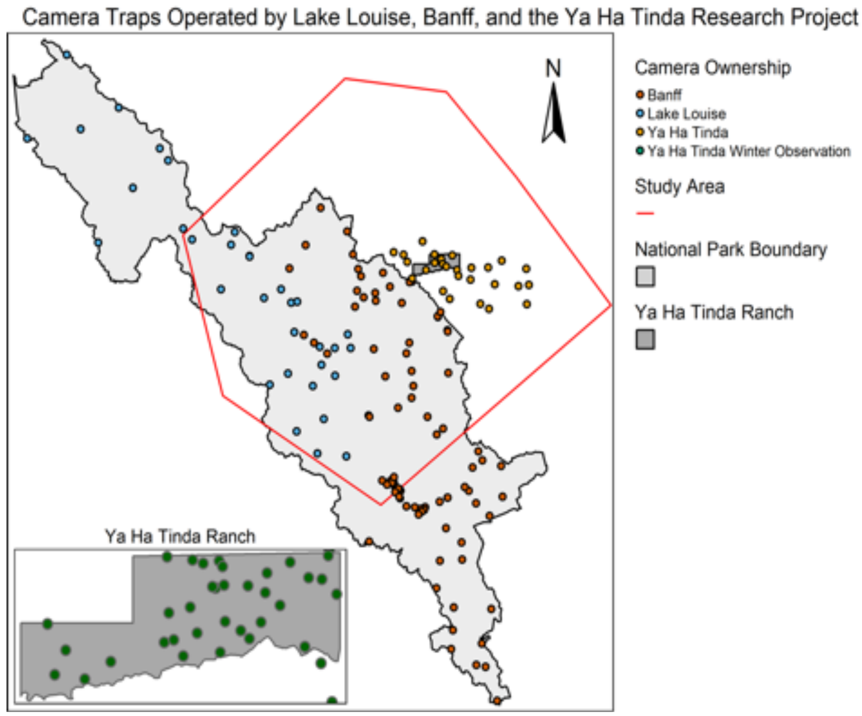


Fig. 17. The collaborative camera trap effort between the Ya Ha Tinda Elk and Predator Research project and Parks Canada.

The Ya Ha Tinda Elk and Predator Project maintains ~30 long-term remote camera traps (Fig. 17) on the Ya Ha Tinda Ranch and adjacent provincial lands. This sampling design is consistent with and extends the Parks Canada camera trapping grid with at least 1 camera within each 10x10km grid cell. Cameras were deployed in 2013/14, and again continuously in summer of 2016 to the present. In addition, for a short time period of 2 years, Mitchell Flowers (MS student at University of Alberta) has deployed an additional ~ 30 camera in a more intense camera trapping grid (2.5 km^2, see Inset Figure in Figure 17).

6.2 Image Classification

Camera data has been analyzed using the same Timelapse software (Greenberg and Goudin 2012) used by Parks Canada, enabling easy integration of our data into the Parks Canada databases. Events were defined as any consecutive sequence of images of the same species. For wolves and cougars, sequences separated by at least 5 minutes will be considered independent, regardless of whether the same individuals are being photographed. This definition was chosen specifically for the analysis of predator imagery because heightened use (*i.e.* high number of events) of an area can result from intense use by a single individual or moderate use by several. Image sequences of all other species will be assigned a threshold of 10 minutes, in accordance with current classification protocols for Parks Canada. Elk events separated by more than 10 minutes are not be considered a new event if there are other individuals present beyond the camera's field of detection throughout consecutive sequences.

6.3 Estimating Juvenile Recruitment of Elk in an Occupancy Modeling Framework

Mateen A Hessami (Undergraduate Senior Thesis, University of Montana)
Hans Martin (University of Montana)

Juvenile recruitment is a key parameter in understanding ungulate population dynamics. Traditional methods in population composition surveys, such as estimating young: adult-female ratio's, are often costly, and pose safety and feasibility challenges. Here, we tested the potential of remote cameras to estimate calf: cow ratios and calf survival of elk using the (Royle and Nichols 2003) occupancy model. We compared camera-based estimates of calf: cow ratio to traditional ground-based estimates obtained from group classification surveys (Duquette et al. 2014). We used all remote cameras from our extensive and intensive sampling design (Fig. 17, n=44), across the YHT. We fit Royle-Nichols occupancy models for female and young-of-year elk, estimating abundance of respective age classes for a 110-day sampling interval between 15 May – 1 September 2018. We estimated calf survival by comparing the abundance estimates of calves between 7 primary sampling periods and determined the effect of abiotic, biotic and anthropogenic covariates on detection probability and abundance.

We chose our sampling period based on the biological life history of calf elk in our study area. The first calf to be detected by a camera was 15 May 2018. The 110 days of camera-data was further partitioned into five, three-week sample intervals to best account for detection probability (i.e., hiding period) and calf phenology. Early-spring was defined between (15 May – 5 June), spring (6 June– 27 June), early summer (28 June – 19 July), summer (20 July – 10 August), and fall (11 August – 1 September). Ground observation data was temporally partitioned identical to remote-camera data. We converted adult female and young of year data to detection/non-detection for each sample interval to model abundance.

We used package *unmarked* (Fiske and Chandler 2011) in program R (R Development Core 3.3 Team 2011) to first determine covariates that effect detection probability, next we estimated adult female and calf abundance using the occuRN function in unmarked and the Poisson distribution to characterize site abundance (Royle and Nichols 2003; Duquette 2014). The occuRN function fits the latent abundance mixture model described in Royle and Nichols (2003), which uses detection/non-detection data of un-marked individuals by linking heterogeneity in detection probability to differences in site abundances (Royle Nichols 2003)

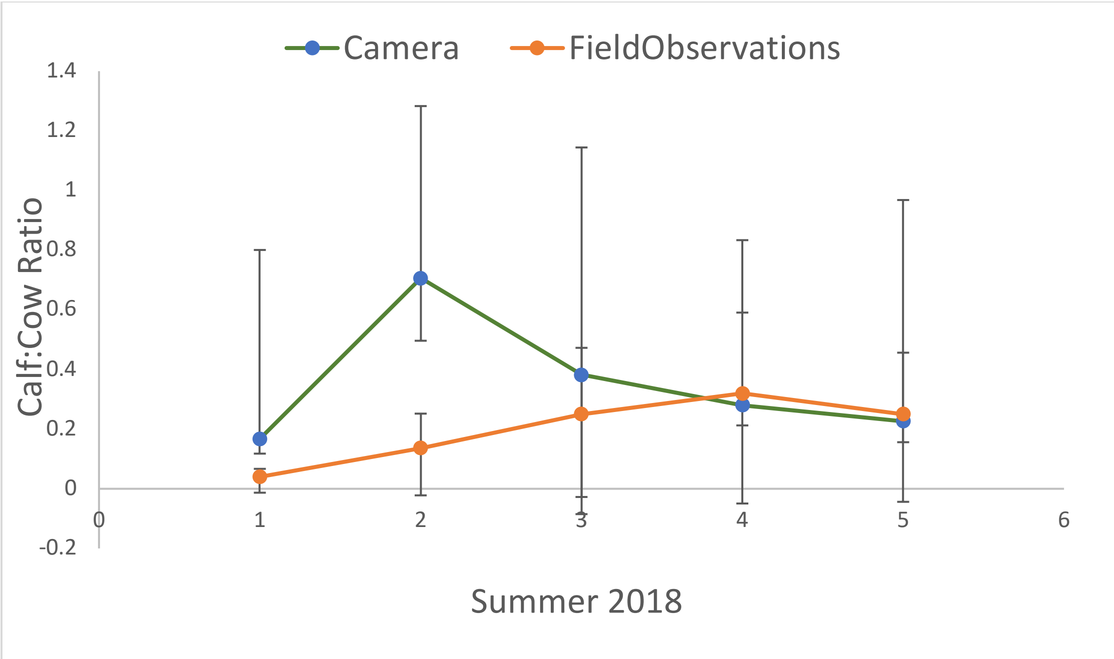


Figure 18*.* Sampling intervals on the X axis (three week-intervals) and ratio value on the Y axis from derived remote camera and ground estimates of calf:cow ratio at the Ya Ha Tinda, Alberta, Canada.

Our camera-based ratio results made biological sense; following expected trends in detection variability, peak calf abundance, and declining ratios associated with predation over time. Ground observations followed an initial increasing trend of survival associated with sightability bias of hiding calves becoming integrated into large populations. We then compared the estimates of calf survival and group composition to those of traditional field estimates collected in the same time period. We conducted a Pearson correlation test and found a 0.46 correlation between our camera-based and ground observations of calf:cow ratio. These results demonstrate the utility of using remote cameras to derive important parameters for understanding ungulate population dynamics.

6.5 The Waiting Game: Elk avoid predators at fine spatial scales

Mitchell Flowers (MS Student, University of Alberta)

Predator and prey have a number ways of sensing each other's presence and will alter their behavior in response to predation risk across a variety of spatial and temporal scales. However, it is unclear whether elk alter space use to all predators in a similar manner. Because wolves range widely, elk may not be able to reduce encounter rates by altering their space-use, whereas they may avoid ambush predators like cougars or bears that may search an area. Approaches to assess how elk respond to predators at Ya Ha Tinda have focused directly on radiocollared elk and their habitat selection of risky areas. In this study, we took a site-based approach to determine whether elk reduced return times to sites in response to the occurrence of predators. We used motion-activated remote cameras and a time-to-event modeling approach in summer and winter to assess the effect of predator occurrence, but present preliminary results only from summer in this report. We test for changes in elk movement rates during summer and account for movement rates and habitat preferences to determine if elk avoid area where predators have occurred. We hypothesized that elk would increase their return times to a site if a predator had recently used the site, and the response would be greater for cougars and bears than wolves.

6.5.1 Methods

We used a time-to-event framework to determine how return time of any elk to a camera site in summer 2017 and 2018 was related to elk movement rates, elk group size and composition, site characteristics, and whether predators had visited the site. An "event" was defined as an image of an elk or group of elk detected by the camera. The time to an event was determined as the time between two consecutive elk events >12 hrs apart at a camera site. We used a mixed effects Cox proportional hazards model to determine the influence of covariates on elk return times, and Schoenfeld residual analysis to determine whether the hazard of elk returning to sites was proportional across summer. Random effects were included to control for repeated observations at the same camera. We tested whether movement rates of GPS-collared elk (n =21) changed over the course of the season and included movement rate into all models. Models were developed with the 'coxme' function in the R survival package and tested with model selection using AIC. Prior to their use in candidate models, we tested for collinearity among covariates and did not include any with a Pearson correlation (r) ≥ 0.50.

Elk movement rates

We tested for a change in mean daily 2-hr step length across of GPS-collared elk (n = 21) in 2017 by comparing the fit of the data to a null model (average), linear regression, quadratic, and cubic function model using a model selection approach because number of parameters varied. Because we found a nonlinear (cubic) model best fit the 2017 data, we used the model to predict the mean movement rate across the specific days between each pair of elk events and included movement rate in all models. We used the same model in 2018 because GPS-collared elk were monitored on 12-hr time steps in 2018, which was considered too course a temporal resolution to determine movement rates.

Camera specifications and image classification

Camera settings and general installation protocols followed those used by Parks Canada (Hunt and Bourdin, 2015). Cameras (n = 44) where assigned to 2.5-km^2 grid cells stratified by habitat (open/forested/edge) and distance to human infrastructure (perimeter fencing surrounding the ranch buildings). Cameras operated for 24 hours per day and were set to take 5 pictures in rapid succession when triggered with no delay between consecutive triggers. Cameras were deployed to maximize the zone of detection and minimize the probability of not capturing faster moving animals by angling cameras at 45° and placing them approximately 2.5 m from the trail. This arrangement has been shown to be effective at capturing both large carnivore passage and the much higher speed of recreational vehicles. Camera data were analyzed using Timelapse software (Greenberg and Goudin, 2012). Image sequences of elk, predators, or humans separated by at least 10 minutes were considered independent events.

Herd counts began on the first image of an event and elk moving into the frame were added as they appeared. Return times were censored at 60 days (n = 11 of 665; 2%) to limit the contribution of sites not being used/returned to by elk.

6.5.2 Results and Discussion

Elk were detected at 42 of 44 remote camera locations and distributions of return times did not significantly differ between years (Kolmogorov-Smirnov test, *P* = 0.114). Return times in summer had a median of 5.11 days and a mean [± SE] of 9.66 ± 0.48 days (n = 665). There were 85 wolf events, 54 grizzly events and 9 cougar events that occurred between elk events across both summers. Variation in summer elk movements was best predicted by a cubic function (ΔAIC > 2; Fig. 19).

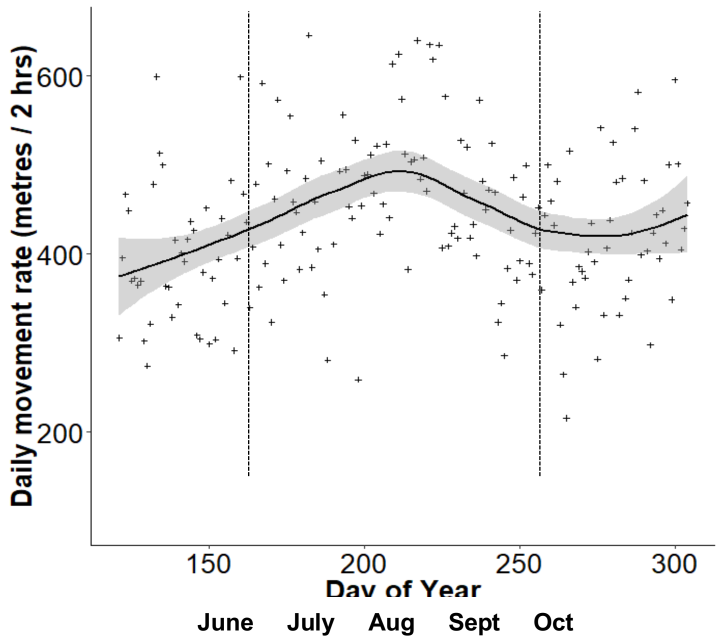


Figure 19. Daily movement rates of GPS-collared elk (n = 21) during summer of 2017. Summer was defined as 1 June to 15 Sept (dotted lines), when only resident elk were occupying the YHT.

Preliminary model selection in summer indicated that after controlling for movement rates, return times of elk were related to the amount of edge habitat surrounding the site as well as the occurrence of wolves, grizzlies, and cougars (ΔAIC > 2). Higher edge densities around sites delayed return times. The presence of a cougar and wolves increased return times by 65% and 59%, respectively, whereas the occurrence of grizzlies increased return times by 26% (Fig. 20). There was little support for interactions between predator occurrences and habitat characteristics.

In summer, return times to camera sites with high edge densities were longer. Cougars are known to hunt prey along forested edges and wolf predation of large ungulates can be facilitated by both natural edges and linear features, where prey might be most easily detected and vulnerable. Elk return times were further increased after a predator occurrence, regardless of habitat characteristics, suggesting elk actively avoided areas with recent predator sign.

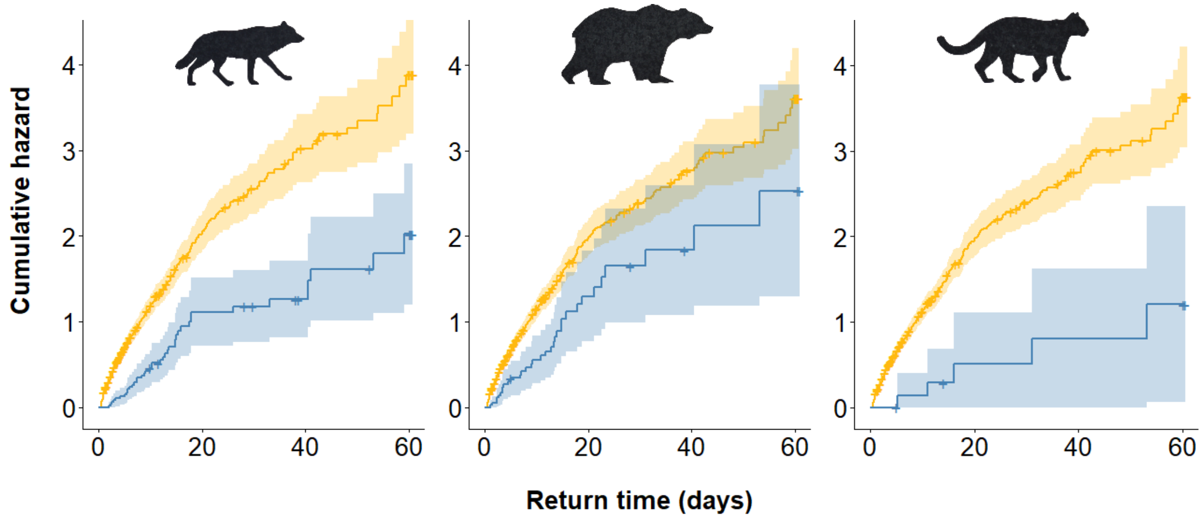


Figure 20. Cumulative hazard curves stratified by predator presence (blue) and absence (orange) throughout the summers of 2017 and 2018 (n = 665, CI = 0.95). Each set of curves represents the cumulative probability of an elk returning to a site in the presence of a different predator; Wolves (left), grizzlies (centre), and cougars (right). The hazard (or likelihood) of an elk returning to a site is consistently lower when predators have been detected between elk events.

Next Steps

We are currently applying this same approach to modelling return times in winter when density of elk on the winter range is higher, when movements can be more restricted by snow, and bears no longer pose a risk to elk.

7.0 SCIENTIFIC COMMUNICATION AND OUTREACH

Reporting period: June 1, 2017 to June 1, 2019.

Overview

Our Ya Ha Tinda elk project is now the longest-running study of a wild elk population in the world. As a result, our scientific work is increasingly being recognized as a key long-term study that informs management and science in other shorter-term studies. This highlights the critical role in Parks Canada and Alberta Environment and Parks, as well as our long-term funders, in supporting our work at Ya Ha Tinda.

We have now published approximately ~50 papers stemming directly or indirectly from our work at the Ya Ha Tinda site that have been cited over 2,000 times (Web of Science) or 3,700 times (Google Scholar). The h-index calculated just on Ya Ha Tinda related scientific publications is ~ 20 or 29 (respectively). An h-index score indicates how many times, on average, a scientific paper is cited a measure of its impact on the scientific field. These measures indicate that our work is having a broad impact on citations at least in the field of ecology, with the most being cited ~250 - 400 times (Hebblewhite et al. 2008, Ecological Monographs).

7.1 Peer-reviewed articles (students underlined):

1. <u>Berg, J.E.,</u> **Hebblewhite, M**., Cassady St. Clair, C. & **Merrill, E.H**. (2019) Prevalence and mechanisms of partial migration in ungulates. *Frontiers in Ecology and Evolution,* **In Revision**.
2. Twombly, S., Belovsky, G.E., Frey, S.D., **Hebblewhite, M**., Hobbs, N.T., Ives, A., Lenski, R.E., Melillo, J.M., Peterson, R.O., Petraitis, P., Sedinger, J.S., Stahler, D.R., Vanni, M.J. & Vucetich, J.A. (2019) Understanding Ecological and Evolutionary Surprises. *Bioscience,* **In Revision**.
3. **Hebblewhite, M**., Eacker, D.R., <u>Eggeman, S</u>., Bohm, H. & Merrill, E.H. (2018) Density-Independent Predation Affects Migrants and Residents Equally in a Declining Partially Migratory Elk Population. *Oikos,* **127,** 1304-1318.
4. <u>Normandeau, J., Macaulay, K., Berg, J.</u> & **Merrill, E.** (2018) Identifying guard hairs of Rocky Mountain carnivores. *Wildlife Society Bulletin,* **42,** 706-712.
5. Schlagel, U.E., **Merrill, E.H.** & Lewis, M.A. (2017) Territory surveillance and prey management: Wolves keep track of space and time. *Ecol Evol,* **7,** 8388-8405.
6. <u>Steenweg, R.,</u> **Hebblewhite, M.,** McKelvey, K., Lukacs, P. & Whittington, J. (2019) Species-specific trade-offs in statistical power when monitoring trends in multispecies occupancy. *Ecosphere,* **10,** e02639.
7. <u>Steenweg, R.,</u> **Hebblewhite, M**., Whittington, J., Mckelvey, K. & Lukacs, P. (2018) Sampling scales define occupancy and the occupancy-abundance relationship in animals. *Ecology,* **99,** 172-183.
8. <u>Steenweg, R.,</u> **Hebblewhite, M**., Kays, R., Ahumada, J., Fisher, J.T., Burton, C., Townsend, S.E., Carbone, C., Rowcliffe, J.M., Whittington, J., Brodie, J., Royle, J.A., Switalski, A., Clevenger, A.P., Heim, N. & Rich, L.N. (2017) Scaling-up camera traps: monitoring the planet's biodiversity with networks of remote sensors. *Frontiers in Ecology and the Environment,* **15,** 26–34.
9. Tucker, M.A., Bohning-Gaese, K., Fagan, W.F., Fryxell, J.M., Van Moorter, B., Alberts, S.C., Ali, A.H., Allen, A.M., Attias, N., Avgar, T., Bartlam-Brooks, H.L.A., Bayarbaatar, B., Belant, J.L., Bertassoni, A., Beyer, D.E., Bidner, L., van Beest, F.M., Blake, S., Blaum, N., Bracis, C., Brown, D., de Bruyn, P.N., Cagnacci, F., Calabrese, J.M., Camilo-Alves, C., Chamaille-Jammes, S., Chiaradia, A., Davidson, S.C., Dennis, T.,

DeStefano, S., Deifenbach, D., Douglas-Hamilton, I., Fennesey, J., Fichtel, C., Fiedler, W., Fischer, C., Fischoff, I., Fleming, C.H., Ford, A.T., Fritz, S., Gehr, B., Goheen, J.R., Gurarie, E., **Hebblewhite, M.**, Heurich, M., Hewison, A.J., Hof, C., Hurme, E., Isbell, L.A., Janssen, R., Jeltsch, F., Kaczensky, P., Kane, A., Kappler, P., Kauffman, M., Kays, R., Kimuyu, D., Koch, F., Kranstauber, B., Lapoint, S.D., Leimgruber, P., Linnell, J.D.C., Lopez-Lopez, P., Markham, A.C., Mattison, J., Medici, E.P., Mellone, U., **Merrill, E.H.**, de Miranda-Mourao, G., Morato, R.G., Morellet, N., Morrison, T.A., Diaz-Munoz, S.L., Mysterud, A., Nandintsetseg, D., Nathan, R., Niamir, A., Odden, J., O'Hara, R.B., Olvieria-Santos, G.R., Olson, K.A., Patterson, B.D., de Paula, R.C., Pedrotti, L., Rimmler, M., Rogers, T.L., Rolandsen, C.M., Rosenberry, C.S., Rubenstein, D.I., Safi, K., Said, S., Sapir, N., Sawyer, H., Schmidt, N.M., Selva, N., Sergiel, A., Shiilegdamba, E., Silva, J.P., Singh, N.J., Solberg, E.J., et al. (2017) Moving in the anthropocene: global reductions in terrestrial mammalian movements. *Science,* **359,** 466-469.

10. Spitz, D.B., **Hebblewhite, M**. & Stephenson, T.R. 2017. 'MigrateR': extending model-driven methods for classifying and quantifying animal movement behavior. *Ecography,* 40, 788-799.

7.2 Completed Graduate Theses: 2 PhD and 6 MSc theses since 2001:

1. Berg, J.E. (2019) *Shifts in strategy: Calving and calf survival in a partially migratory elk population*. University of Alberta. http://www.umt.edu/yahatinda/files/Berg_Submitted%20Dissertation%2031Jan2019.pdf
2. Spilker, E. (2018). *Spatial predation risk and interactions within a predator community on the Rocky Mountains east slopes, Alberta*. University of Alberta.
3. MacAulay, K.M. (2019) *Spatial predation risk for elk (Cervus elaphus) in a multi-predator community on the Rocky Mountain East Slopes, Alberta*. University of Alberta. http://www.umt.edu/yahatinda/files/FMacAulay%Kara%201901%MSc.pdf

7.3 In-progress Graduate Theses: 1 PhD and 4 MSc in progress

1. Martin, H. Role of migration dynamics of male and female elk in the population dynamics at Ya Ha Tinda. PhD, University of Montana. Expected completion: Fall 2020.
2. Keery, L. 2019. Effects of bison reintroduction on vegetation and landcover in Banff National Park. Royal Rhodes University, Mark Hebblewhite Advisor. Expected completion, June 2019.
3. Normandeau, J. 2019. Elk contact networks and parasite dynamics. MSc, University of Alberta. Expected completion: Fall 2019.
4. Flowers, M. 2019. Winter behavior of resident and migrant elk at Ya Ha Tinda Ranch. MS Thesis, University of Alberta. Expected completion Summer 2019.
5. Trottier, M. 2020. The Waiting Game: Elk avoid predators at fine spatial scales MS thesis, University of Alberta. Expected completion Fall 2020.

7.4 Undergraduate Honors Theses

1. Hessami, M. (2019). Estimating Migratory-Resident Elk Populations and Juvenile Recruitment Using Remote Cameras in the Canadian Rockies. Senior thesis. University of Montana.

7.5 Conference Presentations

1. Hebblewhite, M. (2019) Plenary: Twenty Years of the GPS-Infused Movement Revolution: Linking Movement Responses to Humans to Animal Fitness. In *Gordon Research Conference: Animal Movement as a Link Between Ecology, Evolution and Behavior*, Lucca, Italy.
2. Normandeau, J., Kutz, S., Merrill, E.H., Hebblewhite, M. (2018). *Are there costs to shifting migration linked to parasitism?*. RE Peter Student Symposium. Edmonton, Alberta.

3. Normandeau, J., Kutz, S., Merrill, E.H., Hebblewhite, M. (2018). *Are there costs to shifting migration linked to parasitism?*. Alberta Chapter of The Wildlife Society conference. Lethbridge, Alberta, Canada.
4. Hebblewhite, M., Merrill, E.H. (2017). *Ecology & Management of Partially Migratory Ungulates: Insights from Canada's Longest Running Elk Research Project, the Ya Ha Tinda*. Invited plenary speaker at University of British Columbia-Okanagan Department of Biology Speaker Series. Kelowna, BC, Canada.
5. MacAuley, K., Spilker, E., Berg, J., Merrill, E.H. (2017). *Guess who's coming to dinner? Linking predator diets to elk predation risk*. A Celebration of ACA Research Funding Reception. Edmonton, Alberta, Canada.
6. Lukacs, P., Nowak, J., Hebblewhite, M., Martin, H. (2018). *Integrated population modeling for wildlife management*. Webinar presentation to 43 Alberta Fish and Wildlife Biologists. Webinar.
7. Flowers, M., Melsted, J., Hebblewhite, M., Merrill, E.H. (2018). *Remote cameras for investigating elk responses to wolves*. Alberta Chapter of The Wildlife Society conference. Lethbridge, Alberta, Canada.
8. MacAuley, K., Spilker, E., Berg, J., Merrill, E.H. (2018). *Spatial mortality risk for elk in a multi-predator community*. RE Peter Student Symposium. Edmonton, Alberta, Canada.
9. MacAuley, K., Spilker, E., Berg, J., Merrill, E.H. (2018). *Spatial mortality risk for elk in a multi-predator community*. Alberta Chapter of The Wildlife Society conference. Lethbridge, Alberta, Canada.
10. Martin, H., J. Normandeau, E. Merrill, M. Hebblewhite. (2019). *Bull Elk Ecology and Vulnerability in a Partially Migratory Population*. Poster Presentation. Alberta Chapter of the Wildlife Society Conference. Canmore, AB.
11. Martin, H.**,** J. Killeen, E. Merrill, M. Hebblewhite, J. Berg, S. Eggeman, H. Bohm. (2018). *Migratory flexibility suggests facultative switching in a partially migratory elk herd.* Poster Presentation. Greater Yellowstone Coordinating Committee Wildlife Migration Symposium. Jackson Hole, WY.
12. Martin, H., Merrill, E.H., Hebblewhite, M. (2017). *The history of elk research and ecology at the Ya Ha Tinda*. Ya Ha Tinda 100th Year Parks Canada Celebration Conference. Ya Ha Tinda Ranch, Alberta, Canada.
13. Hebblewhite, M., Merrill, E.H., Eggeman, S., Bohm, H., Berg, J., Kileen, J. (2017). *Unexpected flexibility in migratory behavior, its drivers, and population consequences in a large herbivore.*. Ecological Society of America. Portland.
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7.6 Websites

1. *Gurarie, E., Hebblewhite, M. 2018. Animal movement for conservation: New Tools for Data Management, Visualization and Analysis. Workshop presented at the International Conservation Biology Congress, Cartagena, Columbia, 2018.* *https://terpconnect.umd.edu/~egurarie/teaching/MovementAtICCB2017/index.html*
2. *2) Ya Ha Tinda Long-Term Elk Monitoring Project* http://www.umt.edu/yahatinda/

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