

# Final Report for Testing monitoring techniques for wolves in southwest Alberta

March 14, 2016



Photo: S. Rettler

David E. Ausband<sup>1</sup> & Sarah B. Bassing  
University of Montana, Natural Science Building - Room 205  
Missoula, MT, USA 59812

Phone: 406-243-4329

<sup>1</sup>E-mail: [david.ausband@mso.umt.edu](mailto:david.ausband@mso.umt.edu)



## Abstract

Gray wolf populations are difficult to monitor because wolves can be elusive and occur in relatively low densities. Monitoring is necessary, however, to make informed management decisions and assess the effectiveness of management actions. In southwest Alberta wolf harvest is considered high and there is currently no program in place to monitor wolves in this region. As a result, Alberta Environment and Sustainable Resource Development was interested in establishing a long-term wolf monitoring program to estimate wolf population demographics and inform management decisions in southwest Alberta.

We tested a population monitoring framework in southwest Alberta, 2012-2014. We surveyed big-game hunters for wolf observations and conducted field surveys for wolves at predicted rendezvous sites. We mailed refrigerator magnets with our contact information to grazing leaseholders and landowners twice in 2013 and 2014 to obtain wolf sightings made by the public and contacted several members of the South Country Trappers Association to obtain recent wolf activity information from trappers.

We combined data from our 2 survey methods into a patch occupancy model that estimated wolf pack abundance and distribution across our study area. Our final model used a 1,200 km<sup>2</sup> grid cell which contained the least uncertainty in population estimates. A model that accounts for false positive detections (i.e., reporting a wolf pack when it is not present) estimated 5.99 (3.27-8.65; 95% CI) wolf packs in our study area in 2012, and 11.60 (7.12-16.42; 95% CI) and 15.29 (10.32-21.52; 95% CI) in our expanded study area in 2013 and 2014, respectively. The 2014 model did not account for false positives. Between 10-15% of wolf observations by hunters were made on private land during the big-game hunting seasons. We did not acquire enough public sightings of wolves or reports of wolf activity from trappers to use as a data source in our model but were able to use the several reports we did obtain to test model estimates and found spatial overlap between model predictions and public reports.

We conclude we were able to successfully estimate wolf pack abundance and distribution in southwest Alberta in 2012, 2013, and 2014. Such a framework should benefit management and conservation of wolves in the region. We showed that even in our relatively small study area where wolf harvest is considered high our methods are able to successfully detect wolves and estimate wolf pack abundance in the absence of radiotelemetry. These methods can be incorporated into a long-term monitoring framework specific to southwest Alberta allowing managers to track demographics trends and inform management decisions.

Based on our results we recommend:

- Using free software programs PRESENCE and R to run patch occupancy models;
- Accounting for false positive detections in the detection data;
- Including human density, wolf harvest, and survey effort covariates on occupancy and detection estimates, as well as testing livestock density as a covariate once the data are compiled;
- Continuing field surveys (i.e., rendezvous site surveys) in addition to online hunter surveys.

## Introduction

Gray wolf (*Canis lupus*) populations are difficult to monitor because wolves tend to be elusive, occur in low densities, and live in remote and inaccessible terrain where surveying is difficult. In addition, wolves are territorial and the challenge of locating an individual, or even sign of an individual, within a large territory can be daunting. Radiotelemetry is an effective tool for monitoring wolves where mortality is relatively low, radiocollars remain deployed for extended periods and funding and manpower are sufficient to collar and track a large proportion of a population. Where turnover is high within the wolf population and resources (staff and funding) to maintain wolf collaring programs are limited, long-term radiotelemetry-based monitoring of wolves has limited application (G. Hale, Alberta Environment and Sustainable Resource Development, [AESRD], pers. comm.). Noninvasive alternatives to radiotelemetry monitoring are available, however, and could provide critical information on wolf populations. Such data would increase the ability of resource managers to make informed and cost-effective management decisions involving wolves. In recent years, a number of noninvasive methods were developed to reliably survey for carnivores (Long et al. 2008). Often these noninvasive techniques do not require highly trained personnel (unlike trapping and collaring) and sampling sites do not have to be checked daily thereby reducing labor costs. This reduction in effort means that more area can be surveyed with given budgets and more data can be obtained about the population as opposed to information about a few collared individuals. Lastly, a region-wide noninvasive monitoring program can provide annual estimates of the abundance and distribution of the population allowing managers to observe trends over time and incorporate this knowledge into management decisions and planning.

A noninvasive monitoring program is well suited for regions like southwest Alberta, where harvest pressure on wolves is considered high and maintaining radiocollars in the population is difficult. There is currently no program in place to monitor the wolf population in southwest Alberta due to high harvest and limited agency resources. As a result, agency biologists were interested in establishing a long-term wolf monitoring program in the absence of radiotelemetry that can be used to inform management decisions and assess the effectiveness of management actions, observe trends in the wolf population, and keep interested landowners up-to-date on the regional wolf population. The Montana Cooperative Wildlife Research Unit (MTCWRU) began collaborating with AESRD in 2008 to develop a long-term monitoring framework specific to the wolf population in southwest Alberta based on work conducted in Idaho and Montana, USA.

We began working collaboratively with the Nez Perce Tribe, Idaho Department of Fish and Game, and Montana Fish, Wildlife and Parks in 2006 on a research project to develop techniques for monitoring gray wolf populations across large scales in the absence of radiotelemetry in the U.S. We tested the use of patch occupancy modeling to monitor wolves at large spatial scales. Patch occupancy modeling provides a means to combine data from multiple different survey methods into one meaningful model of distribution and abundance (MacKenzie et al. 2006). Occupancy models, at their most basic level, can be viewed as presence/absence models that incorporate the reality that species are detected imperfectly (probability of detection  $< 1.0$ ; MacKenzie et al. 2006). Occupancy models use detection probabilities gathered by repeatedly sampling multiple sites, or spatially replicated visits, to obtain an occupancy estimate that accounts for imperfect detection. Occupancy models use data derived from sampling units to provide a probability of detection and occupancy over a larger area making them ideal for large-scale monitoring programs (MacKenzie et al. 2006). For example, Ausband et al. (2014a) used patch occupancy models populated with data from hunter and rendezvous site surveys to accurately estimate wolf pack abundance in Idaho, USA (Fig. 1) and Rich et al. (2013) populated

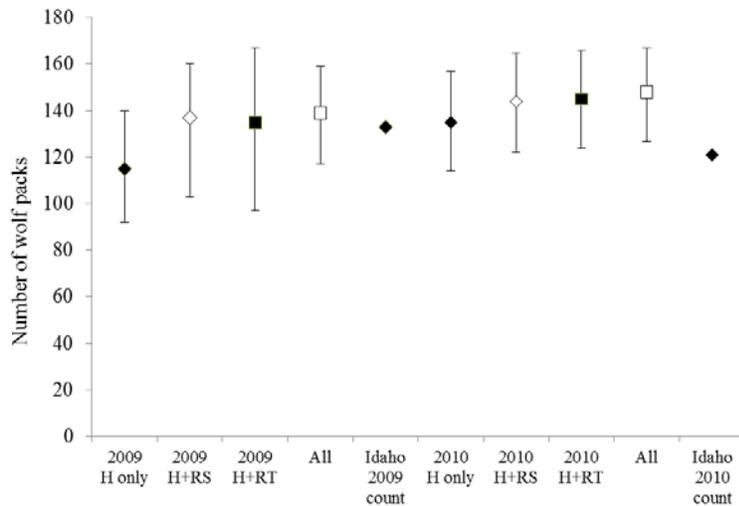


Figure 1. Estimated number of wolf packs using hunter surveys (H), rendezvous site surveys (RS), radiotelemetry locations (RT), and a patch occupancy model compared to the minimum number of packs present in Idaho, USA, 2009-2010 (Ausband et al. 2014a).

patch occupancy models with hunter detection data to estimate wolf pack abundance, colonization, and local extinction probabilities in Montana, USA.

Managers may wish to test model estimates and, further, may desire more detailed information on packs in areas of high management interest. Numerous sampling methods exist for surveying for wolves, all of which can generate detection data to be incorporated into patch occupancy models. For example, in addition to testing hunter surveys in Idaho and Montana we developed and tested 3 field-based survey methods for collecting data from wolves without the need for

capture and radiocollaring; specifically, rendezvous site surveys and subsequent DNA analyses, rub stations, and howlboxes (Ausband et al. 2011; Brennan et al. 2013; Ausband et al. 2014a). Each of these methods is designed to provide different levels of information given management interests and all are designed to provide data necessary to populate a patch occupancy model.

We set out to test a patch occupancy model populated with detection data derived from sampling methods refined specifically for the wolf population in southwest Alberta. Our goal was to develop an accurate and reliable monitoring framework that could estimate wolf pack abundance and distribution across the study area and be implemented as a monitoring program in the future, thereby increasing the ability of managers to make informed management and conservation decisions.

Our objectives for this study were to:

- deploy sampling methods found effective for monitoring wolves in Idaho and Montana in southwest Alberta
- refine and adjust methods as needed to increase field efficiency and accuracy and precision of population estimates
- develop patch occupancy model that combines multiple data sources into a framework that can be used for continued long-term wolf population monitoring in southwest Alberta

## Study Area

The study area in 2012 encompassed 12,950 km<sup>2</sup> in southwest Alberta, spanning the US border to Hwy 1, west to the BC border, and east to Hwy 6 and 22, including the Porcupine Hills east of Hwy 22 as well (Fig. 3). Based on the preliminary 2012 model results we expanded the 2013 and 2014 hunter survey to further test model performance and precision, encompassing a total of 30,000 km<sup>2</sup> in southwest Alberta by extending the original study area north of Hwy 1 along Hwy 22 to the Brazeau River, and west to the eastern borders of Banff and Jasper National Parks (Fig. 4).

## Methods

### *Rendezvous site surveys*

Just after the denning period wolves move pups to rendezvous sites. Pups will remain at the rendezvous site for several weeks while adults hunt and return intermittently with food to provision the pups. Rendezvous sites can be occupied for up to several weeks and are often located near, or in, meadows or bogs (Joslin 1967; Mech 1970).

Sampling rendezvous sites provides valuable information on breeding packs, which are often the units of management interest, and every individual in the pack spends at least a portion of time at the site and can thus be sampled using genetic tools. Focusing survey efforts at predicted

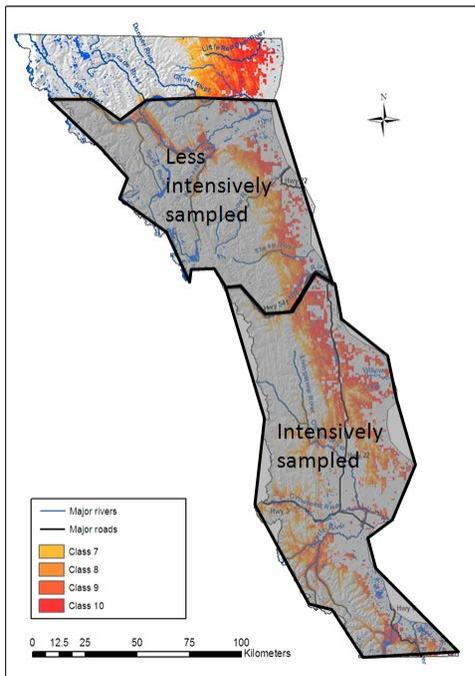


Figure 3. Study area (2012) in southwest Alberta showing intensively and less intensively sampled areas for wolves.

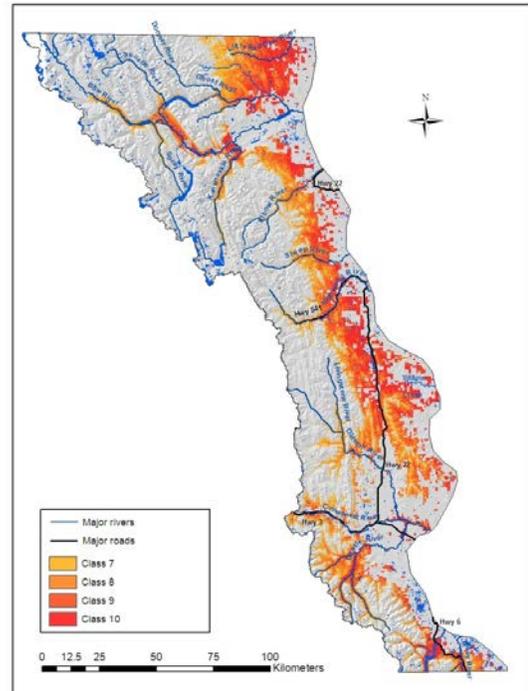


Figure 2. Map of top 4 classes of predicted gray wolf rendezvous site habitat in southwest Alberta.

rendezvous sites can narrow the search area for wolves by 89% (Ausband et al. 2010). We used a predictive rendezvous site model to survey for wolves in Idaho and were able to detect 74% of the litters of pups and all study packs without the need for radiotelemetry (Ausband et al. 2010). Additionally, Stenglein et al. (2010a) found that numbers of wolves could be accurately estimated from DNA analyses of scats and hairs collected at predicted sites. In 2010, we developed a predictive rendezvous site habitat model for southwest Alberta (Fig. 2). Results of this effort were presented to managers in Pincher Creek, Alberta in March 2011 and are reported in Ausband and Mitchell (2011). This habitat model was used as the foundation for field surveys of wolves in southwest Alberta 2012, 2013, and 2014.

In summer 2012, we surveyed potential rendezvous site locations in the top 3 predicted habitat classes within the intensively surveyed portion of the study area (US border to the Highwood River), with the exception of sites on private lands (Fig. 3). We did not survey the less intensively surveyed portion of the study

area (Highwood River to Hwy 1) due to budget constraints in 2012. Most wolf detections and historic rendezvous sites were in predicted habitat classes 7-9 and we refined our survey in 2013 and 2014 to focus on these habitat classes instead of classes 8-10. In addition, in 2013 and 2014 we surveyed 86 and 120 randomly-selected predicted rendezvous site locations, respectively, in the less intensively surveyed portion of the study area.

We surveyed only sites with contiguous patches  $\geq 1.0$  ha. At each site a technician gave a series of howls (Harrington and Mech 1982); if wolves responded by howling, technicians attempted to obtain a visual observation. If technicians did not detect wolves after howling, they surveyed for wolf sign along the perimeter of the site where daybeds and high-use areas are commonly found, and on trails leading away from or through the site. If a potential site was too large to survey its entire perimeter and all trails, 2 technicians conducted sign surveys in the site for 30 minutes. Predicted rendezvous sites can sometimes be very large meadow complexes encompassing several square kilometers. We divided such sites into  $1.6 \text{ km}^2$  blocks and technicians surveyed alternating blocks because we assume the unsurveyed portions will be within the broadcast range of technicians' howls (Harrington and Mech 1982). When sites contained drivable roads, we conducted sign surveys in vehicles at 20 km/h along all roads within the site (Crete and Messier 1987).

The minimum observed distance between historical rendezvous sites of adjacent packs in Idaho was 6.4 km (C. Mack, NPT, unpublished data); we therefore placed a 6.4 km-radius circle around predicted rendezvous sites that were occupied by wolves and did not survey additional sites within that buffer.

We considered canid scats  $\geq 2.5$  cm diameter to be wolf scats (Weaver and Fritts 1979). Because coyote (*C. latrans*) scats and wolf pup scats overlap in size, we did not consider scats  $< 2.5$  cm to be wolf pup scats unless there was abundant wolf sign (e.g., pup play areas; Joslin 1967) or live wolves at the site. We collected a small sample (e.g. pencil-eraser sized) from the side of the scat with sterilized forceps and placed it in DMSO/EDTA/Tris/salt solution buffer (Frantzen et al. 1998; Stenglein et al. 2010b).

We mapped the geographic coordinates of individual wolf genotypes in ArcMap 10.1 (ESRI 2012) to generate detection histories for each grid cell across the entire study area for 2012, 2013, and 2014 (Appendix 1; Fig. 4). We used the resulting detection/non-detection data (along with hunter survey data – see below) to populate study area-wide patch occupancy models.

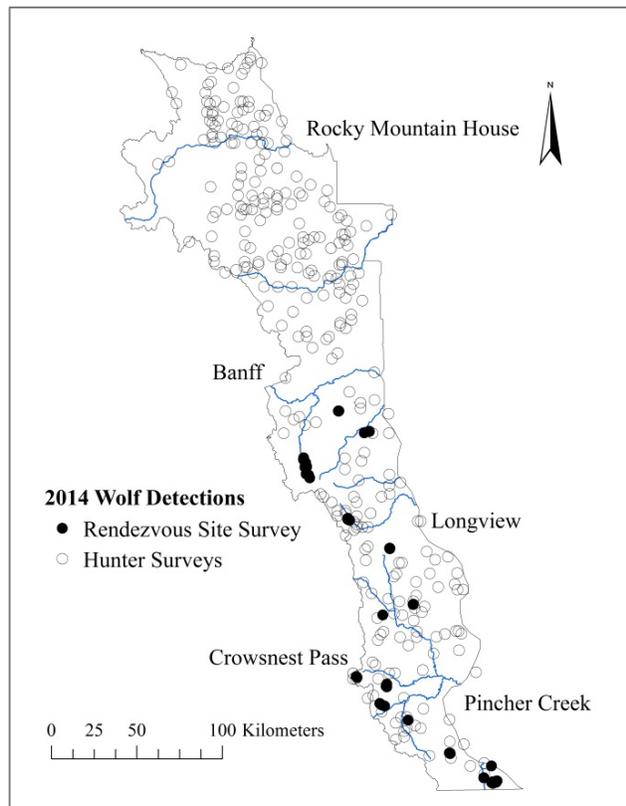


Figure 4. Wolf detection locations from our two sampling methods in the expanded 2014 study area. In 2012, 2013, and 2014 we extracted DNA collected from wolf scats to identify individuals and distributed online questionnaires to hunters for wolf observations made during the big game hunting season. Rendezvous site surveys were only conducted in the intensively surveyed portion of the study area in 2012 and were expanded throughout the full original study area in 2013 and 2014. We created detection histories for our patch occupancy models using these data.

### *Hunter Surveys*

In early 2013, 2014, and 2015 we surveyed hunters for any observations of live wolves made during the respective 2012, 2013, and 2014 big game hunting seasons. We added 4 questions (Appendix 2) to the existing online hunter reporting form currently used by Alberta ESRD to survey big game hunters (Rich et al. 2013; Ausband et al. 2014a). Based on the preliminary 2012 model results we expanded the 2013 and 2014 hunter surveys to further test model performance and improve precision, encompassing a total of 30,000 km<sup>2</sup> in southwest Alberta by expanding the original study area north of Hwy 1 along Hwy 22 to the Brazeau River, and west to the eastern borders of Banff and Jasper National Parks (Fig. 4). We also implemented an interactive map in the 2013 and 2014 hunter surveys so hunters could identify the exact section within a Wildlife Management Unit (WMU) where they observed wolves, providing us with more accurate wolf-sighting locations. We recorded the geographic coordinates and mapped the resulting hunter sightings in ArcMap 10.1 (ESRI 2012; Appendix 1; Fig. 4). Wolf sightings were used to generate detection histories for each grid cell across the entire study area. We used the resulting detection/non-detection data in combination with the rendezvous site survey data to populate a study area-wide patch occupancy model.

In addition to conducting hunter surveys we mailed letters and distributed magnets with our contact information to grazing leaseholders and landowners twice in 2013 and 2014 to obtain wolf sightings made by the public (Fig. 5). We also spoke with several members of the South Country Trappers Association to obtain information on recent wolf activity.



Figure 5. Refrigerator magnet sent to grazing leaseholders and given to participants at public talks in 2013 and 2014 as part of a concerted effort to incorporate more local knowledge of wolf distribution in southwest Alberta.

### *Patch Occupancy Model*

We populated our occupancy models with detection data using genetic results from rendezvous site surveys and wolf sightings from hunter surveys to estimate wolf occupancy in southwest Alberta in 2012, 2013, and 2014. Both detection methods generated multiple detection states (i.e., certain and uncertain) as described by Miller et al. (2011). Our annual survey period was 1 June to 31 December. We assumed the population was closed to changes in pack occupancy during each sampling season (i.e., no pack colonizations or local extinctions) and detection of a pack in one site was independent of detections in another site. In 2012 and 2013 we fit our detection data to an occupancy model that incorporates false positive detections (i.e., a wolf pack was reported but is not actually present; Ausband et al. 2014b). The false positive detection occupancy model allowed us to address the third model assumption that packs were not falsely detected (MacKenzie et al. 2006; Miller et al. 2011; Miller et al. 2013; Ausband et al. 2014a). Because of current limitations of Program Presence, in 2014 we fit our detection data to a model that does not account for false positive detections.

Informed by our preliminary models we use biweekly wolf sightings from hunter surveys to maximize sample size while retaining sufficient wolf detections for best model performance (Ausband et al. 2014b). Our final model design included 9 sampling occasions per sampling season, 1 from rendezvous site surveys, and 8 from hunter surveys. The rendezvous site survey sampling occasion included the entire summer field season (June-Aug). The hunter survey detections were condensed into 8, two-week sampling occasion (Sept-Dec).

In the rendezvous site survey sampling occasion, the  $i$ th grid cell was treated as being a certain detection if individual genotypes indicated the presence of  $\geq 2$  adults and  $\geq 1$  pups (i.e., a reproductive pack), an uncertain detection if only  $\geq 2$  adult wolves were present, and no pack was detected if only 1 adult wolf was present. Uncertain detections were only incorporated in the false positive detection models (i.e., 2012 and 2013 models). In some instances, one individual wolf genotype was detected in  $\geq 2$  grid cells. To avoid overestimating detection frequencies, we only counted the detection in one cell using one of the following rules. If the same wolf was detected multiple times in the  $i$ th cell we counted the detection in that cell and all other cells ignored the presence of that individual. If the same wolf was detected equally in multiple cells then we chose to ignore the detection in one cell at random. Hunter survey detections for the  $i$ th grid cell in the  $t$ th sampling occasions were treated as being certain if  $\geq 3$  hunters observed  $\geq 2$  wolves, uncertain if  $\geq 2$  hunters observed  $\geq 2$  wolves, and no pack detected if hunters observed 1 wolf. For both sampling methods, we assigned a missing data value to grid cells that were not surveyed during the  $t$ th sampling occasion. We were interested in estimating the presence of wolf packs as opposed to individual wolves. Public observations can include misidentifications and both our survey methods can detect transient wolves unassociated with established packs (Miller et al. 2013; Rich et al. 2013). We excluded detections of single wolves (Ausband et al. 2014a) to ensure fewer false positive detections occurred in our occupancy models (Rich et al. 2013).

We assessed 10 site-specific covariates (Table 1), including 3 habitat and landscape covariates. We calculated percent forest cover from ABMI Wall-to-wall Land Cover Map (2010) based on digital classification of 30 m spatial-resolution Landsat satellite imagery (Alberta Biodiversity Monitoring Institute, University of Alberta) in each grid cell to assess the effects of percent forest cover on wolf occupancy and detection. We derived elevation and slope data from 25 m<sup>2</sup> resolution digital elevation models (DEM; Alberta ESRD) and calculated mean elevation and slope for each grid cell to evaluate landscape effects on occupancy. We estimated the effects of partial grid cells in the study area, human density, 4wd-road density, wolf harvest, and the presence of grizzly bear intercept feed sites (Alberta ESRD) in each grid cell. We calculated the area of each grid cell to assess the effects of grid cells that only partially fall within the study area on occupancy and detection. We assessed the effects of human density on occupancy using Alberta Municipal Affairs population list statistics and Alberta municipal boundaries to calculate area-weighted mean number of humans in each grid cell (Alberta ESRD). We estimated area-weighted mean road length in each grid cell based on cut lines and OHV trails to assess the effects of 4wd roads on wolf occupancy and detection (Alberta ESRD). Preliminary modeling with 2012 data informed our decision to retain the road density covariate from further analyses due to correlations with other covariates. We calculated the number of wolves harvested per year per grid cell based on the area-weighted number of harvested wolves reported in each Registered Fur Management Area (RFMA) and WMU (Alberta ESRD) to evaluate the effect of harvest on occupancy. We also assessed the effects of grizzly bear (*Ursus arctos*) intercept feeding sites on wolf occupancy in 2012 and 2013 by summing the number of feed sites present in each grid cell (Alberta ESRD). The grizzly bear intercept feeding program was suspended in 2014 and excluded from the 2014 model. Finally, we estimated the effects of summer surveying effort, hunter effort, percent forest cover, and grid cell area on the probability a wolf pack is detected. We evaluated the effects of summer field sampling effort by summing the number of rendezvous sites surveyed in each grid cell. We used responses from the online hunter surveys to estimate area-weighted hunter effort per grid cell, standardized by the proportion of Wildlife Management Units (WMU) in each grid cell. We also estimated the differences in detection for hunter surveys by month. Lastly, we standardized all covariates so their variances were 1 (i.e., z-transformation) to improve software performance.

Table 1. Mean values of unstandardized covariates tested in a patch occupancy analysis for gray wolves in southwest Alberta, 2012, 2013, and 2014, and expected relationships between covariates and a wolf pack's probability of occupancy ( $\psi$ ), detection ( $p_{11}$ ), false positive detection ( $p_{10}$ ), and certain detection ( $b$ ).

Model Covariates	2012		2013		2014		Hypothesized Relationship			
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\psi$	$p_{11}$	$p_{10}$	$b$
Forest cover (%)	0.41	0.044	0.50	0.035	0.50	0.035	+	-	+	+/-
Elevation (km)	1.67	0.066	1.61	0.054	1.61	0.054	-			
Slope (°)	0.15	0.016	0.13	0.012	0.13	0.012	-			
Area (km <sup>2</sup> )	562.78	89.295	637.96	66.489	637.96	66.489	+	+		
Human density (humans/km <sup>2</sup> )	1.35	0.378	1.17	0.210	1.17	0.210	-			
No. wolves harvested/grid cell <sup>a</sup>	1.40	0.346	2.68	0.446	0.55	0.106	+/-		+	
No. grizzly bear intercept feed sites/grid cell	9x10 <sup>-4</sup>	6x10 <sup>-4</sup>	4x10 <sup>-3</sup>	4x10 <sup>-3</sup>	---	---	+		+	
No. rendezvous site surveyed/grid cell <sup>b</sup>	18.22	6.098	6.38	1.72	6.79	1.790	+	-		
Hunter effort for big game (hunter days/km <sup>2</sup> ) <sup>c</sup>	1.29	0.119	0.70	0.060	0.94	0.076	+	-		

<sup>a</sup>Covariate data from reported harvest in Registered Fur Management Areas and Wildlife Management Units

<sup>b</sup>Covariate data for sampling occasions from rendezvous site field surveys

<sup>c</sup>Covariate data for sampling occasions from online hunter surveys

We fit occupancy models to the 2012, 2013, and 2014 detection data with Program PRESENCE 7.9 (Hines 2006). Based on results from preliminary work (see Ausband et al. 2014b) we derived unique detection histories and calculated covariates using a 1200km<sup>2</sup> grid. We assessed alternative model parameterizations where detection varied by survey and time (Ausband et al. 2014b). We used results from our exploratory work to inform our final model design, which allowed detection to vary by survey method and month, as well as a function of detection covariates. Finally, we excluded the 2012 and 2014 December sampling occasions, and half of the 2013 December sampling occasion, due to a lack of wolf detections (Ausband et al. 2014b). We tested 27 models in 2012 and 2013, respectively, and 22 models in 2014.

We ran a Goodness of Fit test on the global (most parameterized) 2014 basic single season occupancy model to assess over-dispersion and model structure (Burnham and Anderson 2002). Currently, there is no Goodness of Fit test for false positive detection occupancy models so we could not assess over-dispersion in the 2012 and 2013 models. We used Akaike's information criterion value corrected for small sample size ( $AIC_c$ ; Burnham and Anderson 2002) to identify the best supported model for each year. We considered models with the lowest  $AIC_c$  value as our best model. Models within 2  $AIC_c$  values of the lowest  $AIC_c$  also had substantial support and were considered in model selection and used to infer covariate effects (Burnham and Anderson 2002).

To help account for possible over-dispersion in our best models we employed a non-parametric bootstrap approach to all models within 2  $AIC_c$  values of the top model in R (R Core Team 2014) to estimate pack abundance and 95% confidence intervals (95% CI; Ausband et al. 2014a). This involved resampling the detection histories and associated covariates from the top models 10,000 times to calculate the variance from the simulated distributions (Ausband et al. 2014a). We used the bootstrapped 50% confidence interval as our estimate of wolf pack abundance.

## **Results**

### *Rendezvous Site Surveys*

We surveyed 420 potential wolf rendezvous sites in 2012 (Table 2). We detected 3 litters of pups in the study area and located 3 unoccupied rendezvous sites from 2011. In addition, we collected 439 genetic samples (278 adult, 161 pup). The majority (62%) of the samples were collected in occupied rendezvous sites. Scats were the most common form of wolf sign detected with tracks and howling following, respectively. Fecal samples collected during our surveys yielded 45 individual wolf genotypes.

In summer 2013, we surveyed 301 potential wolf rendezvous sites (Table 2). We detected 4 litters of pups in the study area. The Bob Creek litter was detected by the presence of pup tracks only; no pup scats were detected. We detected 2 adults but no pups in the Oil Basin pack during rendezvous site surveys but Park scientists supplied us remote-sensing camera photos that confirmed pups in Waterton Park (B. Johnston, Waterton Lakes National Park of Canada, pers. comm). In addition, we collected 415 genetic samples (201 adult, 214 pup) in 2013. The majority (69%) of the samples were collected in occupied rendezvous sites. Scats were the most common form of wolf sign detected with tracks and howling following, respectively. Fecal samples collected during our surveys yielded 38 individual wolf genotypes. Of those, 7 were genetic recaptures from 2012, 2 of which were members of the Castle/Carbondale pack. Rendezvous site survey sampling effort was lowest in 2013 due to access difficulties associated with flooding in the study area in 2013 (Table 1).

In summer 2014, we surveyed 321 potential wolf rendezvous sites (Table 2). We detected 10 litters of pups in the study area. We collected 553 genetic samples (338 adults, 215 pup) in 2014. The majority (85%) of the samples were collected in occupied rendezvous sites. Scats were the most common form of wolf sign detected with tracks and howling following, respectively. Fecal samples collected during our surveys yielded 76 individual wolf genotypes. Of those, 19 were genetic recaptures from 2013, 4 of which were pups the previous year.

Table 2. Survey results from southwest Alberta rendezvous site surveys, 2012, 2013, and 2014. Predicted rendezvous sites were surveyed for wolf sign (i.e., scat, tracks, and howl responses) and DNA samples were collected when scat was detected for genetic analysis. Incidental wolf sign was also collected outside predicted rendezvous sites. Rendezvous site surveys were only conducted in the intensively surveyed portion of the study area in 2012 and were expanded throughout the full original study area in 2013 and 2014.

Year	No. sites surveyed	No. sites wolves detected (%)	No. sites scat detected (%)	No. sites incidental scat detected (%)	No. sites tracks detected (%)	No. sites howling detected (%)	No. of litters detected (%)	No. of individuals detected genetically
2012	420	82 (19.5)	67 (16.0)	18 (4.3)	34 (8.1)	3 (0.7)	3 (0.7)	45
2013	301	74 (24.6)	58 (19.3)	28 (9.3)	24 (7.9)	4 (1.3)	4 (1.3)	38
2014	321	68 (21.2)	53 (16.5)	31 (9.7)	30 (9.3)	12* (3.7)	10 (3.1)	76

\*two packs responded to howls on several occasions but moved multiple times before rendezvous sites were finally located.



Typical puppy play area in a wolf rendezvous site, Photo: S. Bassing

### *Hunter Surveys*

We received 2,227 responses to our 2012 online survey in January 2013. Of those responding, 161 hunters (7.2%) reported seeing  $\geq 2$  live wolves during the 16-week survey period of the 2012 big game hunting season. We received 2,843 responses to our 2013 online hunter survey in February 2014. Of those, 242 hunters (8.5%) observed  $\geq 2$  live wolves during the 16-week survey period of the big game hunting season. We received 3,257 responses to our 2014 online survey in March 2015. Of those, 406 hunters (12.5 %) observed  $\geq 2$  live wolves during the 16-week survey period of the big game hunting season. The 2013 online hunter survey included the late-winter hunting season in January 2014, but we excluded these hunter responses and wolf sightings to avoid violating population closure assumptions. Locations of hunter sightings were similar to summer wolf detection locations throughout most of the intensively surveyed portion of the study area (Fig. 4). Hunter survey sampling effort was greatest in 2012 but this is likely due to hunter effort being averaged across the smaller original study area in 2012 (Table 1, Appendix 1). Between 10-15% of wolf observations made by hunters during the hunting season were on private land in 2012, 2013, and 2014. We received 8 responses to our mailers enquiring about wolf sightings made by the public.

### *Patch Occupancy Model*

Many models were unable to successfully estimate the probability sites were occupied likely due to sparse detections or small sample size. After standardizing the covariate data and expanding the study area and the hunter surveys in 2013 and 2014 the data were able to support more complex models and converged more successfully. Wolf harvest, human density, and grid cell area influenced wolf pack occupancy (Table 3). Detection probabilities were influenced by survey method and survey effort (rendezvous site surveys and hunter effort, respectively), percent forest cover, month, and area (Table 3). The Goodness of Fit test on the 2014 occupancy model did not indicate over-dispersion problems in the basic single season models. It is unknown whether the 2012 and 2013 false positive models are over-dispersed.

Table 3. Top occupancy models predicting gray wolf distribution and estimated wolf pack abundance in southwest Alberta based on a 1,200km<sup>2</sup> grid where  $\psi$  = occupancy,  $p$  = detection probability,  $p_{10}$  = probability of a false positive detection,  $b$  = detection probability given a certain detection, -2Log-likelihood (-2LL), number of parameters (K), Akaike's Information Criterion Value corrected for small sample size (AIC<sub>c</sub>), change in ( $\Delta$ ) AIC<sub>c</sub> value, Akaike's weight ( $w_i$ ), estimated wolf pack abundance (Est. #of Packs), and 95% Confidence Interval (95% CI). 2012 estimates are for area from International Border to Highway 1, bordered on the east by Highway 22, with the exception of the Porcupine Hills. 2013 and 2014 estimates are for original 2012 area plus area north of Highway 1 along Highway 22 to the Brazeau River, and west to the eastern borders of Banff and Jasper National Parks.

Top Models, 2012							
Model <sup>a</sup>	-2LL	K	AIC <sub>c</sub>	$\Delta$ AIC <sub>c</sub>	AIC <sub>c</sub> $w$	Est. # of Packs	95% CI
<b><math>\psi(\text{area}+\text{human}),p(\text{rnd}+\text{hunter}+\text{area}),p_{10}(\text{rnd}+\text{hunter}),b(\text{rnd}+\text{hunter})</math></b>	<b>166.17</b>	<b>19</b>	<b>457.5</b>	<b>0.00</b>	<b>0.29</b>	<b>6.0</b>	<b>3.27 - 8.65</b>
$\psi(\text{area}+\text{harvest}),p(\text{rnd}+\text{hunter}+\text{area}),p_{10}(\text{rnd}+\text{hunter}),b(\text{rnd}+\text{hunter})$	166.80	19	458.13	0.63	0.21	5.9	3.02 - 8.71
$\psi(\text{area}+\text{slope}),p(\text{rnd}+\text{hunter}+\text{area}),p_{10}(\text{rnd}+\text{hunter}),b(\text{rnd}+\text{hunter})$	167.08	19	458.41	0.91	0.19	5.8	3.02 - 8.66
$\psi(\text{area}+\text{elev}),p(\text{rnd}+\text{hunter}+\text{area}),p_{10}(\text{rnd}+\text{hunter}),b(\text{rnd}+\text{hunter})$	167.89	19	459.22	1.72	0.12	5.8	3.01 - 8.64

<sup>a</sup>Area = size of grid cell within study area (km<sup>2</sup>); human = human density (humans/km<sup>2</sup>); rnd = rendezvous site survey effort (no. rendezvous site surveys/cell); hunter = hunter effort (hunter days/cell); harvest = no. wolves harvested/cell; slope = slope (°); elev = elevation (km).

Top Model, 2013							
Model <sup>a</sup>	-2LL	K	AIC <sub>c</sub>	$\Delta$ AIC <sub>c</sub>	AIC <sub>c</sub> $w$	Est. # of Packs	95% CI
<b><math>\psi(\text{human}+\text{harvest}),p(\text{forest}),p_{10}(\text{forest}),b(.)</math></b>	<b>308.34</b>	<b>14</b>	<b>349.47</b>	<b>0.00</b>	<b>0.79</b>	<b>11.6</b>	<b>7.12 - 16.42</b>
<sup>1</sup> $\psi(\text{slope}+\text{human}+\text{harvest}),p(\text{forest}),p_{10}(\text{forest}),b(.)$	307.98	15	353.46	4.00	0.11	--	--

<sup>a</sup>Human = human density (humans/km<sup>2</sup>); harvest = no. wolves harvested/cell; forest = % forest cover; slope = slope (°).

<sup>1</sup>Model presented for comparison but not considered a top model.

Top Models, 2014							
Model <sup>a,b</sup>	-2LL	K	AIC <sub>c</sub>	$\Delta$ AIC <sub>c</sub>	AIC <sub>c</sub> $w$	Est. # of Packs	95% CI
<b><math>\psi(\text{harvest}),p(\text{rnd}+\text{hunter}+\text{forest})</math></b>	<b>186.44</b>	<b>12</b>	<b>219.62</b>	<b>0.00</b>	<b>0.29</b>	<b>15.3</b>	<b>10.32 - 21.52</b>
$\psi(\text{human}+\text{harvest}),p(\text{rnd}+\text{hunter}+\text{forest})$	183.10	13	220.13	0.51	0.23	15.3	10.29 - 21.26
$\psi(\text{human}),p(\text{rnd}+\text{hunter}+\text{forest})$	187.91	12	221.09	1.47	0.14	17.7	12.21 - 24.01

<sup>a</sup>Harvest = no. wolves harvested/cell; rnd = rendezvous site survey effort (no. rendezvous site surveys/cell); hunter = hunter effort (hunter days/cell); forest = % forest cover; human = human density (humans/km<sup>2</sup>).

<sup>b</sup>Models do not account for false positive detections.

We estimated 5.99 (3.27-8.65; 95% CI) wolf packs in the original study area in 2012 (Table 3). We estimated 11.60 (7.12-16.42; 95% CI; Table 3) wolf packs in the expanded study area in 2013 and 15.29 (10.32-21.52; 95% CI) wolf packs in the expanded study area in 2014 (Table 3). Predicted distribution in the original portion of the study area was similar in 2012, 2013, and 2014, with one exception (Fig. 6). The 2012 and 2014 models predicted a medium to high probability of pack occupancy in the Kananaskis Valley, where as the 2013 model predicted a low probability of occupancy in these cells likely due to limited sampling because of flooding (Fig. 6). Similarly, the predicted distribution in the expanded portion of the study area was similar in 2013 and 2014, with one exception where the 2013 model predicted a medium probability of pack occupancy along the north eastern edge of Banff National Park, where as the 2014 model predicted a low probability of occupancy in these cells (Fig. 6). This is likely due to differences in detection histories related to basic vs false positive model structure. We found estimated wolf pack abundance varied by grid cell size but estimates based on the 1,200 km<sup>2</sup> grid had the lowest variance and most consistency across years (Ausband et al. 2014b).



Adult wolf attending two pups at a late summer rendezvous site, Photo: S. Bassing

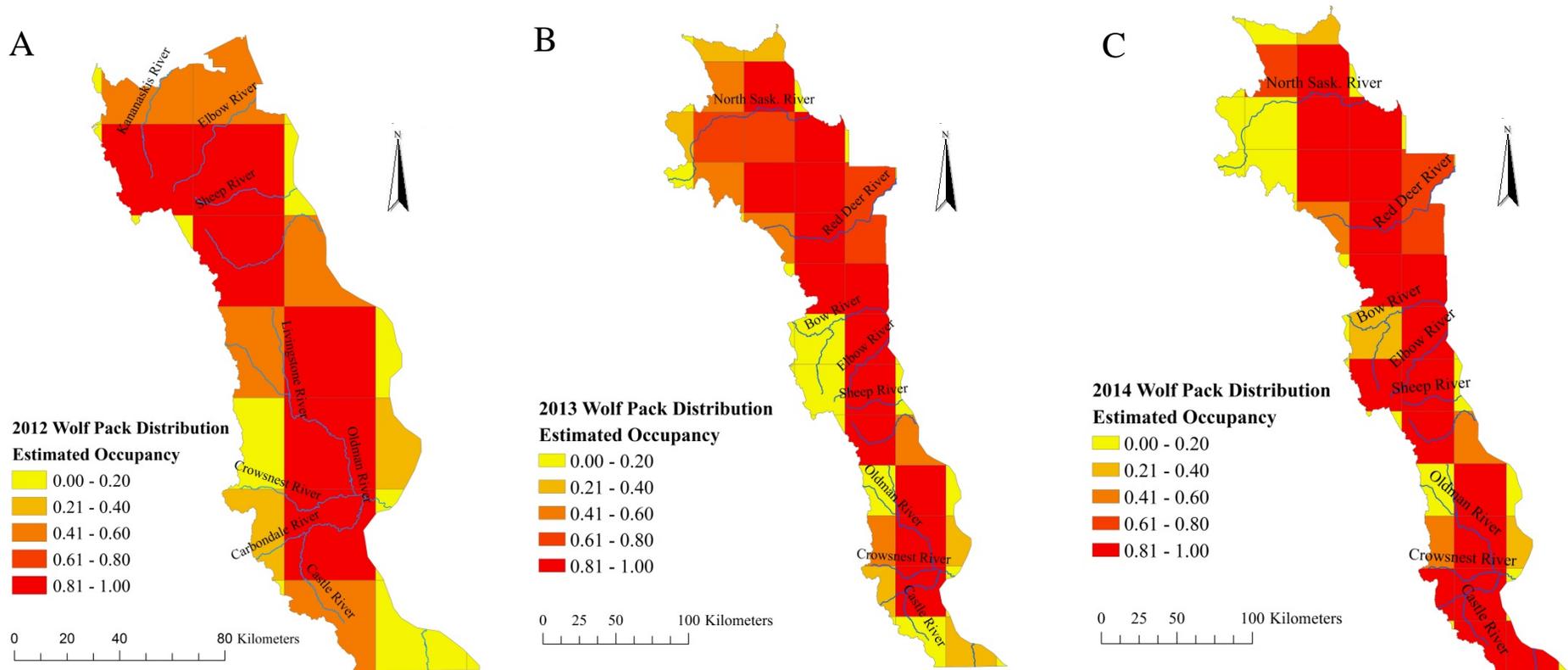


Figure 6. The predicted probability each 1,200km<sup>2</sup> cell in southwest Alberta, Canada was occupied by wolves in (A) the original study area in 2012, (B) the expanded study area in 2013, and (C) the expanded study area in 2014. We estimated occupancy probabilities using a single season model that accounts for false positive detections with rendezvous site surveys and hunter surveys as the sampling methods and wolf harvest, human density, and cell area as predictor variables. The 2014 model did not account for false positive detections due to current limitations of Program PRESENCE.

Detection probabilities varied among sampling methods and across years (Table 4). In 2012, rendezvous site survey detections were positively related to the number of sites surveyed and negatively related to the size of the cell within the study area. Hunter survey detections varied by sampling month and hunter effort (Table 5). In 2013, hunter survey detections varied by sampling month and were positively related to percent forest cover (Table 5). In 2014, rendezvous site survey detections were negatively related to the number of sites surveyed and positively related to percent forest cover. Hunter survey detections were positively related to percent forest cover and varied by hunter effort and month (Table 5). The probability that wolves were considered falsely detected (i.e., 1 wolf detected;  $p_{10}$ ) and the probability that a true positive detection was classified as certain ( $b$ ) also varied by sampling method, sampling effort, and percent forest cover (Table 4; Table 5). We found detection probabilities ( $p_{11}$ ) and false positive detection probabilities ( $p_{10}$ ) were highest in rendezvous site surveys across years whereas true positive detection probabilities ( $b$ ) were highest in hunter surveys across years (Table 4). The percentage of true wolf observations that were classified as certain in rendezvous site surveys decreased from 42.0% in 2012 to 32.0% in 2013, while it remained fairly constant (mean = 53.5%) for hunter surveys across years ( $b$ ; Table 4). Occupancy was positively related to area and human density in 2012. In 2013, wolf pack occupancy was positively related to human density and wolf harvest. And in 2014, occupancy was positively related to wolf harvest (Table 5).

Table 4. Estimates for the mean probabilities wolf packs were detected ( $p_{11}$ ) through surveys of predicted rendezvous sites and hunter surveys; the mean probabilities wolves were detected in unoccupied sites ( $p_{10}$ ) during rendezvous site surveys and hunter surveys; and the mean probability wolf detections during rendezvous site surveys or hunter observations were considered certain given that the site was occupied and wolves were detected ( $b$ ) in 2012, 2013, and 2014. Detection probabilities varied as a function of sampling method, month, survey effort, forest cover, and area across years.

Year	Variable	2012	2013	2014*
		$p$ (SE)	$p$ (SE)	$p$ (SE)
$p_{11}$				
	Rendezvous site survey	0.74 (0.066)	0.65 (0.160)	0.60 (0.032)
	Hunter survey			
	September	0.31 (0.032)	0.20 (0.014)	0.18 (0.025)
	October	0.44 (0.011)	0.37 (0.020)	0.16 (0.020)
	November	0.53 (0.036)	0.51 (0.026)	0.36 (0.019)
	December <sup>a</sup>	--	0.05 (0.006)	--
$p_{10}$				
	Rendezvous site survey	0.38 (0.044)	0.33 (0.213)	--
	Hunter survey	0.01 (0.002)	0.02 ( $4 \times 10^{-4}$ )	--
$b$				
	Rendezvous site survey	0.42 (0.043)	0.32 (0.189)	--
	Hunter Survey	0.56 (0.013)	0.51 (0.071)	--

\*Model did not account for false positive detections so the false positive and certain detection parameters were not included in the model.

<sup>a</sup>December surveys were excluded from models due to lack of wolf detections in 2012 and 2014. Only half of the December surveys were included in the 2013 model due to lack of wolf detections during the latter half of December.

Table 5. Parameter estimates for occupancy analysis of gray wolf packs in southwest, Alberta, 2012, 2013, and 2014. Models include two detection methods: summer rendezvous site surveys and online hunter surveys. We tested false positive detection occupancy models to estimate wolf pack occupancy, probability a wolf pack was detected in an occupied site ( $p_{11}$ ), probability a wolf pack was detected in an unoccupied site ( $p_{10}$ ), and probability wolf observations were classified as a certain detection given the site was occupied and wolves were detected ( $b$ ).

Parameter	Variable	2012		2013		2014 <sup>a</sup>	
		$\beta^*$	SE	$\beta^*$	SE	$\beta^*$	SE
Occupancy	Intercept	-0.30	1.104	1.04	0.885	2.55	1.801
	Area	7.51	5.128				
	Human density	1.28	0.996	4.64	2.339		
	Harvest			2.09	0.978	4.71	2.787
$p_{11}$ Rendezvous surveys	Intercept	2.03	1.714	0.60	0.699	0.50	1.245
	Area	-3.07	2.044				
	No. surveys	1.09	0.832			-0.12	0.679
	Forest cover					1.04	1.050
Hunter surveys	Intercept Sept.	-1.19	0.626	-1.73	0.435	-3.86	1.096
	Intercept Oct.	-0.25	0.539	-0.71	0.357	-1.92	0.426
	Intercept Nov.	0.22	0.567	0.73	0.375	-0.77	0.358
	Intercept Dec.	--	--	-3.32	1.049	--	--
	Hunter effort Sept.	-1.56	0.775			-2.71	1.268
	Hunter effort Oct.	-1.0x10 <sup>-3</sup>	0.598			0.73	0.534
	Hunter effort Nov.	1.34	0.740			1.03	0.489
	Hunter effort Dec.	--	--			--	--
	Area	0.32	0.420				
	Forest cover			1.12	0.339	1.23	0.392
$p_{10}$ Rendezvous surveys	Intercept	-0.46	1.545	-0.69	0.958	--	--
	No. surveys	1.09	0.832				
Hunter surveys	Intercept	-5.28	1.965	-3.75	0.607	--	--
	Hunter effort	1.04	0.900				
	Forest cover			0.32	0.485		
$b$ Rendezvous surveys	Intercept	-0.25	1.048	-0.74	0.866	--	--
	No. surveys	1.09	0.832				
Hunter surveys	Intercept	0.30	0.377	0.05	0.282	--	--
	Hunter effort	1.04	0.900				

<sup>a</sup>Model does not account for false positive detections.

\*betas represent standardized coefficients that have been z transformed

## Discussion

Traditional radiotelemetry-based monitoring is effective where wolf mortality is low and agency resources (manpower and funding) are high enough to maintain radiocollars in a large portion of the wolf population. In regions where wolf harvest is high and agency resources are limited however, maintaining a radiotelemetry-based wolf monitoring program is difficult and often not practical. For this reason, there is currently no wolf monitoring program in the southwest Alberta region. As a result, AESRD was interesting in establishing a long-term wolf

monitoring framework in the absence of radiotelemetry that could be used to inform management decisions and observe wolf population trends. The MTCWRU worked in collaboration with AESRD to test and refine a population monitoring framework that uses data from hunter surveys and field-based rendezvous site surveys to estimate wolf pack abundance and distribution across southwest Alberta.

We collected presence/absence detection data in 2012, 2013, and 2014 to populate and test patch occupancy model design and performance for the gray wolf population in southwest Alberta. Much initial work was exploratory to determine ideal model type, model structure, and test covariate data, thus many preliminary models were run prior to determining ideal model parameterization (Ausband et al. 2014b). Similar wolf occupancy studies encompassed large study areas (Miller et al. 2013; Rich et al. 2013; Ausband et al. 2014a). Because our study area was small by comparison we were unsure of our expectations for model estimates. We expanded our study area and hunter surveys in 2013 and 2014 due to evidence of lack-of-fit in our preliminary 2012 basic occupancy models that did not account for false positive detections (Ausband et al. 2014b). As a result, we found no evidence of lack-of-fit in our 2013 (Ausband et al. 2014b) or 2014 basic single season models.

Similar to other wolf patch occupancy studies, we found that single season false positive (i.e., wolf pack reported present when it actually is not) occupancy models are more appropriate for the southwest Alberta wolf population than basic single season occupancy models (Ausband et al. 2014b). Miller et al. (2011; 2013) demonstrated that false positive detection errors can have a significant effect on occupancy estimates if unaccounted for and results in over-estimating occupancy. By accounting for false positive detections we can reduce bias and increase precision in our occupancy estimates (Miller et al. 2011). Due to software limitations we were unable to fit a false positive occupancy model to the 2014 detection.

Our final models used a 1,200 km<sup>2</sup> grid structure to derive detection histories and covariate data (Ausband et al. 2014a). This grid cell size was similar to the average wolf pack territory size in west-central Alberta (Ausband et al. 2014b; N. Webb, Alberta ESRD, pers. comm.). Territory size is more variable in wolf populations that experience human exploitation (Ballard et al. 1987; Haber 1996; Rich et al. 2012) and are more directly related to pack size than in unexploited wolf populations (Peterson et al. 1984; Haber 1996). Average wolf pack territory size and thus, grid cell size, can bias pack abundance estimates. For example, in 2014 we detected multiple wolf packs within one cell on several occasions. This may be because we overestimate the average wolf pack territory size in southwest Alberta. Too large grid cells can also hamper our ability to measure the full effects of covariates on occupancy and detection as subtle variations in covariates may be lost when we average across large grid cells. Square sample sites or grid placement across the study area can also lead to biased estimates. In larger study areas (i.e., Idaho and Montana, USA) any mismatch between actual territories and defined sample sites averaged out across all cells but this may not be the case in smaller study areas where the number of grid cells is low. Despite these assumptions there is consistent overlap between our hunter survey and rendezvous site survey detection data. The only disparity in these data occurred in areas where hunter access was limited or not allowed (e.g., Waterton Lakes National Park and Kananaskis Valley) where our field methods detected wolves but hunter observations of wolves were low. We therefore feel our methods and estimates are fairly robust despite these assumptions.

We assumed the distribution and abundance of wolf packs did not change during our sampling season, 1 June to 31 December, and that detections were independent of each other

(MacKenzie et al. 2006; Rich et al. 2013; Ausband et al. 2014a). Although individual wolves were lost from the population due to mortality or emigration, and added to the population through births and immigration, we assumed occupancy in each cell was stable and that packs did not move into adjacent cells during a sampling season. To our knowledge, registered trapping and control actions did not remove entire wolf packs during our sampling seasons in 2012, 2013, or 2014. In addition, we assumed no territory overlap within our study area and minimal gaps between territories. Previous wolf research supports this assumption (Mech and Boitani 2003; Robichaud and Boyce 2010) and results from similar occupancy studies found this assumption to hold true (Rich et al. 2013; Ausband et al. 2014a). However, as with average territory size estimate, it is necessary to monitor the level of overlap and interstitial space between wolf pack territories over time as these characteristics in wolf populations can change (Rich et al. 2013; Ausband et al. 2014a).

Pack abundance and distribution estimates varied between years and grid cell size (Ausband et al. 2014b). As we should expect, abundance estimates were greater once we expanded the study area from 2012 to 2013 (Table 3). The 2014 pack abundance estimate was greater than the 2013 estimate but this difference is not statistically significant. It is interesting to note, however, that at least one new pack established quickly during our study. The 2013 and 2014 wolf genotypes from the Willow Creek pack showed they consisted of entirely different individuals than the 2012 Willow Creek pack. Although this did not lead to an increase in pack abundance, it demonstrates pack turnover within the study area and that it can occur rapidly. This turnover suggests packs can establish territories quickly in southwest Alberta, which can influence occupancy estimates.

Covariate effects on occupancy and detection probability varied by year. Due to the small study area and resulting low sample size (i.e., relatively few patches) we did not see strong relationships between site covariates and occupancy or detection probability. Covariates fit to detection probability were idiosyncratic, also likely due to the small study area and sample size. As a result, we are limited in our understanding of how these factors influence wolf pack occupancy and detection probability. However, including covariates improved model precision and wolf pack abundance estimates are still reasonable despite variation in covariates across years. In addition, the human density and wolf harvest covariates were consistently in the top models across years and suggest these covariates are in fact influential to wolf pack occupancy. Human density had a positive influence on pack occupancy in 2012 and 2013. We suspect there is a positive relationship between human density and occupancy because humans, prey, and wolves alike tend to congregate in the lower elevations of our study area, however human density and elevation were not highly correlated ( $r = -0.25$ ). Wolf harvest had a positive influence on wolf pack occupancy in 2013 and 2014. We believe there is a positive association between harvest and occupancy because logically a site must be occupied by wolves for a hunter or trapper to be successful. The positive association is likely not related to big game hunter effort as most wolf harvest occurred outside of the big game hunting season (~80%). If harvest were too high, however, we would expect it to affect occupancy negatively.

We were unable to test the effects of several covariates, including livestock density and prey density, on wolf pack occupancy but previous studies found prey and livestock densities were influential to wolf occupancy (Rich et al. 2013; Ausband et al. 2014a). We believe this is likely true in our study area as well, especially when we consider Morehouse and Boyce (2011) found cattle made up almost 75% of the biomass consumed by wolves during the grazing season

(summer and early fall) in southwest Alberta. We were unable to obtain the necessary data to include these covariates but hope to in the future.

Detection probabilities varied by method, sampling effort, and sampling season. Similar to results from Ausband et al. (2014a), we showed that rendezvous site surveys yield higher detection probabilities than hunter surveys. Rendezvous site surveys had higher false positive detection probabilities than hunter surveys likely due to our definition of “certain detections”. For example, if we detected two adult wolves from genetic sampling but not their pups the cell was classified as an “uncertain” detection. Survey effort was greatest in 2012 for both hunter and rendezvous site survey methods but its influence on detection probability was ambiguous.

Ausband et al. (2014a) demonstrated that the use of multiple survey methods helps ensure occupancy estimates are robust to changes in any one method (Nichols et al. 2008). Hunter surveys can become less reliable over time as public interest wanes or if individuals attempt to influence estimates by misrepresenting sightings (Rich et al. 2013; Ausband et al. 2014a). Because hunter sightings are the primary data source for our models, additional survey methods help calibrate these occupancy models by ensuring hunter sightings are still a reliable indicator of wolf pack presence (Nichols et al. 2008; Rich et al. 2013; Ausband et al. 2014a).

Fine-scale survey methods, such as rendezvous site surveys, can also provide population characteristics, like pack size or territory size, which are necessary for accurate distribution and abundance estimates, but difficult to obtain with hunter surveys (Ausband et al. 2014a). Rendezvous site surveys yielded higher detection probabilities than hunter surveys and provide a wealth of additional data beyond the presence/absence of wolves, including reproduction, pack composition, individual genotypes, gene flow, and dispersal. When coupled with tissue samples collected from harvested and controlled wolves rendezvous site surveys can also provide capture-mark-recapture data and be used to estimate harvest rates. Although rendezvous site surveys are fairly intensive, other sampling methods can also be used to collect fine-scale detection data, including remote-sensing camera photos and general sign surveys. Finally, public sightings, trapper reports, hunter reports of wolf howls, public remote-sensing camera photos, and harvested wolves can provide additional forms of model testing and additional insight. Our efforts to acquire public sightings in addition to hunter surveys and trapper information on wolf activity did not yield an abundance of data. We were able to compare estimated wolf pack distributions from our models with the sparse location data submitted by the general public and found spatial overlap between model estimates and public reports.

### *Recommendations*

The goal of this work was to develop a long-term gray wolf monitoring framework that managers and biologists can incorporate into future wolf management programs in southwest Alberta. Our work demonstrates we reached that target objective. Our patch occupancy model provides a flexible framework that uses detection data from multiple sampling methods that have been refined specifically to the wolf ecology and management practices of southwest Alberta. Even in this relatively small study areas where wolf harvest is considered high our methods were able to successfully detect and estimate the abundance and distribution of wolf packs in the absence of radiotelemetry. These methods can be implemented as a long-term monitoring framework that allows for accurate and reliable population estimates. Finally, incorporating this monitoring framework into future wolf management programs will increase the ability of managers to make informed conservation and management decisions for gray wolves in southwest Alberta.

Based on our findings we recommend:

- Program PRESENCE (Hines 2006) and R (R Core Team 2014): to run and bootstrap models. These software programs are both free and easy to download. Program PRESENCE offers a user-friendly interface that is simple to navigate and preprogrammed with many customizable types of occupancy models. In addition, there are numerous help files and exercises available online and a forum to pose and answer most questions. R scripts for bootstrapping single season occupancy models (both basic and false positive detection models) are already written and easy to adjust for new models.
- Models that account for false positive detections: reduce the likelihood of inflating detection histories and overestimating pack abundance. Because hunter surveys can include false positive detections, either through misidentification or by observing non-resident animals, it is important to fit detection data to models that account for false positive detections. Certain and uncertain detections can be defined for most sampling methods.
- Using site specific covariates: such as human density, wolf harvest, and survey effort on occupancy and detection. Although the small study area and sample size led to covariate idiosyncrasies in the models, including covariates improved precision of the estimates and provided insight to wolf pack occupancy and ecology in southwest Alberta. Covariates like livestock density and prey density may also be informative if the data can be compiled and included in future models.
- Using multiple sampling methods: to survey for wolf packs and acquire detection data. Multiple methods help ensure estimates are robust to changes in any one survey method and tighten model precision (Ausband et al. 2014a). In particular, we recommend continuing rendezvous site surveys in addition to hunter surveys. Intensive field surveys, like rendezvous site surveys, help test hunter observations and calibrate surveys that may lose accuracy over time as public interest wanes (Rich et al. 2013; Ausband et al. 2014a). In addition, DNA data collected during rendezvous site surveys yield detailed information about the wolf population that public surveys cannot provide, such as reproduction, pack composition, and gene flow (Ausband et al. 2010; Ausband et al. 2014a). Finally, when rendezvous site surveys are not feasible we recommend incorporating wolf surveys into other monitoring programs. For example, collecting wolf scat on roads and trails for DNA analysis and placing remote-sensing cameras near predicted rendezvous sites while surveying for other wildlife can provide detection data and population characteristics. Although these data would be less informative than data collected during rendezvous site surveys they can still be used to populate occupancy models and gain insight into the wolf population.

### **Acknowledgments**

Thank you to Greg Hale, the Waterton Biosphere Reserve Association Carnivore Working Group, the South Country Trappers Association, Kim Pearson and Nature Conservancy of Canada, Andrea Morehouse, Barb Johnston, Grant Chapman, Jon Jorgenson, Nathan Webb, Nora Manners, Jeff Bectell, John Conely, Bill Dolan, Melanie Percy, Mike Taje, Dennis Spackman, Jeff Smith, Angela Braun, Mike Alexander, Rod Sinclair, Brent Sinclair, Paul Lukacs, the Livingstone Gap Fire Base, Spray Lakes Sawmills, Darin Cook, Jerry Newman, Jim Simpson, Bruce McIntosh, University of Montana Public Safety, Matt Nordhagen, Betsy Glenn,

Justin Demianew, Joel Ruprecht, Ryan Wilbur, and Ania Wrona, Adam Fahnestock, Jillian Solar, Ellie Cosgrove, Ben Hawkins, Matt Smith, Jon Linch, Sarah Zielke, Taylor McDowel, Spencer Rettler, Ken Hildebrand, and many others within AESRD for their assistance, support, and hard work. We also thank leaseholders who were generous with their time and granted us permission to access lease lands for survey work. Finally, this research could not have been done without the gracious support of Waterton Biosphere Reserve Association, Alberta Innovates BioSolutions, Alberta Conservation Association, Regina Bauer Frankenberg Foundation, Eppley Foundation for Scientific Research, Steven Leuthold Family Foundation, and the Shikar Safari Club International.

## **Presentations/Publications**

- Bassing, S.B., M.S. Mitchell, P. Lukacs, D.E. Ausband, L. Waits, G. Hale. Wolf pack distribution in relation to heavy harvest in Southwest Alberta, MT TWS, Missoula, MT, February 2016.
- Bassing, S.B., M.S. Mitchell, D.E. Ausband, P. Lukacs, L. Waits, G. Hale. Developing a monitoring framework to estimate wolf occupancy dynamics in Southwest Alberta, TWS, Winnipeg, MB, October 2015.
- Bassing, S.B. Wolves on the Move, Waterton Lakes National Park, September 2015.
- Bassing, S.B., M.S. Mitchell, D.E. Ausband, L. Waits, G. Hale. Developing a monitoring framework to estimate wolf distribution and abundance in Southwest Alberta, MT TWS, Helena, MT, February 2015.
- Ausband, D.E. Gray wolves in the working landscape of southwest Alberta, Beauvais Lake Provincial Park, July 2013.
- Ausband, D.E. A population monitoring framework for wolves in southwest Alberta. Chain Lakes Provincial Park, January 2013.
- Ausband, D.E. Gray wolves in southwest Alberta: How many do we have and where? Pincher Creek Library, January 2013.
- Ausband, D.E. A population monitoring framework for wolves in southwest Alberta. Cardston, Alberta, January 2013.
- Ausband, D.E. A population monitoring framework for wolves in southwest Alberta. Pincher Creek, Alberta, January 2013.
- Reports
- Ausband, D.E., M.S. Mitchell, and S.B. Bassing. 2012. 2012 progress report for developing a wolf population monitoring framework in southwest Alberta. 10 p. Missoula, MT, USA.
- Ausband, D.E., M.S. Mitchell, and S.B. Bassing. 2013. 2013 progress report for developing a wolf population monitoring framework in southwest Alberta. 13 p. Missoula, MT, USA.
- Ausband, D.E., S.B. Bassing, and M.S. Mitchell. 2014. Progress report for testing monitoring techniques for wolves in southwest Alberta. 30 p. Missoula, MT, USA.

## **Literature Cited**

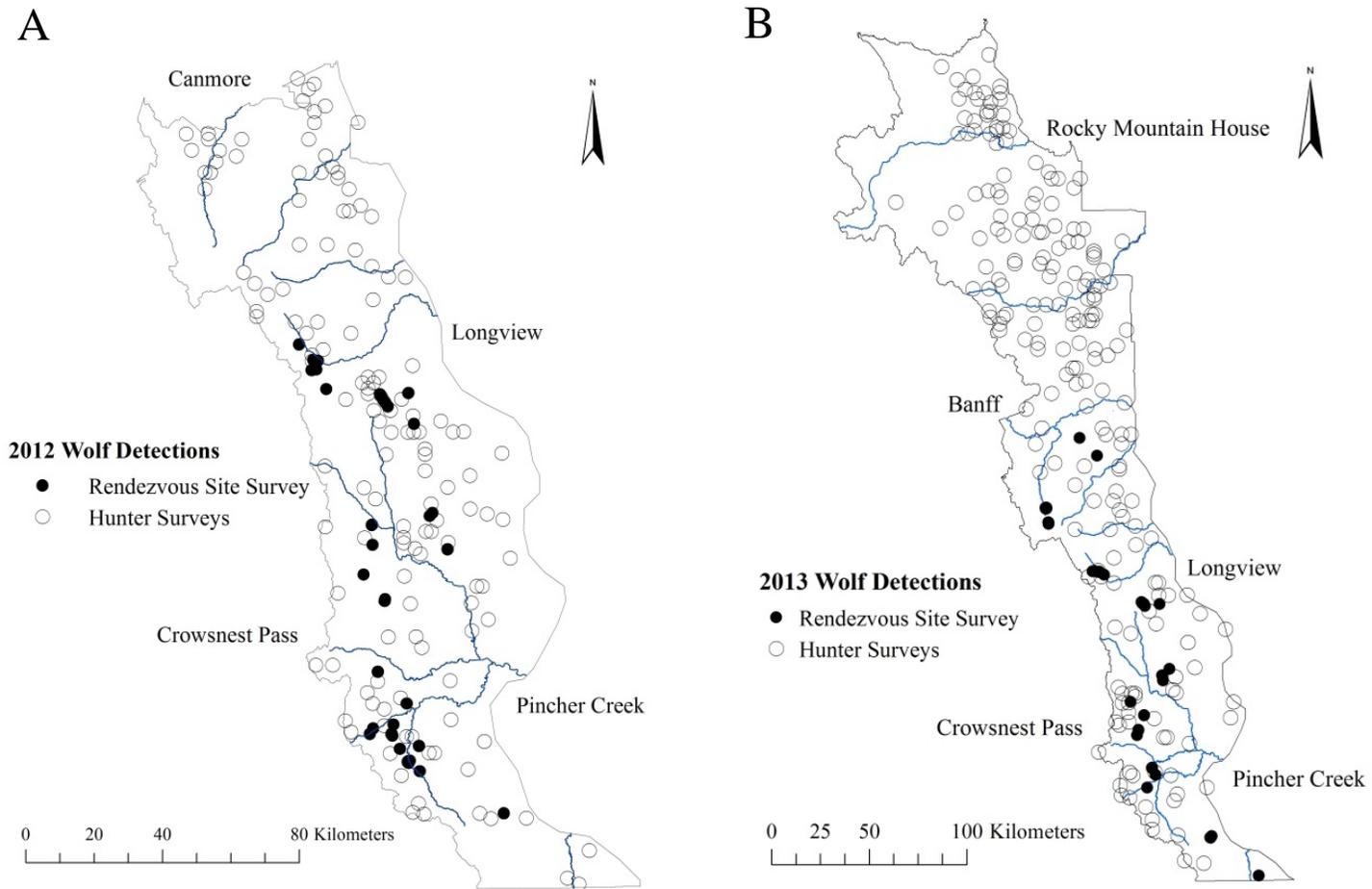
- Ausband, D. E., J. Young, B. Fannin, M. S. Mitchell, J. L. Stenglein, L. P. Waits, and J. A. Shivik. 2011. Hair of the dog: obtaining samples from coyotes and wolves noninvasively. *Wildlife Society Bulletin* 35:105-111.

- Ausband, D. E., L. N. Rich, E. M. Glenn, M. S. Mitchell, P. Zager, D. A. W. Miller, L. P. Waits, B. B. Ackerman, and C. M. Mack. 2014a. Monitoring gray wolf populations using multiple survey methods. *Journal of Wildlife Management* 78:335–346.
- Ausband, D. E., and M. S. Mitchell. 2011. A habitat model for predicting gray wolf rendezvous site locations in southwest Alberta. Missoula, MT.
- Ausband, D. E., M. S. Mitchell, K. Doherty, P. Zager, C. M. Mack, and J. Holyan. 2010. Surveying predicted rendezvous sites to monitor gray wolf populations. *Journal of Wildlife Management* 74:1043-1049.
- Ausband, D. E., S. B. Bassing, M. S. Mitchell. 2014b. Progress report for testing monitoring techniques for wolves in southwest Alberta. Missoula, MT.
- Ballard, W. B., J. S. Whitman, and C. L. Gardner. 1987. Ecology of an exploited wolf population in South-Central Alaska. *Wildlife Monographs* 3–54.
- Brennan, A., P. C. Cross, D. E. Ausband, A. Barbknecht, and S. Creel. 2013. Testing automated howling devices in a wintertime wolf survey. *Wildlife Society Bulletin* 37:389–393.
- Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. 2nd ed. Springer-Verlag New York, Inc. New York, NY. 488 pp.
- Crete, M., and F. Messier. 1987. Evaluation of indices of gray wolf, *Canis lupus*, density in hardwood-conifer forests of southwestern Quebec. *Canadian Field Naturalist*. 101:147-152.
- Frantzen, M. A. J., Silk, J. B., Ferguson, J. W. H., Wayne, R. K., and M. H. Kohn. 1998. Empirical evaluation of preservation methods for faecal DNA. *Molecular Ecology* 7:1423-1428.
- Haber, G. C. 1996. Biological, conservation, and ethical implications of exploiting and controlling wolves. *Conservation Biology* 10:1068–1081.
- Harrington, F. H., and L. D. Mech. 1982. An analysis of howling response parameters useful for wolf pack censusing. *Journal of Wildlife Management* 46:686-693.
- Hebblewhite, M., and E. Merrill. 2008. Modelling wildlife-human relationships for a social species with mixed-effects resource selection models. *Journal of Applied Ecology* 45:834–844.
- Hines, J. E. 2006. PRESENCE: Software to estimate patch occupancy and related parameters. USGS, Patuxent Wildlife Research Center, Laurel, Maryland, USA. <http://www.mbr-pwrc.usgs.gov/software/presence.html>

- Joslin, P. W. B. 1967. Movements and home sites of timber wolves in Algonquin Park. *American Zoologist* 7:279-288.
- Long, R. A., P. Mackay, W. J. Zielinski, and J. C. Ray. 2008. Noninvasive survey methods for carnivores. Island Press, Washington, D.C. 385 pp.
- MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy estimation and modeling. Academic Press. Burlington, MA. 324 pp.
- Mech, L. D. 1970. The wolf. University of Minnesota Press. Minneapolis, MN. 384 pp.
- Mech, L. D. and L. Boitani. 2003. Wolf social ecology. Pages 1-34 *in* L.D. Mech and L. Boitani, editors. *Wolves: behavior, ecology, and conservation*. University of Chicago Press, Illinois, USA.
- Miller, D. A., J. D. Nichols, B. T. McClintock, E. H. C. Grant, L. L. Bailey, and L. A. Weir. 2011. Improving occupancy estimation when two types of observational error occur: non-detection and species misidentification. *Ecology* 92:1422–1428.
- Miller, D. A. W., J. D. Nichols, J. A. Gude, L. N. Rich, K. M. Podruzny, J. E. Hines, and M. S. Mitchell. 2013. Determining occurrence dynamics when false positives occur: estimating the range dynamics of wolves from public survey data. *Plos One* 8:e65808.
- Morehouse, A. T., and M. S. Boyce. 2011. From venison to beef: seasonal changes in wolf diet composition in a livestock grazing landscape. *Frontiers in Ecology and the Environment* 9:440-445.
- Nichols, J. D., L. L. Bailey, F. Allan, O. C. Jr, N. W. Talancy, E. H. C. Grant, A. T. Gilbert, E. M. Annand, and P. Thomas. 2008. Multi-scale occupancy estimation and modelling using multiple detection methods. *Journal of Applied Ecology* 45:1321–1329.
- Peterson, R. O., J. D. Woolington, and T. N. Bailey. 1984. Wolves of the Kenai Peninsula, Alaska. *Wildlife Monographs* 3–52.
- Powell, R. A. 2000. Home ranges, territories, and home range estimators. Pages 65-110 *in* Boitani, L., and T. Fuller, editors, *Techniques in Animal Ecology: Uses and Misuses*. Columbia University Press, New York, NY, USA.
- Rich, L. N., M. S. Mitchell, J. A. Gude, and C. A. Sime. 2012. Anthropogenic mortality, intraspecific competition, and prey availability influence territory sizes of wolves in Montana. *Journal of Mammalogy* 93:722–731.
- Rich, L. N., R. E. Russell, E. M. Glenn, M. S. Mitchell, J. A. Gude, K. M. Podruzny, C. A. Sime, K. Laudon, D. E. Ausband, and J. D. Nichols. 2013. Estimating occupancy and predicting

- numbers of gray wolf packs in Montana using hunter surveys. *Journal of Wildlife Management* 77:1280–1289.
- Robichaud, C. B., and M. S. Boyce. 2010. Spatial and temporal patterns of wolf harvest on registered traplines in Alberta, Canada. *Journal of Wildlife Management* 74:635–643.
- Royle, J. A. and R. M. Dorazio. 2008. *Hierarchical modeling and inference in ecology*. Academic Press, London, UK.
- Stenglein, J. L., L. P. Waits, D. E. Ausband, P. Zager, and C. M. Mack. 2010a. Efficient noninvasive genetic sampling for monitoring reintroduced wolves. *Journal of Wildlife Management* 74:1050-1058.
- Stenglein, J. L., M. De Barba, D. E. Ausband, and L. P. Waits. 2010b. Impacts of sampling location within a faeces on DNA quality in two carnivore species. *Molecular Ecology Resources* 10:109-114.
- Weaver, J. L., and S. H. Fritts. 1979. Comparison of coyote and wolf scat diameters. *Journal of Wildlife Management* 43:786-788.
- Webb, N., E. Merrill, and J. Allen. 2009. Density, demography, and functional response of a harvested wolf population in West-Central Alberta, Canada. *Wolf Management Summary Report*. Alberta Sustainable Resource Development. Edmonton, AB.

Appendix 1



Appendix 1, Figure 1. Wolf detection locations from our two sampling methods in the original 2012 study area (A; 12,950 km<sup>2</sup>) and the expanded 2013 study area (B; 30,000 km<sup>2</sup>). In 2012, 2013, and 2014, we extracted DNA to identify individuals from collected wolf scats and distributed online questionnaires to hunters for wolf observations made during the big game hunting season. Rendezvous site surveys were only conducted in the intensively surveyed portion of the study area in 2012 and were expanded throughout the full original study area in 2013 and 2014. We created detection histories for our patch occupancy models using these data.

## Appendix 2

### **Hunter survey questionnaire**

1. Did you see wolves?
2. When did you see wolves?
3. Where did you see wolves?
4. How many wolves did you see?

Appendix 2, Figure 1. Questions added to the online hunter survey conducted annually by Alberta ESRD. An interactive online map was added to the survey in 2013 and 2014 to assist hunters with reporting wolf observation locations. Resulting wolf detection/non-detection data were used to populate a patch occupancy model and estimate wolf abundance in southwest Alberta.