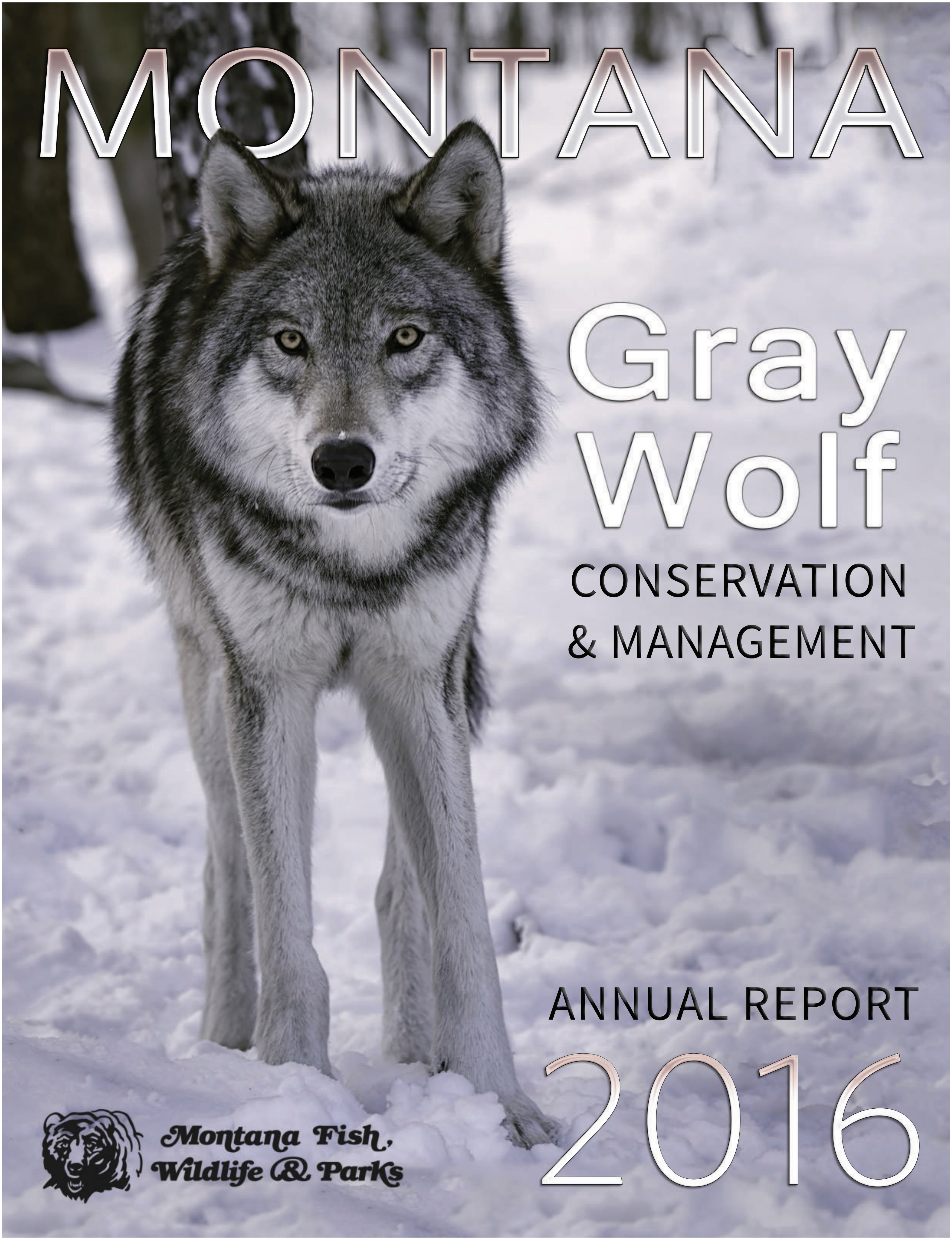

MONTANA

Gray Wolf

CONSERVATION & MANAGEMENT

ANNUAL REPORT 2016

Montana Fish, Wildlife & Parks

This is a cooperative effort by Montana Fish, Wildlife & Parks, USDA Wildlife Services, Glacier National Park, Yellowstone National Park, Blackfeet Nation, and The Confederated Salish and Kootenai Tribes

This report presents information on the status, distribution, and management of wolves in the State of Montana, from January 1, 2016 to December 31, 2016.

This report is also available at: http://fwp.mt.gov/fishAndWildlife/management/wolf/

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Montana Gray Wolf Program
2016 Annual Report

TABLE OF CONTENTS

LIST OF FIGURES

EXECUTIVE SUMMARY

Wolf recovery in Montana began in the early 1980's. The federal wolf recovery goal of 30 breeding pairs for 3 consecutive years in the Northern Rocky Mountains (NRM) of Montana, Idaho and Wyoming was met by 2002. The Montana Wolf Conservation and Management Plan was based on the work of a citizen's advisory council and was approved by the United States Fish and Wildlife Service (USFWS) in 2004. The wolf population in the NRM tripled between the time recovery goals were met and when wolves were ultimately delisted by congressional action during 2011. At present, Montana Fish, Wildlife and Parks (FWP) implements the state management plan using a combination of sportsman license dollars and federal Pittman-Robertson funds (excise tax on firearms, ammunition, and hunting equipment) to monitor the wolf population, regulate sport harvest, collar packs in livestock areas, coordinate and authorize research, and direct problem wolf control under certain circumstances.

Minimum counts of wolves and breeding pairs are a traditional metric initiated during wolf recovery; a minimum count of wolves was used as an indication of overall population size, and a minimum count of breeding pairs was used as an indication of recruitment to next year's population. Minimum counts were achievable and appropriate when wolf numbers were low (for example prior to 1995 year end wolf counts were <75), but the technique has become unduly expensive and unachievable as populations expand and increase. During 2016, FWP's minimum count goal was to verify the presence of at least 150 wolves and 15 breeding pairs as required by the state management plan. Our goal was not, as it had been in the past, to attempt to count every pack, wolf, and breeding pair. We confirmed the presence of at least 109 packs, 477 wolves, and 50 breeding pairs in Montana at the end of 2016 (Figure 1).

The primary means of monitoring wolf distribution and numbers in Montana is now "Patch Occupancy Modeling," or "POM." The POM method utilizes annual hunter effort surveys, known wolf locations, habitat covariates, and estimates of wolf territory size and pack size to estimate wolf distribution and population size across the state. POM estimates of wolf population size have proven to be highly correlated with independent, historical minimum counts of wolves and are therefore the preferred monitoring method due to accuracy, confidence intervals, and cost efficiency (Figure 1). The most recent completed POM estimate for wolf population size was 892 wolves during 2014. Data have been gathered for 2015 and 2016 POM estimates of wolf numbers and distribution, and analysis will take place during summer 2017. FWP is currently working with the University of Montana to refine POM by incorporating contemporary data on territory and pack sizes derived with improved collar technology.

While we have successfully developed and transitioned to POM instead of the overall population size metric that a minimum count of wolves represented, we continue to work with the University of Montana on a technique aimed at tracking recruitment in place of a minimum count of breeding pairs due to the same logistical and financial limitations inherent in the minimum count of wolves approach.

FWP's Wolf Specialists captured and radio-collared 40 wolves during 2016 to meet the legislative requirement for collaring livestock packs and to aid in population monitoring and research efforts.

Wolf hunting was recommended as a management tool in the 2004 Montana Wolf Conservation and Management Plan with the caveat that hunting could only be implemented when wolves were delisted and if there were more than 15 breeding pairs in Montana the previous year. Calendar year 2016 included parts of two hunting/trapping seasons for wolves. During calendar year 2016, 93 wolves were harvested during the spring, and 162 wolves were harvested during the fall for a total of 255 (Figure 1).

Sales of license year 2016/17 wolf hunting licenses generated $393,000 for wolf management in Montana (Figure 1).

The Montana State Office of the U.S. Department of Agriculture's Wildlife Services (WS) confirmed 57 livestock losses to wolves including 52 cattle and 5 sheep during 2016 (Figure 1). This total was down slightly compared to 64 livestock losses during 2015. Additional losses (both injured and dead livestock) occurred, but in some cases could not be confirmed. Most depredations occurred on private property. During 2016 the Montana Livestock Loss Board paid $59,578 for livestock that were confirmed by WS as killed by wolves or probable wolf kills. Sixty-one wolves were killed to reduce the potential for further depredation. Of the 61 wolves, 49 were killed by WS and 12 were killed by private citizens under state regulations that allow citizens to kill wolves seen chasing, killing, or threatening to kill livestock.

Montana's wolf population grew steadily from the early 1980's when there were less than 10 in the state. As numbers approached 1,000 (POM estimate) in 2011, wolf population growth rate may have slowed (Figure 1). POM estimates for 2015 and 2016 will provide more insight. Stabilization, if it has occurred, and reduced livestock depredation may be related to the onset of wolf hunting and trapping along with more aggressive depredation control actions. Montana's wolf population remains well-above requirements. Wolf license sales have generated over $2.75 million for wolf management and monitoring since 2009.

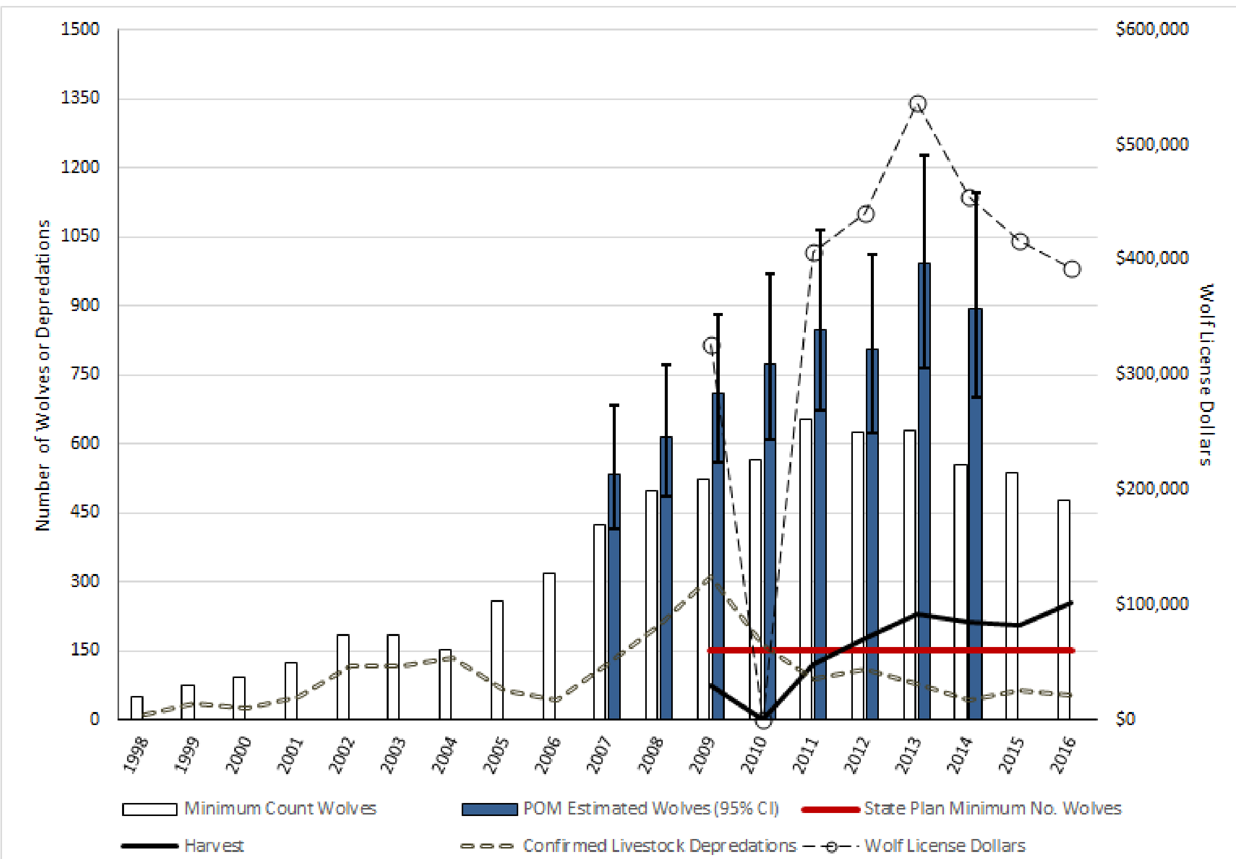

Figure 1. Verified minimum number of wolves residing in Montana and Patch Occupancy Modeling ("POM") estimated number of wolves in Montana (including 95% confidence intervals) in relation to state wolf plan requirements along with trends in wolf harvest, confirmed livestock losses due to wolves, and total dollars generated by sales of wolf hunting licenses, 1998 – 2016.

1. BACKGROUND

Wolf recovery in Montana began in the early 1980's. Wolves increased in number and distribution because of natural emigration from Canada and a successful federal effort that reintroduced wolves into Yellowstone National Park and the wilderness areas of central Idaho. The federal wolf recovery goal of 30 breeding pairs for 3 consecutive years in Montana, Idaho and Wyoming was met during 2002, and wolves were declared to have reached biological recovery by the U.S. Fish and Wildlife Service (USFWS) that year. During 2002 there were a minimum of 43 breeding pairs and 663 wolves in the Northern Rocky Mountains (NRM).

All three states submitted wolf management plans to the USFWS for review during 2003. The Montana Gray Wolf Conservation and Management Plan was approved by the USFWS in 2004. Nine years after having been declared recovered and with a minimum wolf population of more than 1,600 wolves and 100 breeding pairs in the NRM, in April 2011, a congressional budget bill directed the Secretary of the Interior to reissue the final delisting rule for NRM wolves. On May 5, 2011 the USFWS published the final delisting rule designating wolves throughout the Designated Population Segment (DPS), except Wyoming, as a delisted species.

Beginning with delisting in May 2011, the wolf was reclassified as a species in need of management statewide. Montana's laws, administrative rules, and state plan replaced the federal framework. Montana's 2004 Gray Wolf Conservation and Management Plan has been the document guiding wolf management in the state since that time. For 5 years after delisting, the USFWS functioned in an oversight role and continued to provide wolf-specific federal funding for wolf monitoring and management. That 5-year period ended in May 2016 as did federal wolf-specific funding.

The Montana Wolf Conservation and Management Plan is based on the work of a citizen's advisory council. The foundations of the plan are to recognize gray wolves as a native species and a part of Montana's wildlife heritage, to approach wolf management similar to other wildlife species such as mountain lions, to manage adaptively, and to address and resolve conflicts. At present, Montana Fish, Wildlife and Parks (FWP) implements the state management plan using a combination of sportsman license dollars and federal Pittman-Robertson funds (excise tax on firearms, ammunition, and hunting equipment) to monitor the wolf population, regulate sport harvest, coordinate and authorize research, and direct problem wolf control under certain circumstances. Several state statutes also guide FWP's wolf program.

In the early stages of implementation, a core team of experienced individuals led wolf monitoring efforts and worked directly with private landowners. FWP's wolf team also worked closely with and increasingly involved other FWP personnel in program activities. Montana wolf conservation and management has transitioned to a more fully integrated program since delisting, led and implemented at the FWP Regional level. USDA Wildlife Services (WS) continues to investigate injured and dead livestock, and FWP works closely with them to resolve conflicts.

2. WOLF POPULATION MONITORING

Wolf packs have been intensively monitored year-round since their return to the northwestern part of Montana by the 1980's. Objectives for monitoring during the period of recovery were driven by the USFWS's recovery criteria – 30 breeding pairs for 3 consecutive years in Montana, Idaho, and Wyoming. Similar metrics of population status were used over the last 15 years from the time recovery criteria were met in 2002, through delisting in 2011, and for the 5 years when the USFWS retained oversight after delisting. These population monitoring criteria and methods were appropriate and achievable when the wolf population was small and recovering. For instance, in 1995, when the US Fish and Wildlife Service reintroduced wolves into Yellowstone National Park and central Idaho, the end-of-year count for wolves residing in Montana was only 66. In the early years, most wolf packs had radio-collared individuals, and intensive monitoring was possible to identify new packs and most individuals within packs. However, for nearly a decade, the minimum count of wolves has approached or exceeded 500 individuals distributed across western Montana, and the ability to count every pack, every wolf, and every breeding pair has become expensive, unrealistic, and unnecessary.

As Montana transitioned during 2016 to complete management authority without USFWS oversight or funding, these same methods (minimum counts) continued to be used, but only for the purpose of documenting a minimum of 150 wolves and 15 breeding pairs in as indicated in the Montana state wolf plan. During 2016, FWP did not attempt to document every pack, wolf, and breeding pair. It is important to note this transition, because changes in verified numbers of packs, wolves, and breeding pairs will be influenced by effort.

At the same time, FWP continues to work with the U.S. Geological Survey's Cooperative Research Unit at the University of Montana to develop scientifically rigorous wolf population monitoring techniques that are more logistically and financially efficient. Basic goals of this work include 1) use of Patch Occupancy Modeling (POM) to estimate distribution and numbers of wolves across the state (including post-hunting/trapping season initiation data on territory and pack size), and 2) development of a more efficient and effective measure of wolf population recruitment (reproduction and survival of young to breeding age) than a minimum count of breeding pairs.

For 2016, we emphasize the POM monitoring method as our best estimate of total population, and we include traditional metrics (minimum wolves and breeding pairs) as evidence of meeting the thresholds of the state wolf plan.

2.1 Patch Occupancy Modeling of Wolf Distribution and Abundance in Montana 2007-2014.

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Introduction

Since the early 1980s, as wolf populations began recovering in Montana, the numbers of packs, breeding pairs, and total wolves have been documented by attempting to locate and count all individuals. It was assumed that these minimum counts provided an index to the true populations when wolf numbers were small. In the early years, most wolf packs had radio-collared individuals, and intensive monitoring was possible to identify new packs and most individuals within packs. Only verified observations were used, thus these counts represented minimums. In 1995, when the US Fish and Wildlife Service reintroduced wolves into Yellowstone National Park and central Idaho, the end-of-year count for wolves residing in Montana was only 66. By 2011 the minimum count had reached 653 and was 554 in 2014. The capacity for MFWP personnel to monitor a larger and rapidly growing wolf population has been declining given robust wolf population growth since about 2006. The traditional field-based methods yield minimum counts that are conservative and inevitably (and probably increasingly) below the true population sizes, and the degree of undercount is unknown. Consequently, MFWP explored other, cost-effective methods that could more accurately be described as population estimates that account for uncertainty, as opposed to minimum counts.

In anticipation of an increased work load and declining federal funding, MFWP first began considering alternative approaches to monitoring the wolf population in 2006. Preliminary work focused on developing a more reliable and cost-effective method to estimate the number of breeding pairs based on the size of a wolf pack using logistic regression models (Mitchell et al. 2008). Subsequent work focused on finding ways to utilize wolf observations by hunters in a more systematic way. A collaborative research effort with the University of Montana Cooperative Wildlife Research Unit was initiated in 2007. The primary objective was to find an alternative approach to wolf monitoring that would yield statistically reliable estimates of the number of wolves, the number of wolf packs, and the number of breeding pairs (Glenn et al. 2011). Ultimately, a method applicable to a sparsely distributed and elusive carnivore population was developed that used hunter observations as a cost effective means of gathering biological data to estimate the area occupied by wolves in Montana, and additional information gathered from field monitoring by biologists to estimate the number of packs (Rich et al. 2013).

This transition from labor intensive minimum counts that are biased low by an unknown degree to obtaining population estimates allows for fine-tuning and modification as new data and methodologies become available, new techniques are developed, and new research answers key uncertainties. Estimating wolf numbers via this technique bypasses the need to count every individual in every pack, and instead relies on public reported wolf observations, field-documented territory size, and a small number of monitored packs and pack sizes.

Methods

The general method we used to estimate the number of gray wolves in Montana was to 1) estimate the area occupied by wolves in packs, 2) estimate the numbers of wolf packs by dividing area occupied by average territory size and correcting for overlapping territories, and 3) estimate the numbers of wolves by multiplying the number of estimated packs by average annual pack size (Figure 2).

Estimating Area Occupied by Wolves in Packs. – To estimate the area occupied by wolf packs from 2007 to 2014, we used a multi-season false-positives occupancy model (Miller et al. 2013) using program PRESENCE (Hines 2006). First, we created an observation grid for Montana (Figure 2A) with a cell size large enough to ensure observations of packs across sample periods, yet small enough to minimize the occurrences of multiple packs in the same cell on average (cell size = 600 km^2). We used locations of wolves in packs (2-25 wolves) reported by a random sample of unique deer and elk hunters during MFWP annual Hunter Harvest Surveys (Figure 2B) and assigned the locations to cells (Figure 2C). We modeled detection probability, initial occupancy, and local colonization and local extinction from 5, 1-week encounter periods and verified locations (Figure 2D) using covariates that were summarized at the grid level (Figure 2E). We estimated patch-specific estimates of occupancy (Figure 2F) and estimated the total area occupied by wolf packs by multiplying patch-specific estimates of occupancy by their respective patch size and then summing these values across all patches (Figure 2G). Our final estimates of the total area occupied by wolf packs were adjusted for partial cells on the border of Montana and included model projections for reservations and national parks where no hunter survey data were available.

Model covariates for detection included hunter days per hunting district per year (an index to spatial effort), low use forested and non-forested road densities (indices of spatial accessibility), a spatial autocovariate (the proportion of neighboring cells with wolves seen out to a mean dispersal distance of 100 km), and patch area sampled (because smaller cells on the border of Montana, parks, and Indian Reservations have less hunting activity and therefore less opportunity for hunters to see wolves). Model covariates for occupancy, colonization, and local extinction included a principal component constructed from several autocorrelated environmental covariates (percent forest cover, slope, elevation, latitude, percent low use forest roads, and human population density), and recency (the number of years with verified locations in the previous 5 years).

To estimate area occupied in each year, we calculated unconditional estimates of occupancy probabilities which provided probabilities for sites that were not sampled by Montana hunters (such as National Parks and Reservations). We accounted for uncertainty in occupancy estimates using a parametric bootstrap procedure on logit distributions of occupancy probabilities. For each set of bootstrapped estimates we calculated area occupied. The 95% confidence intervals (C.I.s) for these values were obtained from the distribution of estimates calculated from the bootstrapping procedure.

Estimating Numbers of Wolf Packs. – To predict the total number of wolf packs in Montana from 2007 to 2014 we first established an average territory size for wolf packs in Montana (Figure 2H). Rich et al. (2012) calculated 90% kernel home ranges from radio telemetry locations of wolves collared and tracked by MFWP wolf biologists for research and/or management from 2008 to 2009. We assumed the mean estimate of territory size from these data was constant during 2007-2014. For each year, we estimated the number of wolf packs by dividing our estimates of total area occupied by the mean territory size (Figure 2I). We then accounted for annual changes in the proportion of territories that were overlapping (non-exclusive) using the number of observed cells occupied by verified pack centers.

We accounted for uncertainty in territory areas using a parametric bootstrap procedure and a log-normal distribution of territory sizes, and for each set of bootstrapped estimates we calculated mean territory size. The 95% C.I.s for these values were obtained from the distribution of estimates calculated from the bootstrapping procedure.

Estimating Numbers of Wolves. – To predict the total number of wolves in Montana from 2007 to 2014, we first calculated average pack size from the distribution of packs of known size (Figure 2J). Pack sizes were established by MFWP biologists for packs monitored for research and/or management. We used end-of-year pack counts for wolves documented in Montana from 2007 to 2014; we only used pack counts MFWP biologists considered complete. Typically, intensively monitored packs with radio-collars provided good counts more often than packs that were not radio-marked. For each year, we estimated total numbers of wolves in packs by multiplying the estimate of mean pack size by the annual predictions of number of packs (Figure 2K).

We accounted for uncertainty in pack sizes using a parametric bootstrap procedure and a Poisson distribution of pack sizes, and for each set of bootstrapped estimates we calculated mean pack size. The 95% C.I.s for these values were obtained from the distribution of estimates calculated from the bootstrapping procedure. We allowed pack sizes to vary by year but not spatially.

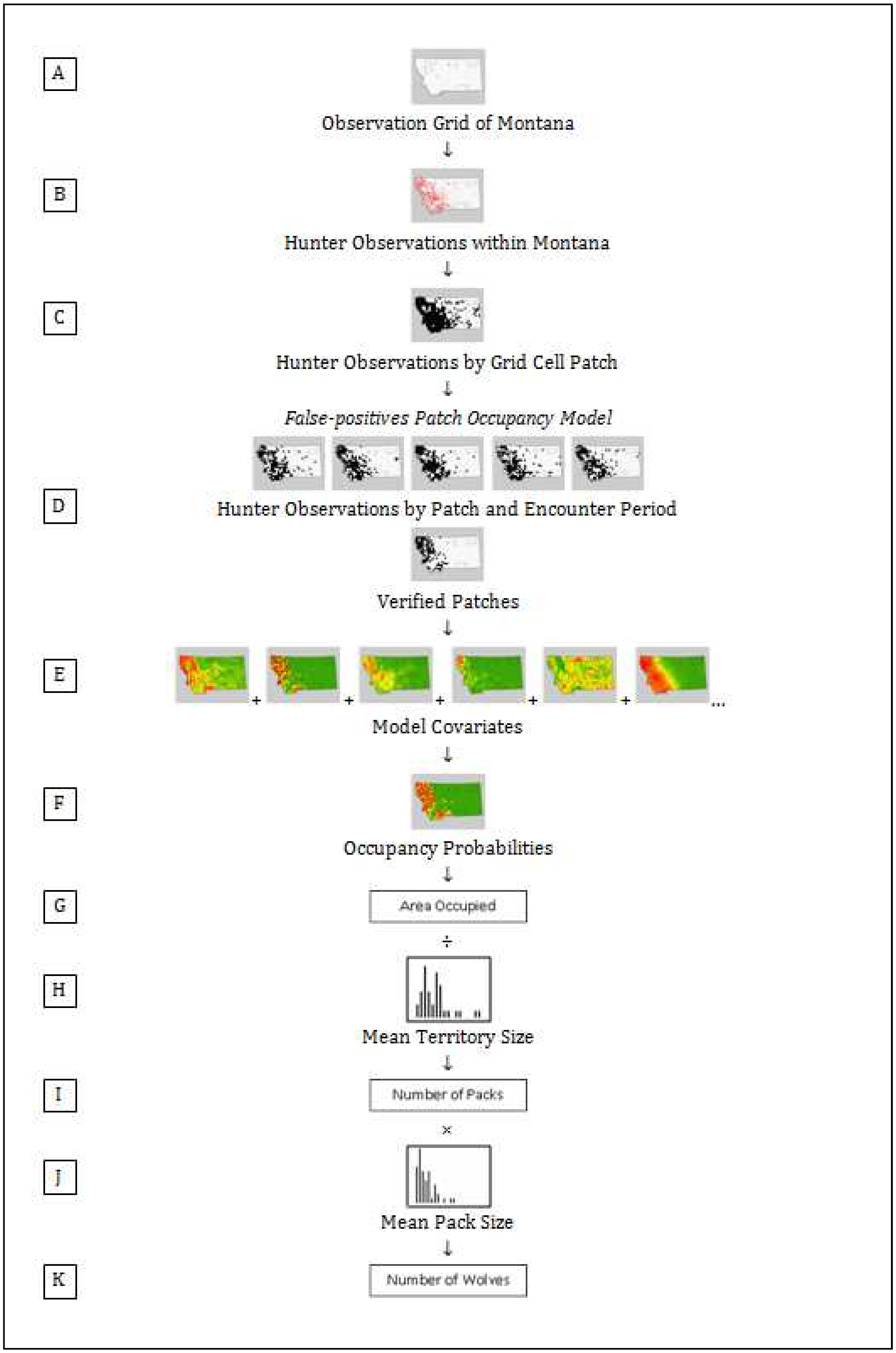

Figure 2. Schematic for method of estimating the area occupied by wolves, number of wolf packs and number of wolves in Montana, 2007-2014.

Results

Estimating Area Occupied by Wolves in Packs. – From 2007 to 2014, 50,039, 81,475, 80,486, 82,386, 81,532, 76,996, 76,862, and 59,747 hunters responded to the wolf sighting surveys. From their reported sightings, 1,202, 2,859, 3,056, 3,469, 3,320, 2391, 1,774, and 1,254 locations of 2 to 25 wolves could be determined during the 5, 1-week sampling periods.

The top model of wolf occupancy showed positive associations between the initial probability that wolves occupied an area and an environmental principal component and recency. The probability that an unoccupied patch became occupied in subsequent years was positively related to an environmental principal component and recency. The probability that an occupied patch became unoccupied in the following year was constant. The probability that wolves were detected by a hunter during a 1-week sampling occasion was positively related to hunter days per hunting district per year, low use forest road density, low use non-forest road density, a spatial autocovariate, and area sampled. The probability that wolves were falsely detected by a hunter during a 1-week sampling occasion was positively related to hunter days per hunting district per year, low use forest road density, low use non-forest road density, and a spatial autocovariate

From 2007 to 2014, estimated area occupied by wolf packs in Montana ranged from 38,859 km^2 (95% CI = 38,521 to 39,946) in 2007 to 79,177 km^2 (95% CI = 78,620 to 79,863; Table 1). The predicted distribution of wolves from the occupancy model closely matched the distribution of field-confirmed wolf locations (verified pack locations and harvested wolves; Figure 3).

Table 1. Estimated area occupied by wolves, number of wolf packs, and number of wolves in Montana, 2007-2014.

	2007	2008	2009	2010	2011	2012	2013	2014
Estimated Area Occupied (km^2)	38,859	48,520	58,723	64,669	72,346	79,177	78,974	74,244
(95% C.I.)	(38,521 - 39,946)	(48,003 - 49,370)	(58,271 - 59,507)	(64,129 - 65,382)	(71,848 - 73,036)	(78,620 - 79,863)	(78,436 - 79,658)	(73,731 - 74,925)
Territory Size (km^2)	599.83	599.83	599.83	599.83	599.83	599.83	599.83	599.83
(95% C.I.)	(493.36 - 740.35)	(493.36 - 740.35)	(493.36 - 740.35)	(493.36 - 740.35)	(493.36 - 740.35)	(493.36 - 740.35)	(493.36 - 740.35)	(493.36 - 740.35)
Estimated Packs (600 km^2 territories)	65	81	98	108	121	132	132	124
(95% C.I.)	(52 - 79)	(66 - 98)	(80 - 119)	(87 - 131)	(98 - 147)	(107 - 161)	(107 - 160)	(100 - 150)
Territory Overlap Index	1.17	1.11	1.13	1.16	1.24	1.25	1.31	1.24
Estimated Packs (600 km^2 territories w/overlap)	76	90	111	125	149	165	173	154
(95% C.I.)	(62 - 92)	(73 - 110)	(90 - 135)	(102 - 152)	(121 - 182)	(134 - 201)	(140 - 209)	(125 - 187)
Average Pack Size (complete counts)	7.03	6.82	6.39	6.16	5.67	4.86	5.75	5.81
(95% C.I.)	(6.06 - 8.00)	(6.12 -7.57)	(5.71 - 7.12)	(5.50 - 6.84)	(5.02 - 6.37)	(4.31 - 5.47)	(5.04 - 6.40)	(5.11 - 6.62)
Estimated Wolves	533	615	709	772	846	804	992	892
(95% C.I.)	(414 - 683)	(485 - 773)	(561 - 880)	(610 - 969)	(672 - 1,064)	(624 - 1,013)	(766 - 1,228)	(701 - 1,145)

Estimating Numbers of Wolf Packs. – In 2008 and 2009, territory sizes from 38 monitored packs ranged from 104.70 km^2 to 1771.24 km^2. Mean territory size was 599.83 km^2 (95% C.I. = 478.81 to 720.86; Rich et al. 2012). Dividing the estimated area occupied by mean territory size resulted in an estimated number of packs that ranged from 65 (95% C.I. = 52 to 79) in 2007 to 132 (95% C.I. = 107 to 161) and 132 (95% C.I. = 107 to 160) in 2012 and 2013 (Table 1). We adjusted these estimates to account for annual changes in the number of verified pack centers per grid from 2007 to 2014 (1.17, 1.11, 1.13, 1.16, 1.24, 1.25, 1.31, and 1.24 for each respective

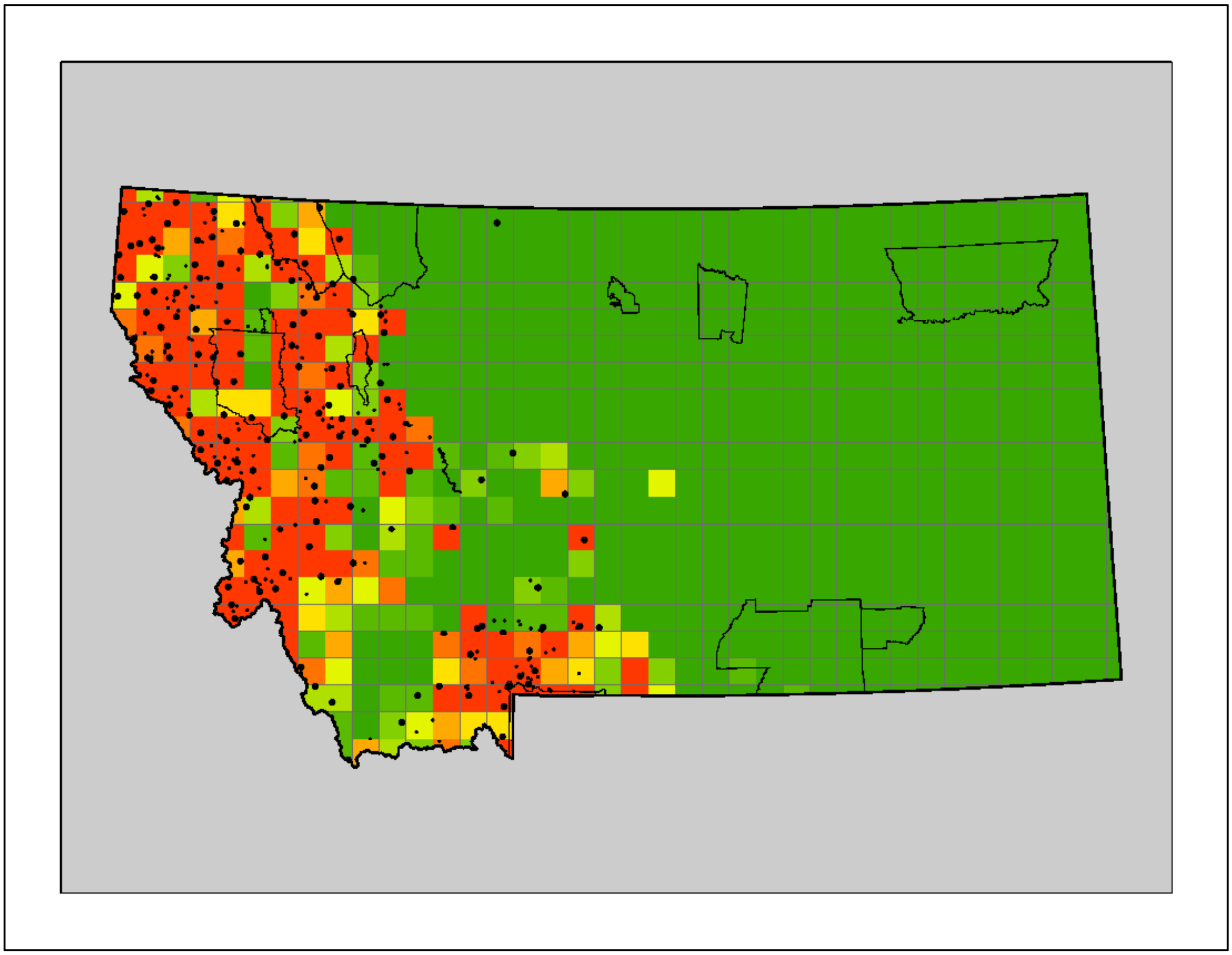

Figure 3. Model predicted probabilities of occupancy (ranging from low to high [green to red]), verified pack centers (large dots), and harvest locations (small dots) in Montana, 2012.

year during 2007-2014) as an index of territory overlap. Accounting for territory overlap, estimated numbers of packs ranged from 76 (95% C.I. = 62 to 92) in 2007 to 173 (95% C.I. = 140 to 209) in 2013 (Table 1). The estimated number of wolf packs ranged from 4% larger than the minimum verified number of packs residing in Montana in 2007 to 16% larger in 2010 (Figure 4).

Estimating Numbers of Wolves. –From 2007 to 2014, complete counts were obtained from 374 packs within Montana. Pack sizes ranged from 2 to 22 and mean pack sizes ranged from 7.03 (95% C.I. = 6.06 to 8.00) in 2007 to 4.86 (95% C.I. = 4.31 to 5.47) in 2012. Multiplying estimated packs by mean pack size resulted in an increase of estimated wolves from 533 (95% C.I. = 414 to 683) in 2007 to 992 (95% C.I. = 776 to 1,228) in 2013 (Table 1). The estimated number of wolves ranged from 24% larger than the minimum verified number of wolves in Montana packs in 2008 to 61% larger in 2014 (Figure 5).

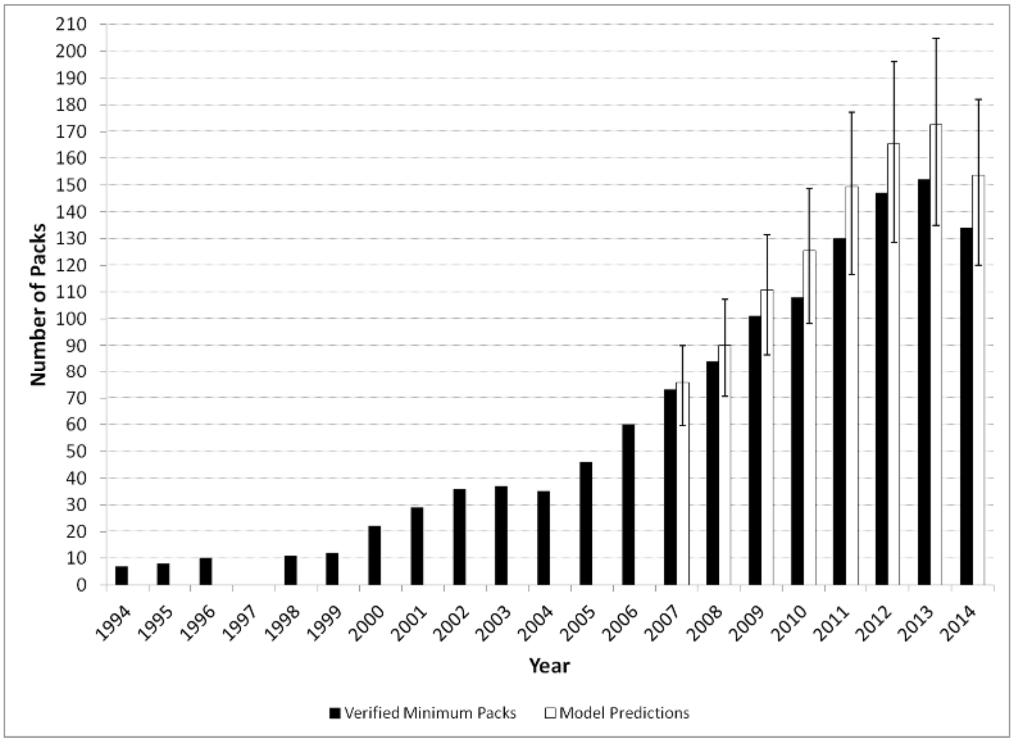

Figure 4. Estimated number of wolf packs in Montana compared to the verified minimum number of packs residing in Montana, 2007-2014.

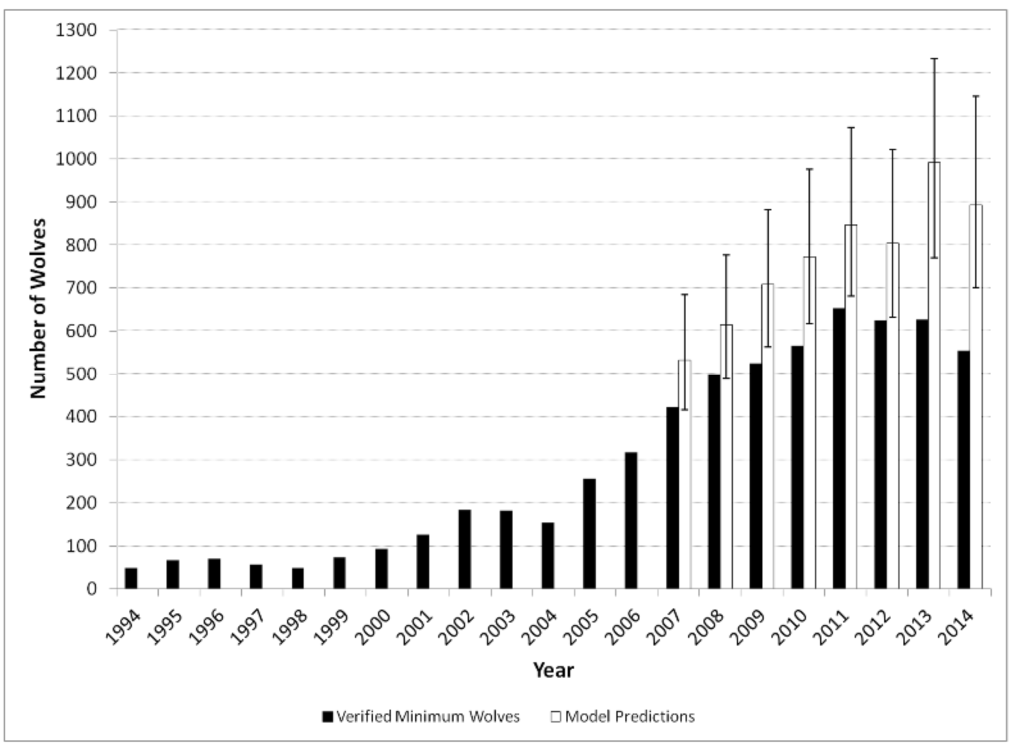

Figure 5. Estimated number of wolves in Montana compared to the verified minimum number of wolves residing in Montana, 2007-2014.

Discussion

Estimated Area Occupied by Wolves in Packs. –Although the estimated area occupied has doubled between 2007 and 2014, the rate of growth for the area occupied has been declining. The extent to which this declining rate of increase represents a population responding to density dependent factors as available habitats become filled, versus a response to hunting and trapping harvest, is unknown.

Estimated Numbers of Wolf Packs. –Our estimate for total numbers of wolf packs exceeded the minimum count by 4 to 16% between 2007 and 2014. Such a level of undercount is not unreasonable for elusive carnivores and is within the range of imperfect detection recorded for many other wildlife species and population estimation methods. For example, detection rates of elk during aerial surveys can be less than 20% (e.g., Vander Wal et al 2011), and detection rates of elk during winter surveys on the open winter ranges in southwestern Montana have been estimated at 44-89% (Hamlin and Ross 2002). Becker et al. (1998) produced a population estimate 48% higher than the number of individual wolves they observed, even though they assumed that they detected all wolf tracks in the area they surveyed.

Our estimate of the number of wolf packs assumes that territory size is constant and equal across space. If territory sizes were actually larger in some years or some areas, then the estimated number of packs in those years or areas would have been biased high, and if territory sizes were actually smaller in some years or some areas, then the pack estimates would have been biased low in those years or areas. Similarly, our estimates of territory overlap were indirect indices rather than field-based observations based on high-quality telemetry data. In future applications of this technique, the assumption of constant territory sizes could be relaxed by modeling territory size as a flexible parameter, incorporating estimates of inter-pack buffer space or territory overlap into estimates of exclusive territory size, and incorporating spatially and temporally variable territory size predictions into estimates of pack numbers.

The estimated number of packs exceeded the minimum number of verified packs to some degree because verified packs did not include border packs attributed to other states or Canada that spent time in Montana and could have been recorded by hunters. We only included verified border packs included in the Montana summaries in comparing our estimates to minimum counts. Also, the minimum number of packs verified was for the end of the year, and wolf population estimates derived from hunter observations represented the deer and elk hunting season in October- November, a period of time before some natural and human-caused wolf mortalities occurred.

Estimated Numbers of Wolves. –Our estimate for total numbers of wolves exceeded the minimum count by 24 to 61% between 2007 and 2014. The degree of difference exceeds that of packs because in addition to undocumented packs, it incorporates undocumented individuals within known packs. This degree of difference between minimum counts and our population estimate remains within that observed in other studies of wolves (Becker et al. 1998) or more common ungulate species (e.g., Hamlin and Ross 2002, Vander Wal et al. 2011).

Our estimate of the number of wolves is dependent on several assumptions that need to be examined further. First, our population estimate assumes that missed packs are the same size as verified packs. If missed packs are smaller (e.g., recently established packs or packs interspersed among known packs), then our estimated number of wolves would be biased high. Also, our estimate assumes that pack size is constant and equal across space. Pack sizes that were actually larger in some years or some areas would induce a negative bias in our estimates of wolves in those years or areas, and pack sizes that were actually smaller in some years or some areas would induce a positive bias in our estimates of wolves in those years or areas. Finally, our population estimate is for wolves in groups of 2 or more and does not factor lone or dispersing wolves into the population estimate. Various studies have documented that on average 10-15% of wolf populations are composed of lone or dispersing wolves (Fuller et al. 2003). The state of Idaho inflates their estimates by 12.5% to account for lone wolves (Idaho Department of Fish and Game and Nez Perce Tribe 2012) and Minnesota inflates their estimate by 15% (Erb 2008). In the future, lone or dispersing wolves could be incorporated into the Montana population estimate in various manners.

The estimated number of wolves exceeded the minimum number of verified wolves to some degree because verified wolves did not include individuals associated with border packs attributed to other states or Canada that spent time in Montana and could have been observed by hunters. As with packs, the minimum number of wolves verified was for the end of the year, and wolf population estimates derived from hunter observations represented a period of time before some natural and human-caused mortalities occurred.

Management Implications

Future applications of this modeling and population estimation technique will include incorporation of harvest (locations and number of harvested wolves) effects on wolf occupancy, territory sizes and overlap, and pack sizes. Incorporation of harvest as a model covariate for each of these aspects of wolf population size will enable a formal assessment of the effects of harvest on wolf populations in Montana. This strategy will also allow for predictions of the effects of different seasons or harvest quotas on wolf populations, to provide information to decision makers as they set wolf hunting and trapping seasons in coming years. Therefore, in addition to its use for monitoring and wolf population estimation, the technique described here also will provide utility for directly informing decisions about public harvest of wolves.

2.2 Minimum Counts of Wolves and Breeding Pairs for State Plan Metrics

2016 Field Efforts

During two decades of wolf recovery (1980's-2002), a decade of delisting (2002-2011), and 5-years of post-delisting oversight by the USFWS (2011-2016), attempts were made to identify every pack and count every wolf and breeding pair in the state of Montana. A wide variety of labor-intensive field techniques were employed (see past annual reports). During the early years, these techniques were appropriate and achievable due to the small total population size. However, in recent years, wolf populations have reached a level where obtaining counts of all wolf packs, individuals, and breeding pairs is unachievable. Because of this situation, FWP has been working since 2006 to develop and refine alternate scientifically rigorous and less expensive methods to replace minimum counts as described previously in this report. Accordingly, our goals related to minimum counts changed during 2016. Rather than attempting to count every pack, wolf , and breeding pair, we focused monitoring efforts on collaring wolves to obtain data that can be used to improve POM estimates and obtaining minimum count data from packs with collared wolves in them.

Methods for Counting Minimum Number of Packs, Individuals, and Breeding Pairs

The total number of wolf packs is determined by counting the number of animal groups with 2 or more individuals holding a territory that existed on the Montana landscape on December 31. If a pack was removed because of livestock conflicts or otherwise did not exist at the end of the calendar year (e.g. disease, natural/legal/illegal mortality or dispersal), it is not included in the year-end total. As in the past, we counted border packs only if they denned or spent the majority of their time in Montana.

FWP estimates the number of individual wolves in each pack when possible. Lone dispersing animals are accounted for when reliable information is available. Montana is required to maintain at least 100 wolves as an absolute minimum to avoid a USFWS status review on wolves, and the state plan calls for a minimum of 150 individual wolves.

FWP also tallies and reports the number of "breeding pairs" according to the federal recovery definition of "an adult male and a female wolf that have produced at least 2 pups that survived until December 31." Montana is required to maintain at least 10 breeding pairs as an absolute minimum to avoid a USFWS status review on wolves, and the Montana state plan calls for at least 15 breeding pairs. Packs of 2 or more adult wolves that meet the recovery definition are considered "breeding pairs" and noted as such in the summary tables (Appendix 4). Breeding pair status for each and every known pack in Montana cannot be verified with existing personnel and funding, especially as the wolf population has increased over time. If the breeding pair status is not known with confidence, it is recorded as "not" a breeding pair or "breeding status unknown." Thus, the count of breeding pairs is also a minimum.

Method for Obtaining Final Counts for the Year

The statewide minimum wolf population is derived by adding up the number of observed wolves in verified packs + known lone animals. We account for all known wolf mortality by assigning harvest and all other known mortalities to a pack or lone/misc. wolf, and these mortalities are subtracted from known pack sizes to derive the minimum estimated pack sizes and minimum count of wolves for the year. This is a minimum count, not a population estimate, and has been reported as such since wolves first began re-colonizing northwestern Montana in the mid 1980's.

2016 Minimum Count of Wolves and Breeding Pairs

The Montana wolf population is far above the 150 wolf and 15 breeding pair minimums of the state plan, as it has been for over a decade. At December 31, 2016, the minimum number of verified packs statewide was 109, the minimum number of wolves was 477, and there were at least 50 breeding pairs (Appendix 4, Figure 6). As noted previously, field efforts to obtain minimum counts were less during 2016 than in previous years.

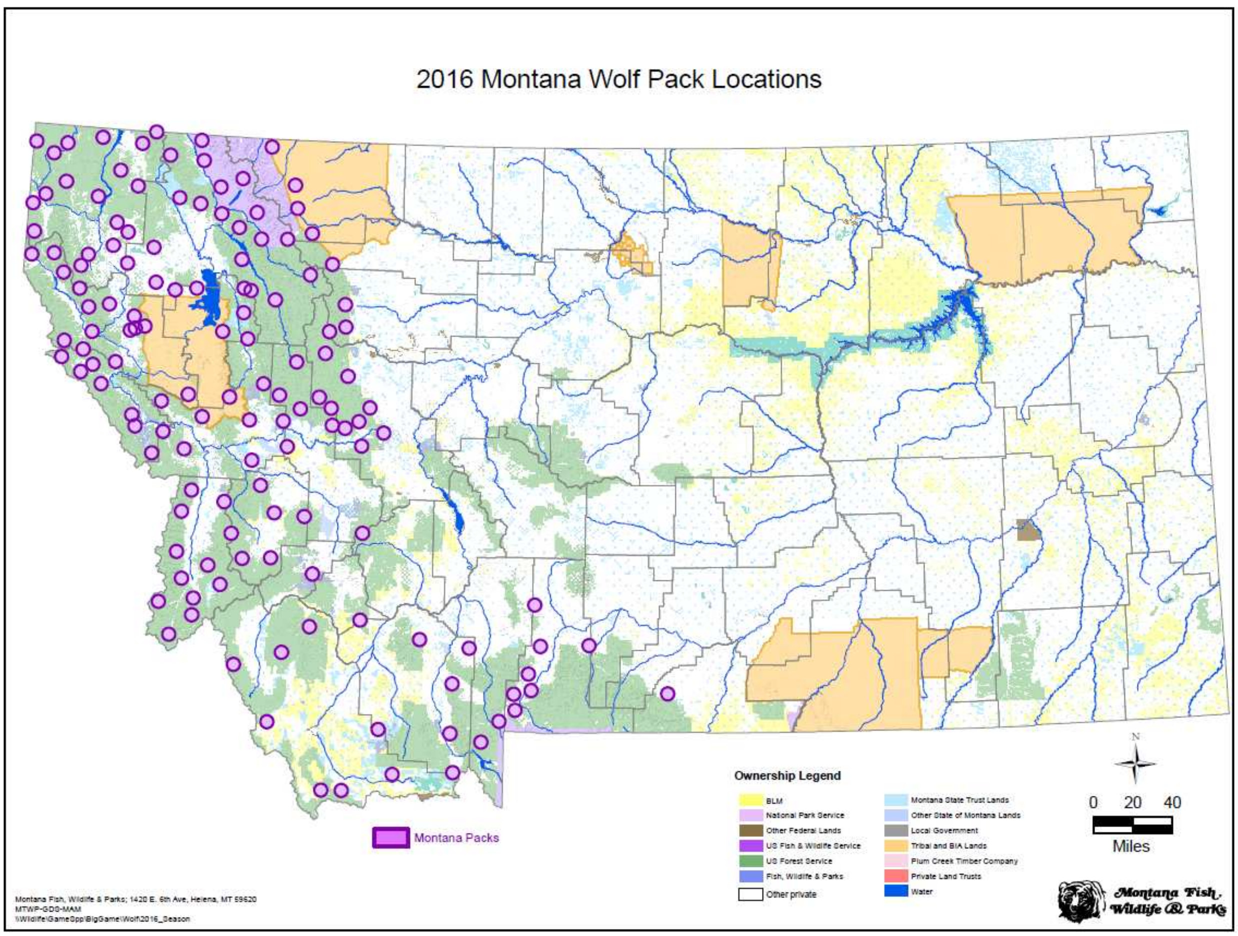

Figure 6. Verified wolf pack distribution in the State of Montana, as of December 31, 2016.

3. WOLF MANAGEMENT

3.1 Regulated Public Hunting and Trapping

Regulated public harvest of wolves was recommended by the Governor's Wolf Advisory Council and included in Montana's Wolf Conservation and Management Plan that was approved by the USFWS during 2004. The Montana plan indicates that hunting can only be implemented when wolves are delisted and under state authority and if more than 15 breeding pairs of wolves existed in Montana the previous year. FWP has developed and implemented wolf harvest strategies that maintain a recovered and connected wolf population, minimize wolf-livestock conflicts, reduce wolf impacts on low or declining ungulate populations and ungulate hunting opportunities, and effectively communicate to all parties the relevance and credibility of the harvest while acknowledging the diversity of values among those parties. The Montana public has the opportunity for continuous and iterative input into specific decisions about wolf harvest throughout the public season-setting process.

During 2016 the FWP Commission adopted the framework for the 2016-17 wolf season. Proposed changes included increases to wolf quota in WMU 313 north of Yellowstone Park from 2 to 6 wolves. The proposed increase was not put forth by the Commission for public comment.

At the close of the 2016-17 wolf season on March 15, 2017, the harvest included 163 taken by hunters and 83 taken by trappers, for a total of 246 wolves harvested during the 2016-2017 season (Figure 7). The total calendar-year 2016 wolf harvest in Montana was 255, including 93 wolves harvested during spring of the 2015-16 season and 162 wolves harvested during fall of the 2016-17 season. Sales of 2016-17 wolf licenses generated $393,000 for wolf management and monitoring in Montana.

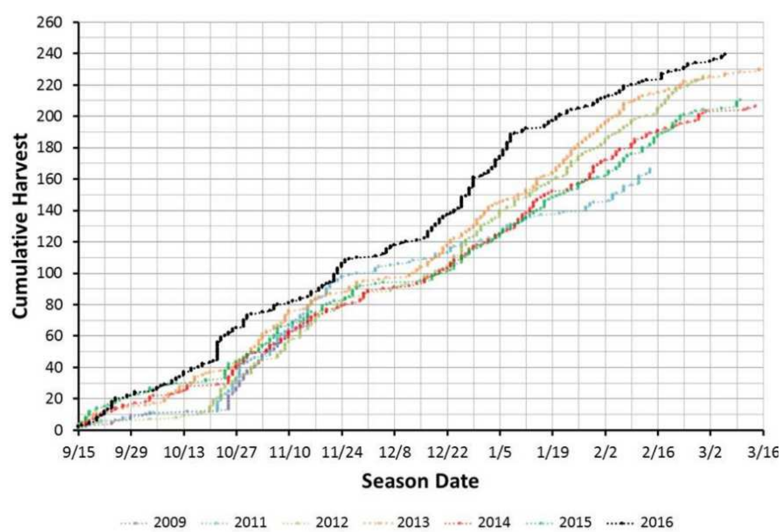

Figure 7. Cumulative wolf hunting and trapping harvest by date, 2009 – 2016.

3.2 Wolf – Livestock Interactions in Montana

Montana wolves routinely encounter livestock on both private land and public grazing allotments. Wolves are opportunistic predators, most often seeking wild prey. However, some wolves learn to prey on livestock and teach this behavior to other wolves. Wolf depredations are difficult to predict in space and time. The majority of cattle and sheep wolf depredation incidents confirmed by USDA Wildlife Services (WS) occur on private lands. The likelihood of detecting injured or dead livestock is probably higher on private lands where there is greater human presence than on remote public land grazing allotments. The magnitude of under-detection of loss on public allotments is unknown. Most cattle depredations occur during the spring or fall months while sheep depredations occur more sporadically throughout the year.

Wildlife Service's workload increased through 2009 as the wolf population increased and distribution expanded. The number of suspected wolf complaints received by WS increased steadily from federal fiscal year 1997 to 2009 (Figure 8). The number of complaints received since those years has declined from 233 complaints in FFY 2009 to 66 in FFY 2016. About 50% of the complaints received by WS are verified as wolf-caused.

In 2012 wolves were under full management authority of the state and wolf-livestock conflict resolution was guided by a combination of Montana's approved state plan and the administrative rules of Montana. Federal and state regulations since 2009 have allowed private citizens to kill wolves seen in the act of attacking, killing, or threatening to kill livestock. In 2009, 14 wolves were taken by private citizens, 17 were taken in 2010, 7 in 2011, 5 in 2012, 8 in 2013, 7 in 2014, 16 in 2015, and 12 in 2016. The remainder of wolves killed in control situations were removed by federal agency personnel (Figure 9).

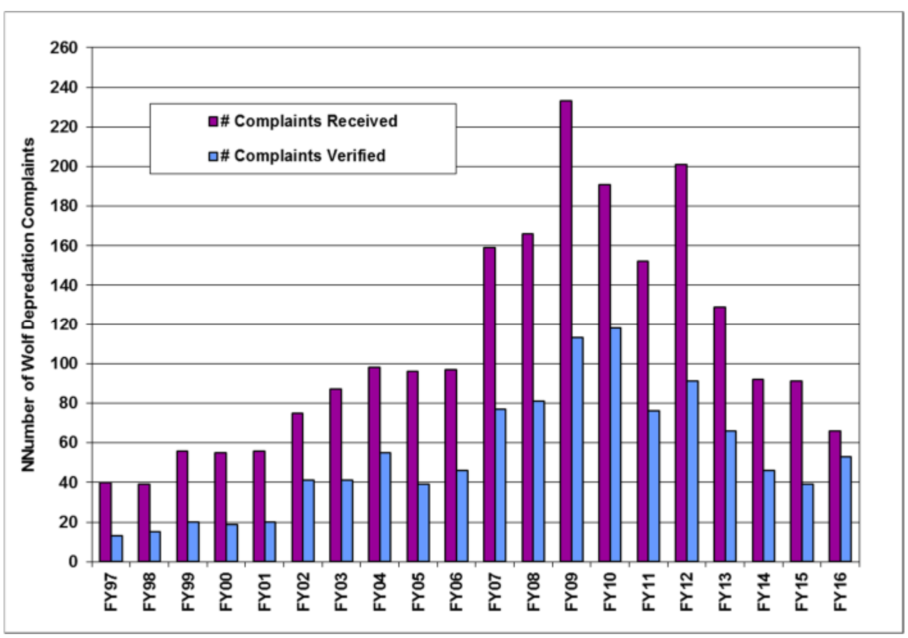

Figure 8. Number of complaints received by USDA Wildlife Services as suspected wolf damage and number of complaints verified as wolf damage, Federal Fiscal Year 1997-2016.

Depredation Incidents during 2016

Wildlife Services confirmed that, statewide, 52 cattle and 5 sheep were killed by wolves during 2016. Total confirmed cattle and sheep losses were similar to 2014 and 2015 numbers (Figure 9). Many livestock producers reported "missing" livestock and suspected wolf predation. Others reported indirect losses including poor weight gain and reduced productivity of livestock. There is no doubt that there are undocumented losses.

To address livestock conflicts and to reduce the potential for further depredations, 61 wolves were killed during 2016, compared to 51 wolves killed during 2015. Forty-nine wolves were removed in control actions by Wildlife Services. Twelve of the 61 wolves were killed by private citizens when wolves were seen chasing, killing, or threatening to kill livestock.

Seventeen packs that existed at some point during 2016 were confirmed to have killed livestock. The general decrease in livestock depredations since 2009 may be a result of several factors including a trend toward more aggressive wolf control in response to depredations and effects of legal wolf harvest (Figure 9, and see Appendix 3).

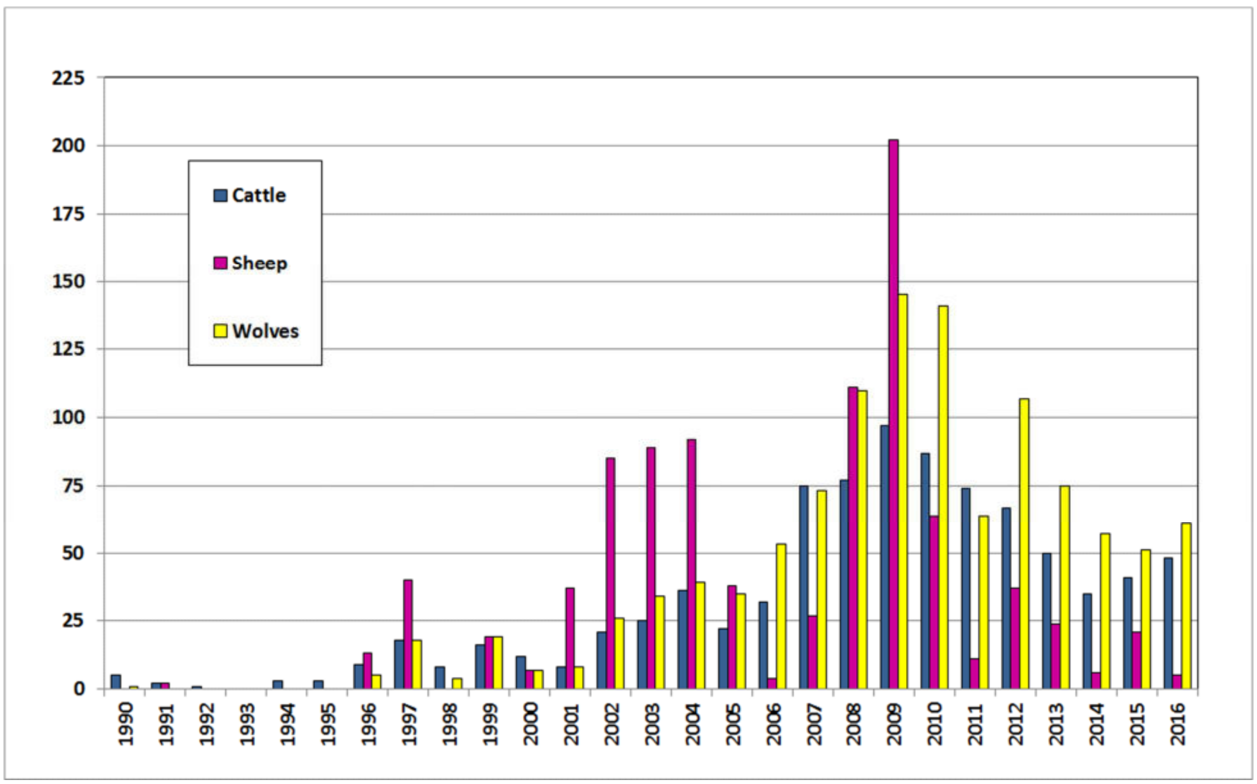

Figure 9. Number of cattle and sheep killed by wolves and number of wolves removed through agency control and take by private citizens, 2000-2016.

Montana Livestock Loss Board

The Montana Wolf Conservation and Management Plan called for creation of this Montana-based program to address the economic impacts of verified wolf-caused livestock losses. The plan identified the need for an entity independent from FWP to administer the program.

The purposes of the MLLB are 1) to provide financial reimbursements to producers for losses caused by wolves based on the program criteria, and 2) to proactively apply prevention tools and incentives to decrease the risk of wolf-caused losses and minimize the number of livestock killed by wolves through proactive livestock management strategies.

The Loss Mitigation element implements a reimbursement payment system for confirmed and probable losses that are verified by USDA Wildlife Services. Indirect losses and costs are not directly covered, but eventually could be addressed through application of a multiplier for confirmed losses and a system of bonus or incentive payments. Eligible livestock losses are cattle, calves, hogs, pigs, horses, mules, sheep, lambs, goats, llamas, and guarding animals. Confirmed and probable death losses are reimbursed at 100% of fair market value. Veterinary bills for injured livestock that are confirmed due to wolves may be covered up to 100% of fair market value of the animal when funding becomes available.

Preliminary reimbursement totals for 2016 wolf depredations are $59,578 paid to livestock owners on 67 head of livestock and 1 dog. These numbers differ slightly from the WS confirmed losses due to wolves because reimbursements are also made for probable wolf depredations.

Livestock loss statistics are available for 2008 to the present on the board's website http://liv.mt.gov/LLB/lossdata_2015.mcpx. The board began accepting claims in the spring of 2008. Total numbers for 2009 to 2016 are for a full calendar year.

The Livestock Loss Board has a Facebook page where the number of livestock killed and the county where the loss occurred is listed. This page is updated on the same day the livestock loss claim is received. To view the page, go to https://www.facebook.com/pages/Livestock-Loss-Board/208087235878971.

During 2016, the Montana Livestock Loss Board also distributed $96,113 in six grants whose work was aimed at proactively applying loss prevention tools.

Blackfoot Challenge - $22,000 was provided for a livestock carcass pickup program and range riders to monitor livestock and wolves. 501 carcasses were removed from approximately 115 ranches on 1.2 million acres. All carcasses were taken to a composting site in order to remove attractants to wolves. Range riders monitored around a dozen livestock herds as well as helping to monitor wolves in partnership with Montana Fish, Wildlife and Parks. Five known wolf packs are in the covered watershed and about 15,000 head of livestock. The Blackfoot Challenge provided $22,000 cash match and $1,007 in-kind match. This project has been in place for over a decade and continues to show a very high success rate. Conflicts with wolves remained low within this ongoing project area.

Big Hole Watershed Committee - $33,000 was provided for a livestock carcass pickup program and range riders to monitor livestock and wolves. This organization is in the beginning stages of setting up a carcass removal project. They have a lease agreement with the Montana Department of Transportation land which is identical to the Blackfoot Challenge site. They have secured a truck, driver and supplies and are in the final stage to begin their carcass program. Currently carcasses are being hauled to a landfill in Beaverhead County. Range riders monitored eight different livestock herds as well as helping to monitor wolves in partnership with Montana Fish, Wildlife and Parks. Five additional large ranches have asked to be included in their range rider program. Five known wolf packs are in the covered watershed and about 15,000 head of livestock. Big Hole Watershed Committee provided $7,043 cash match and $26,856 in-kind match. The range rider project has been in place for many years and continues to show a very high success rate. Now they have expanded to the carcass removal using the Blackfoot Challenge model. Conflicts with wolves remained low within this ongoing project area.

A citizen was provided $660 for a guard dog and dog food. This citizen purchased an additional guard dog and dog food to protect her flock of sheep from wolves and grizzly bears. Wolves have been on her property many times and her old guard dogs were having trouble keeping the sheep protected. The purchase of the new younger dog has helped to prevent any losses on her property. She provided a $660 cash match.

Centennial Valley Association - $15,560 was provided for range riders and carcass removal. This association provided range riders that covered many ranches using a large area of Beaverhead County located West of Yellowstone Park. Wolves and grizzly bears were seen throughout the grazing season. Centennial Valley Association provided a cash match of $8,000 and $9,490 in-kind match. There were documented conflicts and one calf was killed. Overall because of the association’s location and variety of large predators, this project appears to be highly successful.

A ranch in northwest Montana was provided with $7,993 for a range rider. This ranch has had numerous wolf depredations over the past ten years. During 2016 there were two confirmed calf losses, three unconfirmed cow losses and one unconfirmed bull loss. Although the ranch had losses, the range rider helped to reduce more possible losses and was able to contact USDA Wildlife Services in a timely manner in order to confirm losses were due to wolves. The ranch provided a cash match of $4,593 and a $3,400 in-kind match.

Tom Miner Basin Association - $16,900 was provided for fladry, range riders and carcass removal. Tom Miner Basin Association provided $16,900 cash match. This association adjoins Yellowstone Park’s Northern border and has a high level of wolves and grizzly bears using the area. No livestock were lost to wolves within the area covered by the association and continues to be highly successful.

See the MLLB for detailed information http://liv.mt.gov/LLB/default.mcpx .

FWP Collaring of Livestock Packs
State Statute 87-1-623 requires Montana Fish, Wildlife and Parks to allocate wolf license dollars toward collaring wolf packs in livestock areas. The purpose of these efforts is to be able to more readily understand which wolf pack may have been involved in a livestock depredation and so that USDA Wildlife Services can be more efficient and effective at controlling packs that depredate on livestock.

FWP employs six wolf specialists located in Regions 1, 2, 3, 4, and 5 (Appendix 1) along with seasonal technicians in Regions 1 and 2. Wolf specialists and technicians capture wolves and deploy collars during winter helicopter capture efforts and summer/fall trapping efforts.

During 2016, FWP wolf specialists captured and collared 40 wolves (Table 2). Sixteen wolves were captured by helicopter darting during January and February 2016. Snow and wind conditions were very good and the Quicksilver Helicapture Team had very good success during this period. Twenty-four wolves were captured and collared by trapping efforts during summer and fall of 2016. USDA Wildlife Services also captured and collared an additional 6 wolves during 2016.

Table 2. Wolves captured and radio-collared by FWP Wolf Specialists during 2016.

	Helicopter	Summer/Fall	**Total**
Region 1	3	10	**13**
Region 2	4	10	**14**
Region 3	7	1	**8**
Region 4	2	3	**5**
Total	**16**	**24**	**40**

FWP Proactive Wolf Depredation Prevention

In 2016, FWP collaborated on a wolf conflict prevention program with the Tom Miner Basin Association. This was the third year employing conflict prevention techniques in the area, and none of the cattle herds experienced depredations that were actively managed. These management strategies included altering stocking density, range riding, fladry, and carcass and bone pile management. In Northwest Montana, FWP was involved in a collaborative proactive risk management project in the Blackfoot Valley. The Blackfoot Challenge Range Rider Project employed seasonal range riders to monitor livestock and predators in areas occupied by the Arrastra Creek, Chamberlain, Morrell Mountain, Inez, Union Peak wolf packs.

Additonal work on depredation prevention is described in Appendix 3 - Research, Field Studies, and Project Publications and the Montana Livestock Loss Board Section of the report.

3.3 Total 2015 Documented Statewide Wolf Mortalities

FWP detected a total of 334 wolf mortalities during 2016 statewide due to all causes (Figure 10). Undoubtedly, additional mortalities occurred but were not detected. Because mortality counts and total population counts are incomplete, actual mortality rates cannot be determined.

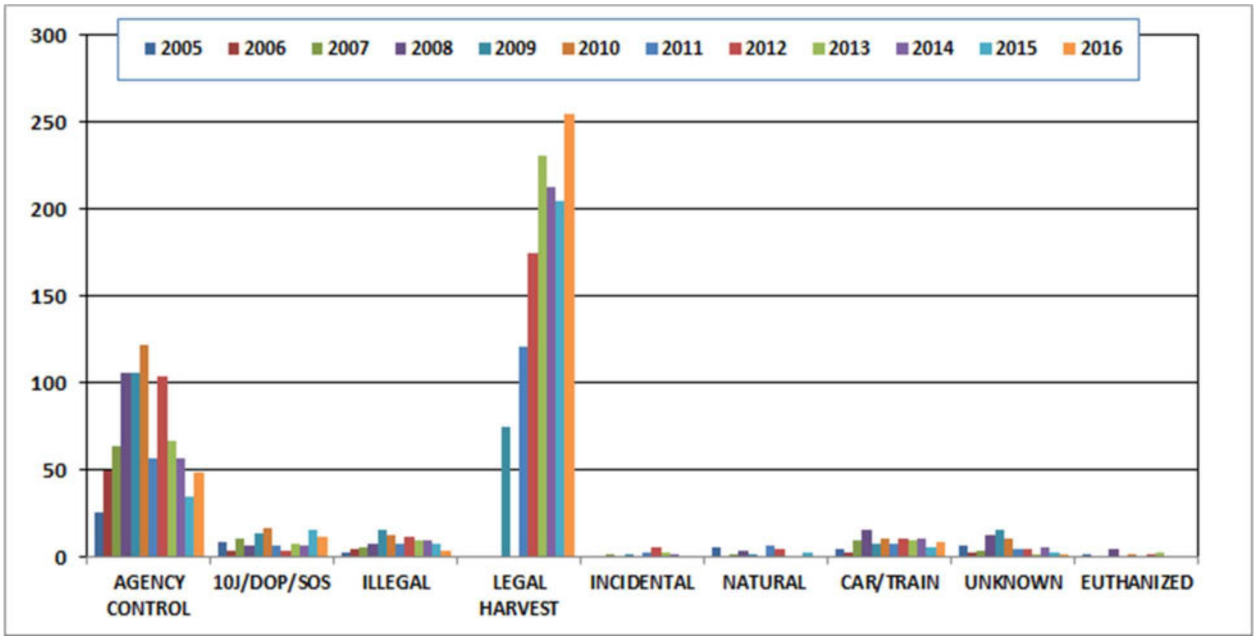

Figure 10. Minimum number of wolf mortalities documented by cause for gray wolves (2005-2016). Total number of documented wolf mortalities during 2016 was 334.

Documented total wolf mortality in 2016 (334) was 14% greater than 5-year average since 2011 when legal harvest began and continued. The majority of the increase was due to higher levels of legal harvest. Control actions were greater than in 2015, but were relatively low compared to peak years. Of the 61 wolves removed in 2016 for livestock depredations, 49 were removed by WS and 12 were legally killed by private citizens under the Montana state law known as the Defense of Property statute or Senate Bill 200. Four wolves were documented as being killed illegally, and 9 wolves were documented as being killed by vehicle or train collision.

4. OUTREACH AND EDUCATION

FWP's wolf program outreach and education efforts are varied, but significant. Outreach activities take a variety of forms including field site visits, phone and email conversations to share information and answer questions, media interviews, and formal and informal presentations. FWP also prepared and distributed a variety of printed outreach materials and media releases to help Montanans become more familiar with the Montana wolf population and the state plan. An increasingly important aspect of outreach is the Internet.

The "Report a Wolf" application continued to generate valuable information from the public in monitoring efforts for existing packs and documenting wolf activity in new areas. Several hundred reports were received through the website. Countless more were received via postal mail and over the phone.

Most wolf program staff spent some time at hunter check stations in FWP Regions 1-5 to talk with hunters about wolves, wolf management, and their hunting experiences.

5. FUNDING

5.1 Montana Fish, Wildlife & Parks Funding

Funding for wolf conservation and management in Montana is controlled by laws enacted by the state legislature. State laws also provide detailed guidance on some wolf management activities. The Montana Code Annotated (MCA) is the current law, and specific sections can be viewed at http://leg.mt.gov/bills/mca/index.html. Legislative bill language and history that has created or amended MCA sections can be accessed at http://leg.mt.gov/css/bills/Default.asp. Three sections of the MCA are of primary significance to wolf management and funding. These are:
MCA 87-5-132 Use of Radio-tracking Collars for Monitoring Wolf Packs
MCA 87-1-623 Wolf Management Account
MCA 87-1-625 Funding for Wolf Management

MCA 87-5-132 was created during the 2005 legislative session by Senate Bill 461. It has been amended twice, both times during the 2011 legislative session, by House Bill 363 and Senate Bill 348. This law requires capturing and radio-collaring an individual within a wolf pack that is active in an area where livestock depredations are chronic or likely.

MCA 87-1-623 was created during the 2011 Legislative Session by House Bill 363. This law requires that a wolf management account be set up and that all wolf license revenue be deposited into this account for wolf collaring and control. Specifically, it states that subject to appropriation by the legislature, money deposited in the account must be used exclusively for the management of wolves and must be equally divided and allocated for the following purposes: (a) wolf-collaring activities conducted pursuant to 87-5-132; and (b) lethal action conducted pursuant to 87-1-217 to take problem wolves that attack livestock.

MCA 87-1-625 was created during the 2011 Legislative Session by Senate Bill 348. This law required FWP to allocate $900,000 annually toward wolf management. "Management" in MCA 87-1-625 is defined as in MCA 87-5-102, which includes the entire range of activities that constitute a modern scientific resource program, including but not limited to research, census, law enforcement, habitat improvement, control, and education. The term also includes the periodic protection of species or populations as well as regulated taking. During the 2015 legislative session, Senate Bill 418 reduced this amount to $500,000 of spending authority.

Wolf management funding for state fiscal year 2016 (July 1, 2015 – June 30, 2016) consisted of the $257,653 of federal money from the last year of the USFWS cooperative agreement, $13,215 of federal PR funds, $355,174 of Montana wolf license dollars, and $48,629 from the Rocky Mountain Elk Foundation.

Funding is and will primarily be used to pay for FWP’s field presence to implement population monitoring, collaring, outreach, hunting, trapping, and livestock depredation response. In addition to the ongoing efforts by Montana FWP wolf specialists, additional efforts to meet the intent of SB 348 and HB 363 include:

- The wolf program increased to a total of 5.5+ FTE in state fiscal year 2012 (wolf specialists dedicated to wolf management plus seasonal technicians and volunteers). Those staffing levels continued in 2016 with the exception of temporary vacancies resulting from employees taking new positions.

- FTE’s were added for technicians in Region 1 and Region 2 during state fiscal year 2012 to increase collaring efforts in wolf packs associated with livestock. Those staffing levels were continued during 2016.

- Funding was dedicated for aerial darting and collaring of wolves in the Madison, Gallatin, and Yellowstone drainages where conflicts with grizzly bears limit trapping and collaring efforts.

- Renewed agreement with Wildlife Services and commitment of $110,000 toward wolf management efforts.

Other wolf management services provided by FWP include law enforcement, harvest/quota monitoring, legal support, public outreach, and overall program administration. Exact cost figures have not been quantified for the value of these services.

5.2 USDA Wildlife Services Funding

Wildlife Services (WS) is the federal agency that assists FWP with wolf damage management. WS personnel conduct investigations of injured or dead livestock to determine if it was a predation event and, if so, what predator species was responsible for the damage. Based on WS determination, livestock owners may be eligible to receive reimbursement through the Montana Livestock Loss Program. If WS determines that the livestock depredation was a confirmed wolf kill or was a probable wolf kill, the livestock owner is eligible for 100% reimbursement on the value of the livestock killed based on USDA market value at the time of the investigation.

Under an MOU with FWP, the Blackfeet Nation (BN), and the Confederated Salish and Kootenai Tribes (CSKT), WS conducts the control actions on wolves as authorized by FWP, BN, and CSKT. Control actions may include radio-collaring and/or lethal removal of wolves implicated in livestock depredation events. FWP, BN, and CSKT also authorize WS to opportunistically radio-collar wolf packs that do not have an operational radio-collar attached to a member of the pack.

As a federal agency, WS receives federal appropriated funds for predator damage management activities but no funding directed specifically for wolf damage management. Prior to Federal Fiscal Year (FFY) 2011, the WS Program in Montana received approximately $250,000 through the Tri-State Predator Control Earmark, some of which was used for wolf damage management operations. However, that earmark was completely removed from the federal budget for FFY 2011 and not replaced in FFY 2012-2016.

In FFY 2016, WS spent $264,594 conducting wolf damage management in Montana (not including administrative costs). The FFY 2016 expenditure included $129,594 Federal appropriations, $110,000 from FWP, and $25,000 from the Rocky Mountain Elk Foundation.

6. PERSONNEL AND ACKNOWLEDGEMENTS

The 2016 FWP wolf team was comprised of Diane Boyd, Nathan Lance, Abigail Nelson, Mike Ross, Tyler Parks, and Ty Smucker. Wolf specialists work closely with regional wildlife managers in FWP regions 1-5, including Neil Anderson, Howard Burt, Ray Mule, Graham Taylor, and Mike Thompson, as well as Wildlife Management Bureau Chief, John Vore, and Carnivore and Furbearer Coordinator, Bob Inman. The wolf team is part of a much bigger team of agency professionals that make up Montana Fish, Wildlife & Parks including regional supervisors, biologists, game wardens, information officers, front desk staff, and many others who contribute their time and expertise. FWP Helena and Wildlife Health Lab staff contributed time and expertise including Ron Aasheim, Keri Carson, Justin Gude, Quentin Kujala, Ken McDonald, Adam Messer, Tom Palmer, Kevin Podruzny, and Jennifer Ramsey.

During 2016, the Montana wolf management program benefited from the contributions of seasonal technicians Molly Parks and Tyler Parks who excelled at their jobs and contributed enormously. The Montana wolf management volunteer program was very fortunate to have Molly Parks, Andrea Widjaja, and Jeremy SunderRaj. Also, a thank you to Blackfoot range riders: Eric Graham, Jordan Mannix, and Sigrid Olson. We thank the Tom Miner Basin Association and Range riders for wolf monitoring information and great communication. We thank the Beartooth Backcountry Horsemen's Association for their interest and efforts in monitoring wolf activity in the Stillwater and the Beartooths. We would also like to thank Dan Huidekuper for volunteering his time, horses, and experience packing people and gear into the Bob Marshall Wilderness.

We thank Northwest Connections for their avid interest and help in documenting wolf presence and outreach in the Swan River Valley. We thank Swan Ecosystem Center for their continued interest and support. We also thank the Blackfoot Challenge for their contributions and efforts toward monitoring wolves in the Blackfoot Valley.

We thank Confederated Salish and Kootenai Tribal biologists Stacey Courville and Shannon Clairmont, and Blackfeet Tribal biologist Dan Carney, wildlife technician Dustin Weatherwax, and wardens Glenn Hall and Jeff Horn for capturing and monitoring wolves in and around their respective tribal reservations.

We acknowledge the work of the citizen-based Montana Livestock Loss Board which oversees implementation of Montana's reimbursement program and the conflict prevention grant money, as well as its coordinator, George Edwards.

We thank Mike Jimenez (USFWS) for his coordination and oversight of state wolf management in the Northern Rockies through May 2016. We congratulate Mike for his retirement in 2016 and his enourmous contributions to wolf recovery and management in the northern rockies. His mentorship and expertise has tremendously benefited management of Montana's wolf population.

USDA APHIS WS investigates all suspected wolf depredations on livestock and under the authority of FWP, carries out all livestock depredation-related wolf damage management activities in Montana. We thank them for contributing their expertise to the state's wolf program and for their willingness to complete investigations and carry out lethal control and radio-collaring activities in a timely fashion. We also thank WS for assisting with monitoring wolves in Montana. WS personnel involved in wolf management in Montana during 2016 included state director John Steuber, western district supervisor Kraig Glazier, eastern district supervisor DalenTidwell, western assistant district supervisor Chad Hoover, eastern assistant district supervisor Alan Brown, wildlife disease biologists Jerry Wiscomb and Jared Hedelius, wildlife biologist Alexandra Few, helicopter pilots Tim Graff and Eric Waldorf, helicopter/airplane pilot Stan Colton, wildlife specialists Denny Biggs, Steve DeMers, Mike Hoggan, Cody Knoop, Jordan Linnell, John Maetzold, Graeme McDougal, John Miedtke, Kurt Miedtke, Brian Noftsker, Ted North, Scott Olson, Jim Rost, Bart Smith, Pat Sinclair, and Dan Thomason.

The Montana Wolf Management program field operations also benefited in a multitude of ways from the continued cooperation and collaboration of other state and federal agencies and private interests such as the USDA Forest Service, Montana Department of Natural Resources and Conservation ("State Lands"), U.S. Bureau of Land Management, Plum Creek Timber Company, Glacier National Park, Yellowstone National Park, Idaho Fish and Game, Wyoming Game and Fish, Nez Perce Tribe, Canadian Provincial wildlife professionals, Turner Endangered Species Fund, People and Carnivores, Wildlife Conservation Society, Keystone Conservation, Boulder Watershed Group, Big Hole Watershed Working Group, the Madison Valley Ranchlands Group, the upper Yellowstone Watershed Group, the Blackfoot Challenge, Tom Miner Basin Association, and the Granite County Headwaters Working Group.

We deeply appreciate and thank our pilots whose unique and specialized skills, help us find wolves, get counts, and keep us safe in highly challenging, low altitude mountain flying situations. They include Joe Rahn (FWP Chief Pilot), Neil Cadwell (FWP Pilot), Ken Justus (FWP Pilot), Trever Throop (FWP Pilot), Mike Campbell (FWP Pilot), Rob Cherot (FWP Pilot), Jim Pierce (Red Eagle Aviation, Kalispell), Roger Stradley (Gallatin Flying Service, Belgrade), Steve Ard (Tracker Aviation Inc., Belgrade), Lowell Hanson (Piedmont Air Services, Helena), Dave Horner (Red Eagle Aviation), Joe Rimensberger (Osprey Aviation, Hamilton), and Mark Duffy (Central Helicopters, Bozeman). We also thank Quicksilver Aviation for their safe and efficient helicopter capture efforts.

Rocky Mountain Elk Foundation contributed donations for collaring wolves in Montana. Over the past four years they have donated a over $123,000.

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APPENDIX 1

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406-444-3940
jvore@mt.gov

USDA Wildlife Services
(to request investigations of injured or dead livestock):

John Steuber
USDA WS State Director, Billings
(406) 657-6464 (w)

Kraig Glazier
USDA WS West District Supervisor, Helena
(406) 458-0106 (w)

Dalen Tidwell
USDA WS East District Supervisor, Columbus
(406) 657-6464 (w)

TO REPORT A DEAD WOLF OR POSSIBLE ILLEGAL ACTIVITY:

Montana Fish, Wildlife & Parks

- Dial 1-800-TIP-MONT (1-800-847-6668) or local game warden

TO SUBMIT WOLF REPORTS ELECTRONICALLY AND TO LEARN MORE ABOUT THE MONTANA WOLF PROGRAM, SEE:

- http://fwp.mt.gov/fishAndWildlife/management/wolf/

MONTANA FISH WILDLIFE & PARKS
ADMINISTRATIVE REGIONS

STATE HEADQUARTERS
MT Fish, Wildlife & Parks
1420 E 6th Avenue
PO Box 200701
Helena, MT 59620-0701
(406) 444-2535

REGION 1
490 N Meridian Rd
Kalispell, MT 59901
(406) 752-5501

REGION 2
3201 Spurgin Rd
Missoula, MT 59804
(406) 542-5500

REGION 3
1400 South 19th
Bozeman, MT 59718
(406) 994-4042

HELENA Area Res Office (HARO)
930 Custer Ave W
Helena, MT 59620
(406) 495-3260

BUTTE Area Res Office (BARO)
1820 Meadowlark Ln
Butte, MT 59701
(406) 494-1953

REGION 4
4600 Giant Springs Rd
Great Falls, MT 59405
(406) 454-5840

LEWISTOWN Area Res Office (LARO)
215 W Aztec Dr
PO Box 938
Lewistown, MT 59457
(406) 538-4658

REGION 5
2300 Lake Elmo Dr
Billings, MT 59105
(406) 247-2940

REGION 6
54078 US Hwy 2 W
Glasgow, MT 59230
(406) 228-3700

HAVRE Area Res Office (HvARO)
2165 Hwy 2 East
Havre, MT 59501
(406) 265-6177

REGION 7
Industrial Site West
PO Box 1630
Miles City, MT 59301
(406)234-0900

APPENDIX 2

BRIEF GRAY WOLF CHRONOLOGY IN MONTANA

1915
- Federal authorities begin wolf control in the West. Wolf populations eliminated by about 1925.

1973
- Wolves protected in Montana as state endangered species and under federal Endangered Species Act.

1993
- An estimated 45 wolves in five packs occupy the federal Northwestern Montana Recovery Area.

1994
- Federal EIS completed and wolves are to be reintroduced into Yellowstone National Park and central Idaho for three to five years under the Endangered Species Acts experimental, non-essential rules. Wolf recovery is defined as 30 breeding pairs--an adult male and an adult female raising two or more pups to Dec. 31--in Montana, Idaho, and Wyoming for three successive years.

1995-1996
- Seventy-nine wolves are relocated to Yellowstone National Park (42) and central Idaho (37).

1999
- Governors of Montana, Idaho, and Wyoming renew a 1997 MOU to coordinate public involvement to pursue plans to manage a recovered wolf population and assure a timely delisting.

2000
- USFWS determines there are 30 breeding pairs in the tri-state Rocky Mountain Recovery Area, marking 2000 as the first year of the three-year countdown to meet wolf population recovery goals.

2001
- Montana Legislature removes gray wolf from list of predatory species once the wolf is delisted. Montana FWP's draft of the Montana Wolf Conservation and Management Planning Document is reviewed, amended, and approved by the Montana Wolf Management Advisory Council.
- An estimated 35 breeding pairs, in 51 packs, are counted in the tri-state Rocky Mountain Recovery Area, totaling about 550 wolves. The USFWS determines 2001 is second year of the three year countdown to trigger an official proposal to delist the wolf.

2002
- Montana Fish, Wildlife & Parks begins to develop an environmental impact statement (EIS) on the state management of wolves. The public is invited to participate at community work sessions around the state and asked to identify issues and help develop management alternatives.
- An estimated 43 breeding pairs are counted in the tri-state Rocky Mountain Wolf Recovery Area, totaling about 663 wolves. The USFWS determines 2002 is the third year of the three-year countdown to trigger official proposal to delist wolves.
- USFWS announces that the northern Rockies gray wolf population has achieved biological recovery under the federal Endangered Species Act.

2003

- State conservation and management plans completed by MT, ID, and WY and submitted to USFWS.
- USFWS begins the official administrative process of delisting gray wolves in the northern Rockies.
- An estimated 761 wolves in 51 breeding pairs are counted in the tri-state Rocky Mountain Wolf Recovery Area at the end of the year.

2004

- USFWS approves state management plans from Montana and Idaho and rejects Wyoming's plan. Delisting is officially delayed until the impasse is resolved.
- An estimated 835 wolves in 66 breeding pairs are counted in the tri-state Rocky Mountain Wolf Recovery Area at the end of the year.

2005

- Montana Senate Bill 461 passes. This law requires capturing and radio-collaring an individual within a wolf pack that is active in an area where livestock depredations are chronic or likely.

2007

- USFWS approves Wyoming's wolf management plan and state laws.
- A minimum of 422 wolves in 39 breeding pairs are counted **in Montana**.

2008

- USFWS publishes the final delisting rule, recognizing the NRM DPS and removing it from the List of Endangered and Threatened Wildlife.
- Twelve parties filed a lawsuit challenging the identification and delisting of the NRM DPS. The plaintiffs also moved to preliminarily enjoin the delisting.
- The U.S. District Court for the District of Montana granted the plaintiffs motion for a preliminary injunction and enjoined the USFWS implementation of the final delisting rule for the NRM DPS of the gray wolf. The ruling placed the gray wolf back under the ESA. The three main issues identified were the regulatory framework in Wyoming, connectivity, and defense of property laws. The NRM DPS wolf population was officially delisted from March 28 to July 18 and preparations for a 2008 wolf hunting season were suspended.
- USFWS asked the Court to vacate the delisting rule and remand it back to the agency for further consideration. The Court agreed. USFWS re-opens a 30-day public comment period on the February 2007 delisting proposal specific to issues raised in the preliminary injunction.
- A minimum of 497 wolves in 34 breeding pairs are counted in Montana.

2009

- USFWS determined and notified Wyoming that its state plan and regulatory framework were not adequate and no longer approved.
- USFWS publishes the final delisting rule which designated the NRM distinct population segment and delists the gray wolf throughout the DPS except WY. In Wyoming, the wolf remained listed as experimental /non-essential under the federal Endangered Species Act.
- The final delisting rule takes effect. Wolves in MT are classified as a species in need of management statewide under Montana law; state rules and the state management plan take full effect. MFWP Commission adopts tentative wolf quotas for public comment in May. Commission adopts the final 2009 wolf quotas of 75.

• Litigation over the 2009 delisting decision was again initiated in federal court in Missoula by the same coalition of organizations. An injunction was requested, based on arguments presented by the plaintiffs that the hunting seasons planned for Idaho and Montana would harm the regional wolf population. The injunction request was denied.
• The 1st fair chase wolf hunting season occurred in fall 2009. The statewide quota was 75, and 72 wolves were taken.
•Wolf hunting license sales generate $326,000 for wolf management. Funding is and will primarily be used to pay for FWP's field presence to implement population monitoring, collaring, outreach, hunting, trapping, and livestock depredation response.
• A minimum of 524 wolves in 37 breeding pairs are counted in Montana.

2010
• Federal District Court ruled that delisting within the NRM DPS could not occur without Wyoming and vacated the delisting of the entire DPS. Wolves throughout the NRM DPS were relisted under ESA.
• The Montana Congressional Delegation and other parties began pursuing federal legislation (as a standalone bill or as a rider amended to budget bills) that would delist the wolf.
•No wolf season is held.
•No wolf license dollars are generated for wolf management.
• A minimum of 566 wolves in 35 breeding pairs are counted in Montana.

2011
• A congressional budget bill directed the Secretary of the Interior to reissue the final delisting rule for Northern Rocky Mountain wolves originally published in April of 2009.
• USFWS publishes the final delisting rule designating wolves throughout the NRM DPS, except Wyoming, as a delisted species.
• Wolves in Montana became a species in need of management statewide under Montana law; state rules and the state management plan took full effect. Using a combination of federal funds and license dollars, FWP implements the state management plan by monitoring the wolf population, directing problem wolf control and take under certain circumstances, coordinating and authorizing research, regulating sport harvest, and leading wolf information and education programs.
• Montana House Bill 363 passes and requires that a wolf management account be set up and that all wolf license revenue be deposited into this account for wolf collaring and control.
• Litigation is filed challenging the constitutionality of the Congressional rider under the Separation of Powers clause of the U.S. Constitution. Decision is upheld in federal court. Decision is appealed and an emergency motion for an injunction is made to stop the wolf hunt. Appeal and motion fail.
• Montana holds its 2nd wolf season. Statewide quota is 220, and 160 wolves are taken by hunters in LY11.
•Wolf license sales generate $407,000 for wolf management.
• A minimum of 653 wolves with 39 breeding pairs are counted in Montana.

2012
• FWP Commission adds trapping to the wolf season, increases the bag limit to 3 wolves (no statewide quota), and adopts pan tension rule to minimize non-target captures.
• FWP instructs the first wolf trapper education course in Montana - 2,414 students.
•Wolf license sales generate $441,000 for wolf management.
• Montana holds its 3rd wolf season. 225 wolves are taken in LY 12, ~60% by hunters, 40% by trappers.
• A minimum of 625 wolves and 37 breeding pairs are counted in Montana.

2013

•FWP Commission increases bag limit to 5 wolves.
• Montana State legislature passes Senate Bill 200 authorizing landowners to shoot wolves on their private property.
• Wolf license sales generate $537,000 for wolf management.
• Montana holds its 4th wolf season. 230 wolves are taken in LY13, ~60% by hunters, 40% by trappers.
• A minimum of 627 wolves and 28 breeding pairs are counted in Montana.

2014

•Wolf license sales generate $455,000 for wolf management.
•Montana's wolf season approved by USFWS CITES program.
• Montana holds its 5th wolf season. 206 wolves are taken in LY14, ~60% by hunters, 40% by trappers.
• A minimum of 554 wolves and 34 breeding pairs are counted in Montana.

2015

• Wolf license sales generate $417,000 for wolf management.
• Montana holds its 6th wolf season. 210 wolves are taken in LY15, ~65% by hunters, 35% by trappers.
• A minimum of 536 wolves and 32 breeding pairs are counted in Montana.

2016

• The 5-year post delisting period of USFWS oversight ends in May 2016.
• Wolf license sales generate $393,000 for wolf management.
• Montana holds its 7th wolf season. 246 wolves are taken in LY16, ~66% by hunters, 34% by trappers.
• Limited-effort minimum counts of wolves and breeding pairs indicate Montana remains well above (at least 3X) the 150 wolves and 15 breeding pairs required by the state plan.

APPENDIX 3

RESEARCH, FIELD STUDIES, AND PROJECT PUBLICATIONS

Each year in Montana, there are a variety of wolf-related research projects and field studies in varying degrees of development, implementation, or completion. These efforts range from wolf ecology and predator-prey relationships to wolf-livestock relationships, policy, or wolf management. In addition, the findings of some completed projects get published in the peer-reviewed literature. The 2016 efforts are summarized below, with updates or project abstracts.

1. SPATIAL AND TEMPORAL PATTERNS OF WOLF-LIVESTOCK CONFLICT IN MONTANA AND THE EFFECTS OF WOLF MANAGEMENT

Investigators: Nick DeCesare, Liz Bradley, Justin Gude, Nathan Lance, Kent Laudon, Abigail Nelson, Mike Ross, Ty Smucker, Bob Inman (Montana Fish, Wildlife and Parks) and Seth Wilson (Montana Livestock Loss Board, Northern Rockies Conservation Cooperative).

Status: Final report completed, manuscript in peer-review process for publication

ABSTRACT: The successful recovery of wolves in portions of North America and Europe has brought challenges of conflicts with livestock. We assessed the spatial and temporal patterns of wolf depredations on livestock in Montana at a statewide scale during 2005–2015. These analyses highlighted areas of concentrated and consistent wolf-livestock conflicts, such that, for example, nearly 50% of the statewide conflicts occur in 5% of the state. We then used statistical modeling to assess drivers of the spatial and temporal patterns of conflicts. We first used linear regression to show that statewide annual totals of depredations were equally driven by changes in the proportion of places with conflict and the number of conflicts in chronically-affected places. Next we used generalized linear mixed models to evaluate covariates we hypothesized to predict both conflict presence (zero vs. non-zero depredation events) and conflict frequency (number of events given at least 1), including an assessment of the effects of targeted lethal control and general public harvest. Using administrative hunting districts as the unit of analysis, we found that conflict presence increased in areas with higher wolf densities ($P=0.005$), higher livestock densities ($P<0.001$), and intermediate proportionate areas of agricultural land ($P<0.001$), indicative of landscapes with mixed land cover types. Additionally, districts with depredations the previous year were more likely to continue having them ($P<0.001$), though targeted lethal removal of wolves significantly reduced this effect ($P=0.021$). General public harvest of wolves did not directly affect the year-to-year presence of conflicts ($P=0.52$). Within the subset of areas with ≥1 livestock depredation conflicts, the number of conflicts was positively correlated with wolf density ($P=0.021$), livestock density ($P=0.003$), and intermediate proportionate areas of forested land ($P=0.002$), as well as with the number of events during the previous year ($P<0.001$). There was also evidence that public harvest reduced

the frequency of depredation events in areas where conflict occurred (P=0.009). Our results suggested that public harvest resulted in an estimated 0.22 fewer depredations per district per year, or a decrease of 5.7 depredation events statewide per year. While our results suggest only a modest direct effect of harvest on reducing depredations, the observed levels of wolf-livestock conflict have decreased substantially since the advent of public harvest in Montana. We discuss alternative possible explanations for this change as well as the effectiveness of targeted lethal removal of wolves for reducing recurrent conflicts. Minimizing livestock losses is a top priority for successful wolf management, and these results shed light on the broad-scale patterns behind chronic problems and some of the tools used to address them.

2. EVALUATING CARNIVORE HARVEST AS A TOOL FOR INCREASING ELK CALF SURVIVAL AND RECRUITMENT

Investigators: Kelly Proffitt, Benjamin Jimenez, Rebecca Mowry, Justin Gude, and Mike Thompson (Montana Fish, Wildlife & Parks), Bob Garrott, Jay Rotella, and Mike Forzely (Montana State University)

Status: In Progress

Declines in elk calf recruitment and populations have continued to raise concerns about the effects of carnivores on elk populations. Recently, integrated carnivore-ungulate management proposals to reduce carnivore populations, including wolf and mountain lion, via increased public harvest in efforts to increase elk recruitment have been implemented in west-central Montana. However, the ability of wildlife managers to use carnivore harvest as a tool for improving elk recruitment, and thus elk population size, has not been evaluated in Montana. The purpose of this project is to evaluate the effects of carnivore management on carnivore population densities and elk calf survival. The project builds directly from the findings of a 2011-2015 study on cause-specific elk calf survival in the Bitterroot Valley, and it is fundamentally an evaluation of the effectiveness of carnivore harvest management decisions designed to increase elk recruitment and abundance.

Fieldwork began in 2016, with objectives focused on initiating the first year of elk calf survival monitoring, collecting data to monitor mountain lion harvest and for mountain lion population estimation in the south Bitterroot Valley, and monitoring known wolf packs and harvest to approximate a minimum wolf population. A total of 131 elk calves were captured, marked with VHF telemetry collars, and monitored for fate during capture events in May-June 2016 and December 2016-January 2017. Known causes of mortality are two-thirds predation-related to date. To date, a total of 41 DNA samples have been collected from live lions in the south Bitterroot area, and an additional 62 DNA samples have been collected from harvested lions in western Montana. Additionally, 9 lions have been fitted with GPS collars to help validate assumptions with the population-estimation method.

3. RE-EVALUATING THE BREEDING PAIRS INDEX FOR WOLVES TO ACCOUNT FOR THE EFFECTS OF HARVEST

Investigators: Mike Mitchell (Montana Cooperative Wildlife Research Unit, University of Montana, Missoula MT), Kevin Podruzny, (Montana Fish, Wildlife and Parks)

Status: In Progress

This project is intended to evaluate whether the statistical models to predict the number of wolf Breeding Pairs developed prior to public wolf harvest still accurately predict Breeding Pair numbers in the contemporary context of significant public wolf harvest. If not, an attempt will be made to develop new, more accurate Breeding Pair predictive models. Per the Montana Wolf Conservation Strategy, Montana is required to have a minimum of 15 Breeding Pairs in order to have a public harvest season, and using these models to predict the number of Breeding Pairs, if possible, offers a substantial cost, time, and effort savings over the field methods required to document Breeding Pairs. Part of the ongoing Montana Wolf Monitoring Study at UM includes the development of other, more useful measures of wolf population recruitment, but until that comes to fruition and is formally adopted into Montana wolf monitoring methods required by law, Montana will have to report Breeding Pair numbers. So this project is essentially a stop-gap to save staff time, money, and field effort until new methods are developed and implemented. Data assembly is underway for this project, and analyses as well as a final report will be completed in 2017.

4. ATTITUDES, PERCEPTIONS, AND VALUES OF RESIDENT MONTANANS RELATED TO WOLF HARVEST MANAGEMENT IN MONTANA

Investigators: Alex & Libby Metcalf (University of Montana); Mike Lewis, Quentin Kujala, Bob Inman & Justin Gude (Montana Fish, Wildlife and Parks)

Status: In Progress

This project is intended to repeat a similar survey done 5 years ago, after the 2011 Montana wolf hunting season, to see if attitudes, perceptions and values about wolves and wolf management have changed among wolf hunting and trapping license holders, deer and elk license holders, and the general public of Montana. While 5 years may be too soon to expect changes in things such as attitudes and values about wolves, the results of the 2011 survey may have been unduly influenced by the fluctuating political environment at the time, including several delisting and relisting episodes, so perhaps the results will be different now. Repeating the survey presently also fits with the termination of the 5-year post-delisting monitoring period by the FWS and is a way to again highlight the FWP commitment to incorporating human dimensions information into state-led management programs for wolves. During the 2011 survey, because of the overwhelmingly negative results regarding wolves and high public support for wolf harvest, there was criticism by some wolf conservation advocates about the survey methodology perhaps biasing the results. So some design features are being modified, to ensure the design and analysis are adequate and with a goal of publishing the results in a peer-reviewed scientific journal.

The survey instruments for this survey have been finalized, and are in the process of being mailed to the randomly sampled populations of Montanans. Survey responses will be analyzed during 2017, and a final report and manuscript for submission to a peer-reviewed scientific journal will be produced in 2018.

5. MINIMIZING AND MITIGATING WOLF/ LIVESTOCK CONFLICTS IN WASHINGTON

Investigators: Zoe Hanley and Robert Wielgus, Washington State University

Status: In progress

This project is led by Washington State University and aims to study wolf-cattle interactions and evaluate the effectiveness of different approaches to preventing wolf-livestock conflict in Washington. The project includes 2 MS students and 2 PhD students. Part of the study will make use of existing data on wolf populations and depredations in the northern Rockies (including Montana) in an attempt to make inferences regarding possible future trends and effective strategies in Washington, where there is also a field portion of the project being conducted. This project will use many types of FWP wolf-related data for this purpose, including wolf depredations from 1995-2014, wolf mortalities from 1995-2014, den site and rendezvous site locations from 1995-2014, and wolf territories from 1995-2014 (including telemetry locations).

6. LIVESTOCK GUARD DOG PROJECT, Update March 2017

Graduate Student: Daniel Kinka, Utah State University, (919) 995-1149, kinkadan@gmail.com
Principal Investigator: Julie Young, Ph.D., USDA APHIS/ Utah State University
Collaborators: Nathan Lance and Mike Ross, Montana Fish, Wildlife & Parks

Overview

In October 2016, USDA's National Wildlife Research Center, in collaboration with Utah State University, completed the fourth and final field season of a research study investigating the effectiveness of certain breeds of livestock guard dogs (LGDs) for reducing domestic sheep depredations. At the start of the project, in the spring of 2013, nine kangal-breed LGDs were placed with sheep producers in Montana through collaboration with Montana Fish, Wildlife and Parks and USDA's Wildlife Services (USDA-WS). In addition to the nine new LGDs, six extant LGDs already being used by participating producers were monitored. All the extant LGDs monitored in the project are mixed-breed or from unknown origin, so we collapsed them into a single mixed-breed category for analysis referred to as "whitedog." The dogs were divided into trios and each trio was assigned to a band of sheep. The project has expanded each year in numbers and geographic region. The project operates concurrently in Montana, Idaho, Oregon, Washington, and Wyoming (Figure 1). Throughout the five states and over the course of four years, the project has collected data from 160 individual LGDs from four breeds (kangal, karakachan, transmontano, and whitedog) through collaboration with 21 different livestock producers (Table 1).

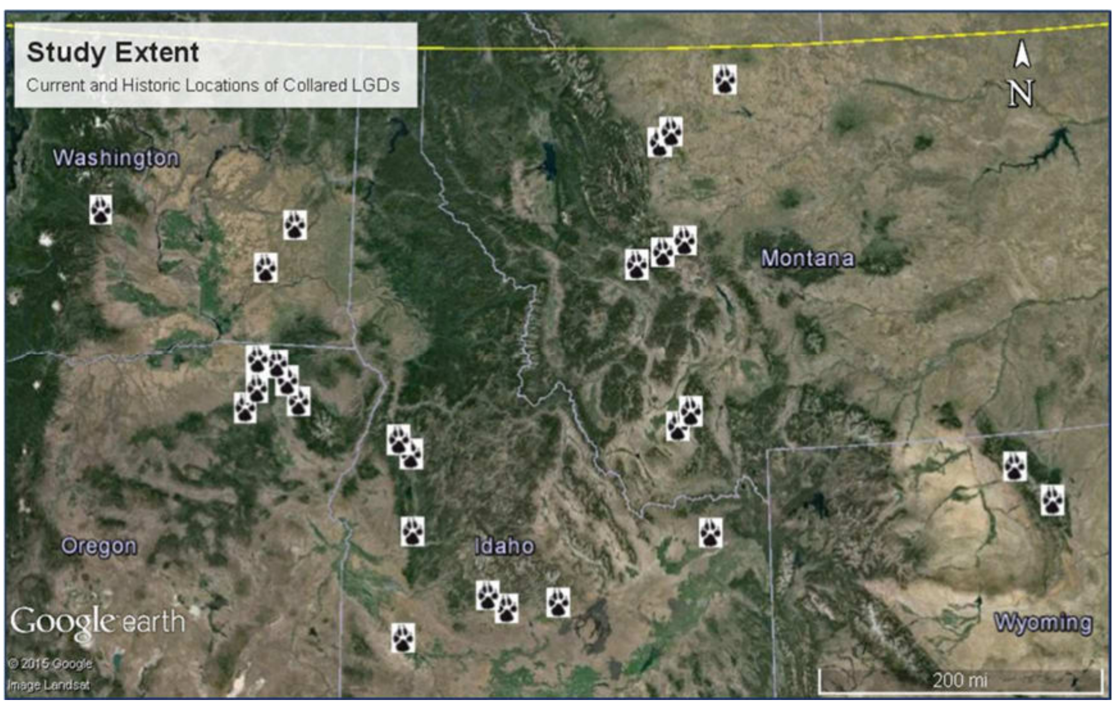

Figure 1. Paw prints indicate locations where LGDs have been studied for this project in any study year (2013-2016).

Table 1. Counts of producer, sheep bands, and collared kangals, karakachans, transmontanos and whitedogs by state and year. Note that totals do not necessarily represent individual producers, bands, or LGDs, but rather the sum of counts by year as a measure of sampling effort.

	Producers	Sheep Bands	Kangal	Karakachan	Transmontano	Whitedog
Montana						
2013	3	5	6	0	0	9
2014	5	6	6	3	0	9
2015	3	4	6	0	2	6
2016	4	5	7	0	1	6
Total	**15**	**20**	**25**	**3**	**3**	**30**
Idaho						
2014	3	5	6	3	0	6
2015	5	7	3	4	5	6
2016	4	4	2	1	5	5
Total	12	16	11	8	10	17
Oregon						
2014	3	6	6	3	0	9
2015	4	6	7	3	3	6
2016	5	5	4	3	2	2
Total	12	17	17	9	5	17
Washington						
2014	1	2	0	0	3	3
2015	3	4	2	3	3	3
2016	2	2	0	3	1	0
Total	6	8	2	6	7	6
Wyoming						
2015	2	2	4	3	0	3
2016	2	2	3	0	0	0
Total	4	4	7	3	0	3
TOTAL	49	65	62	29	25	73

While the majority of LGDs bond well with sheep and become socialized to the producers and herders with whom they are assigned, LGDs occasionally fail to become effective guardians. In these situations LGDs are generally transferred to other producers who may provide a better fit for a specific LGD, due to type of operation (i.e., pasture vs. open-range), temperament of other LGDs, or some other latent variable. LGDs that fail to bond in a different environment were removed from the study. In 2016, six LGDs were permanently removed from the study (two from Montana), generally due to a failure to bond with livestock.

Sheep Mortality

During the 2016 field season, we documented eight sheep depredations from wolves and 14 from grizzly bears. These mortality counts are considered minimums, as they only included mortalities that were found, investigated, and verified by project staff and/or USDA-WS specialists. We are currently working with producers and USDA-WS to merge our mortality records and season-end head counts. Once we have a complete record of sheep loss, we will perform a cause-specific mortality analysis of the data to determine if any breed of LGD increases sheep survival. Thus, the numbers presented here represent a preliminary summary.

LGD Behavior

In addition to sheep mortalities, the project also collects data on LGD behavior. To test how LGDs respond to potential threats on the landscape, we used a wolf (threatening) and a deer (non-threatening) decoy to document LGD responses. The proportion of time each breed spent in a specific behavior during the decoy tests showed some variation (Figure 2). Behavior was observed in each of four categories: activity, proximity (to sheep or decoy), vocalization, and posture. We utilized generalized linear mixed models with a binomial error distribution (GLMMs) to assess whether the proportion of time in any specific behavioral state varies as a function of breed or decoy. While simple preliminary analyses showed omnibus differences in LGD response by decoy type and breed, we have found no significant differences for vigilance, investigating, vocalization, or proximity to sheep as a function of either breed or decoy using GLMMs.

In addition, we developed Cox Proportional-Hazard (CPH) models of time-to-approach and time-to-leave the decoy, to see if breed differences exist. No significant differences exist between breeds either in time-to-approach or time-to-leave the decoy, although trends do appear to exist (Figure 3). Behavioral analyses are ongoing, but preliminary results suggest that LGD behavior do not significantly vary between breeds.

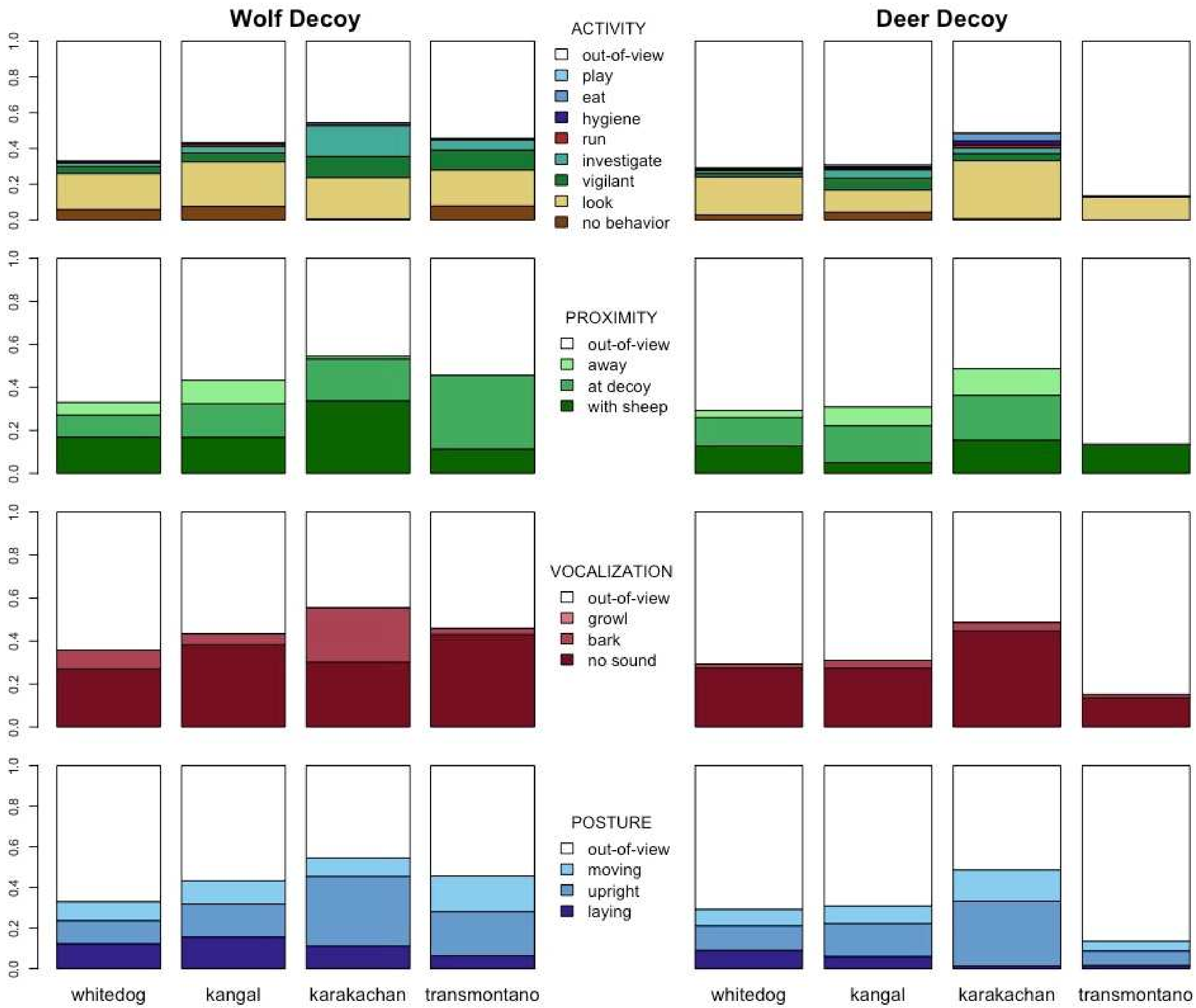

Figure 2. Proportion of time spent in each behavioral state, averaged across 214 tests of 84 individual LGDs. The four behavioral categories (activity, proximity, vocalization, posture) are shown by row. Decoy type (wolf, deer) is shown in the two major columns. Proportion of behavior is collapsed by breed (whitedog, kangal, karakachan, transmontano) and shown by sub column.

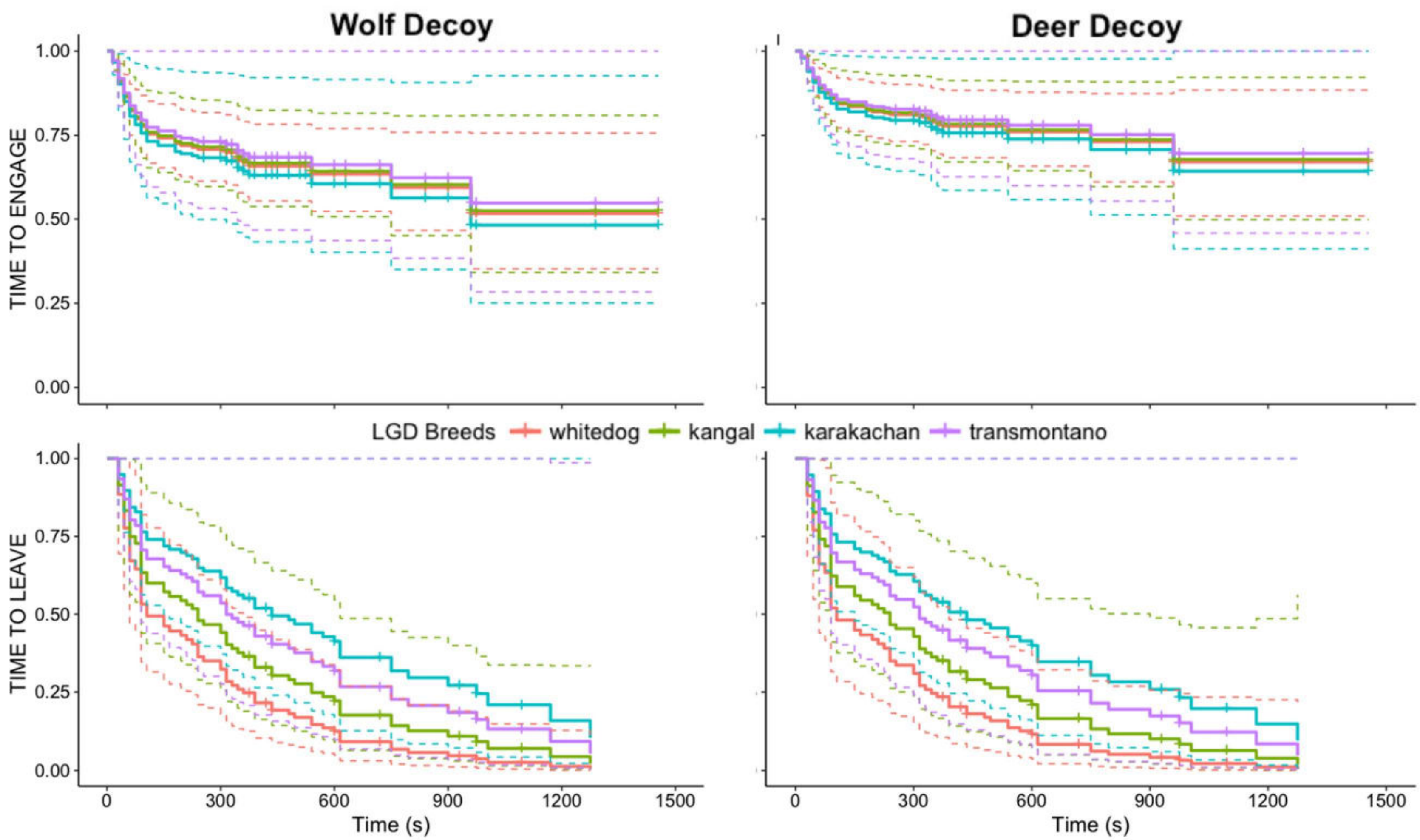

Figure 3. Cox proportional hazard for time-to-engage and time-to-leave decoy. The first row shows time-to-engage with the decoy (n=205). The second row shows time-to-leave the decoy (n=64). Decoy type (wolf, deer) is shown by column. In all graphs, the y-axis (0-1) indicates proportion of dogs not engaged in the behavior of interest. Solid lines represent data collapsed across breed. Hashed lines represent 95% confidence intervals.

Occupancy

Occupancy of large carnivores were detected through the use of remote trail cameras. In addition to verifying the presence of predators near monitored sheep bands, these photos allow us to draw inference on how LGDs and sheep influence the space-use of large carnivores.
Utilizing a BACI design, we intend to calculate how carnivore occupancy varies as a function of sheep presence while sheep move through public lands, as well as the probability that sheep and carnivores co-occur at any point during the grazing season (Figure 4).

Processing of all photo data is complete, but models of occupancy utilizing a BACI design have yet to be run. However, model-averaged species interaction factors (SIF) for (1) wolves and sheep and (2) grizzly bears and sheep were calculated using two species conditional occupancy models. These occupancy models suggest a possible increased likelihood of co-occurrence for wolves near LGDs and sheep, but results are not conclusive (ϕ=1.45, 95% CI= 0.90–2.01). There is also a possible increased likelihood of co-occurrence for grizzly bears near LGDs and sheep, but results are not conclusive (ϕ=1.24, 95% CI= 0.78–1.69).

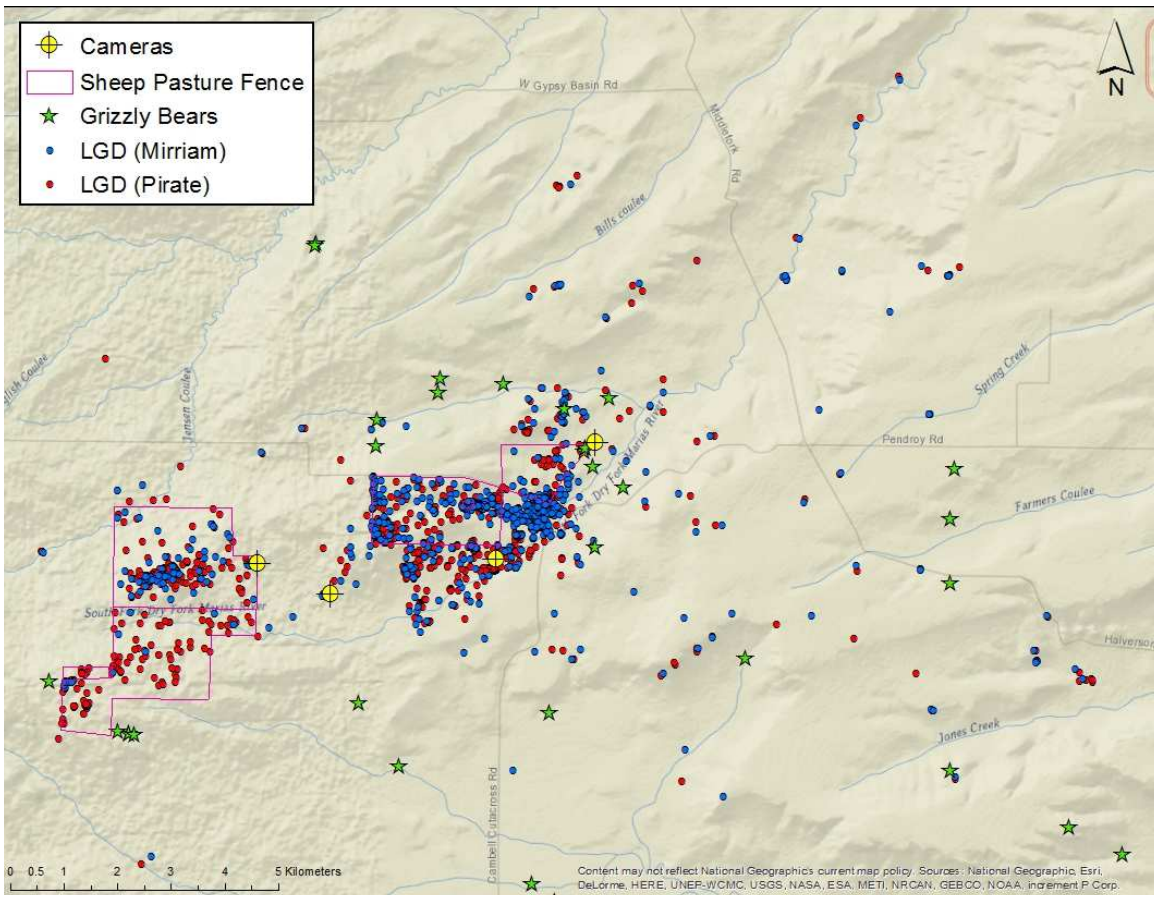

Figure 4. Location of LGDs (GPS collars), grizzly bears (courtesy Montana FWP), remote cameras, and sheep pastures near Pendroy, MT from 1 June – 30 September 2016. Sheep were rotated between pastures throughout the season. Note that this figure is presented here only as an example. Analyses are based on data collected across all five states and from 2014 – 2016.

Human Attitudes Survey

The project is conducting an ongoing survey of attitudes toward LGDs and large carnivores directed toward those involved in the livestock industry. Hard copies of the survey are available in both English and Spanish. We are using a snowball sampling method to disseminate this survey. The survey comes with a prepaid return envelope and responses are kept strictly anonymous. Currently too few surveys have been returned to present preliminary findings.

Preliminary Conclusions

Preliminary analysis suggests that, on average, LGD breeds do not exhibit significantly different behavioral patterns in response to threatening stimuli. However, more analysis is needed to determine if certain behavioral trends may be significant and to determine if sheep survival varies as a function of LGD breed. Even if sheep survival does not significantly differ as a function of breed, detailed behavioral data may allow managers to make tailored recommendations as to which LGD breed is likely to benefit a producer the most. For instance, while overall loss-reduction may be similar for all tested breeds of LGD, certain breeds may be more likely to keep a large perimeter, or work better inside a fenced pasture.

In addition, modeling the effect of sheep presence on carnivore occupancy has never been examined and will help managers and producers better understand how LGDs work and what effect they have on wildlife. Lastly, surveying how human attitudes toward LGDs affects tolerance for large carnivores may add credence to the use of LGDs, not just as a management tool but as a conservation tool as well.

Final results will be submitted for publication throughout 2017. As final results become available they will also be communicated directly to wildlife managers and sheep producers.

Improving Estimation of Wolf Recruitment and Abundance, and Development of an Adaptive Harvest Management Program for Wolves in Montana

Federal Aid in Wildlife Restoration Grant W-161-R-1

Annual interim report, March 2017

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State: Montana
Agency: Fish, Wildlife & Parks
Grant: Montana wolf monitoring study
Grant number: W-161-R-1
Time period: January 1, 2016–December 31, 2016

INTRODUCTION

Wolves (*Canis lupus*) were reintroduced in the northern Rocky Mountains (NRM) in 1995, and after rapid population growth were delisted from the endangered species list in 2011. Since that time, states in the NRM have agreed to maintain populations and breeding pairs (a male and female wolf with 2 surviving pups by December 31; USFWS 1994) above established minimums (≥150 wolves and ≥15 breeding pairs within each state). Montana estimates population size every year using patch occupancy models (POM; MacKenzie et al. 2002, Rich et al. 2013, Miller et al. 2013, Bradley et al. 2015), however, these estimates are sensitive to pack size and territory size, and were developed pre-harvest. Reliability of future estimates based on POM will be contingent on accurate information on territory size, overlap, and pack size, which are expected to be strongly affected by harvest. Additionally, breeding pairs, which has proven to be an ineffective measure of recruitment, are determined via direct counts. Federal funding for wolf monitoring has ended in states where wolves are delisted, and future monitoring will not be able to rely on intensive counts of the wolf population. Furthermore, monitoring has become cumbersome and less effective since the population has grown. With the implementation of harvest, it is pertinent to predict the effects of harvest on the wolf population and continue to monitor to determine effectiveness of management actions to make informed decisions regarding hunting and trapping seasons.

STUDY OBJECTIVES

Our 4 study objectives are to:

1. Improve estimation of recruitment.
2. Improve and maintain calibration of wolf abundance estimates generated through POM.
3. Develop a framework for dynamic, adaptive harvest management based on achievement of objectives 1 & 2.
4. Design a targeted monitoring program to provide information needed for robust estimates and reduce uncertainty in the AHM paradigm over time.

Two PhD students are addressing the 4 study objectives as part of Project 1 (Sarah Sells) and Project 2 (Allison Keever; Fig. 1).

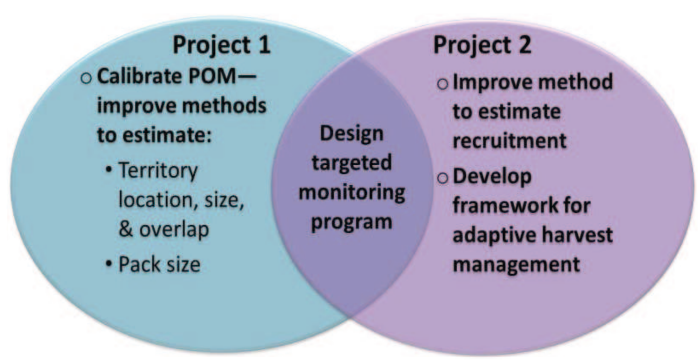

Fig. 1. Objectives for this project are being addressed under 2 separate projects.

DELIVERABLES

1. A method to estimate recruitment for Montana's wolf population that is more cost effective and biologically sound than the breeding pair metric.

2. Models to estimate territory size and pack size that can keep POM estimates calibrated to changing environmental and management conditions for wolves in Montana.

3. An adaptive harvest management model that allows the formal assessment of various harvest regimes and reduces uncertainty over time to facilitate adaptive management of wolves.

4. A recommended monitoring program for wolves to maintain calibration of POM estimates, determine effectiveness of management actions, and facilitate learning in an adaptive framework.

LOCATION

This study encompasses wolf distribution in Montana and Idaho (Fig. 2). Additional data will come from Yellowstone National Park for the territory models developed under objective 2.

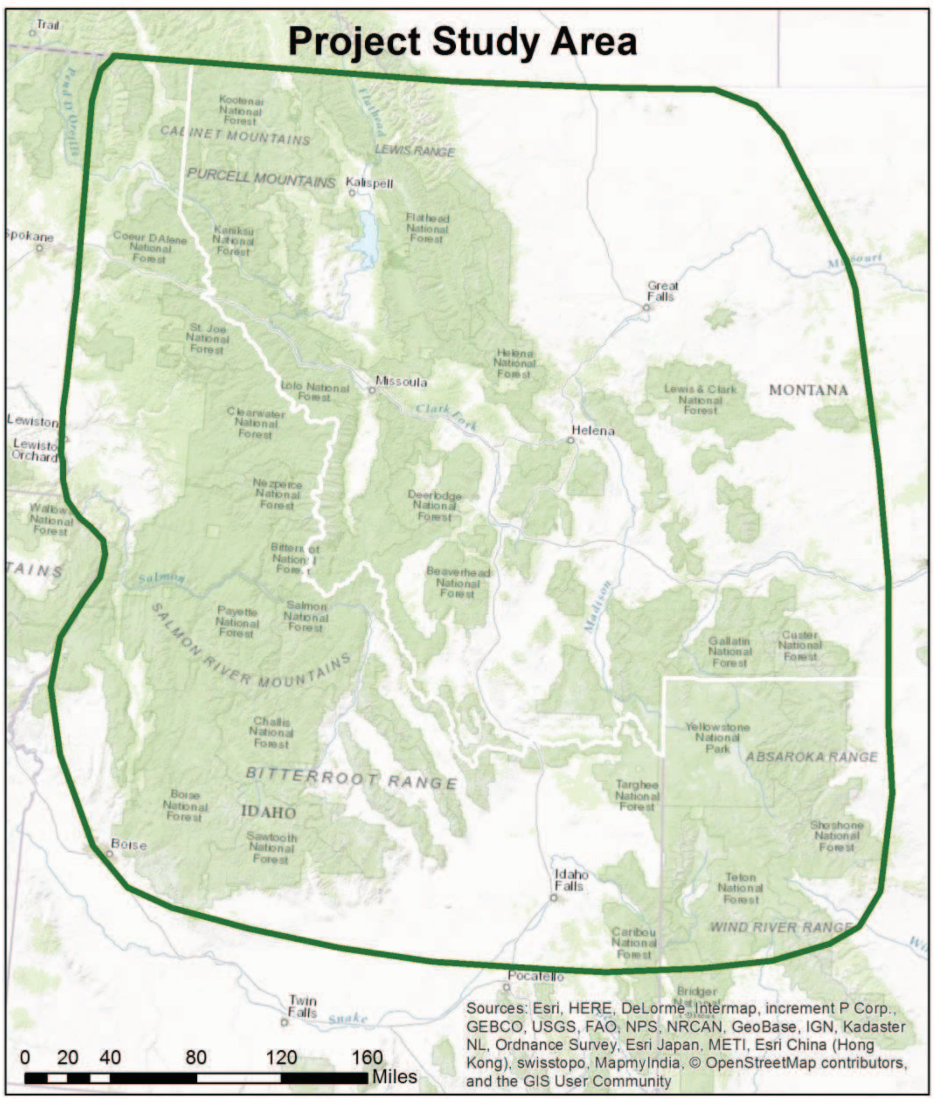

Fig. 2. The project study area includes wolf distribution in Montana and Idaho, as well as Yellowstone.

GENERAL PROGRESS

The 2 PhD students started their programs in January 2015 (Fig. 3). Much of year 1 was devoted to literature reviews on animal behavior, carnivores, modeling, optimal foraging, etc. and determining approaches for the dissertations. The students also formed and held multiple meetings with their committees, worked on completing coursework requirements, and finalized research statements. Additional efforts focused on communicating with wolf specialists, identifying target packs for collaring, managing collar orders and data, and helping coordinate contracts and capture plans for winter aerial captures for January and February 2016. The students also met with wolf specialists in the field to learn more about the wolves in each region, and coordinated and held meetings with the specialists to plan future project efforts.

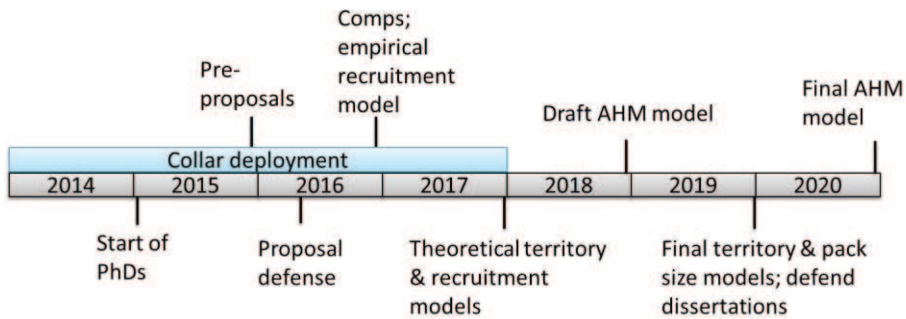

Fig. 3. Project timeline.

Most activities from year 1 continued through year 2, including conducting literature searches, taking classes, holding committee meetings, communicating with wolf specialists, managing collar orders, managing data, etc. The students joined MFWP wolf specialists to assist with a month of trapping.

The students also focused on meeting University requirements and deadlines. The students each successfully completed and defended dissertation proposals. The students have also completed comprehensive exams (S. Sells) or are taking them in spring 2017 (A. Keever).

Project deliverables in years 2017–2020 will include an empirical recruitment model; theoretical territory, group size, and recruitment models; draft and final AHM models; and final territory and pack size models. The students have been working on the empirical recruitment model and the theoretical territory model deliverables towards meeting objectives 1 and 2. Updates are provided below on these objectives. (Additional details on objectives 3 and 4 are available in the 2016 report.)

DATA COLLECTION SUMMARY

Trapping efforts have continued since 2014:

- There have been 51 successful captures directly related to this project through 2016.

- Collars were deployed in approximately 41 packs (this number is fluid as wolves disperse).
- Using ground and aerial captures:
    - 10 collars were deployed in 2014.
    - 14 collars were deployed in 2015.
    - 27 collars were deployed in 2016.
- These collars have yielded >20,000 locations of wolves (Fig. 4).
- Despite collar removals, harvests, other mortalities, and some collar losses, 24 collars remained deployed at the end of 2016.

Collaring efforts will continue via ground and aerial captures through 2017.

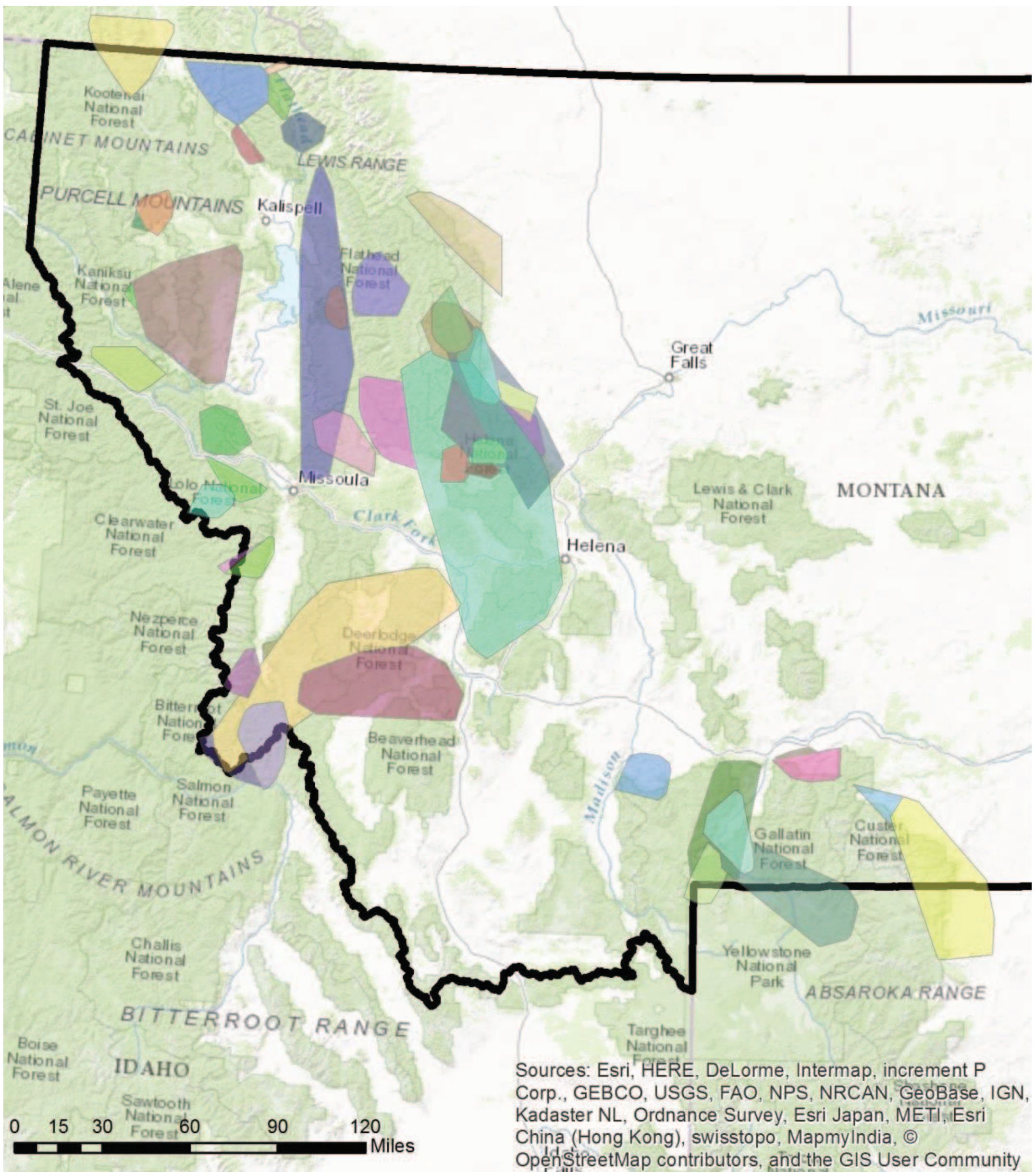

Fig. 4. Locations of wolves collared for this project, 2014–2016. Colors represent different wolves. Note that some polygons include dispersal from original pack's territory.

PROGRESS ON OBJECTIVES

Objective 1: *Improve estimation of recruitment.*

1.1 Background

Estimating recruitment (i.e., number of young produced that survive to an age at which they contribute to the population) of wolves can be difficult due to their complex social structure. Wolves are cooperative breeders, and pack dynamics (e.g., pack tenure, breeder turnover, and number of non-breeding helpers) can affect recruitment and pup survival (e.g., Ausband et al. 2015). Cooperative breeding often relies on the presence of non-breeding individuals that help raise offspring (Solomon and French 1997), and reduction in group size can lead to decreased recruitment in cooperative breeders (Sparkman et al. 2011, Stahler et al. 2013). Human-caused mortality through both direct and indirect means (Ausband et al. 2015) and prey biomass per wolf (Boertje and Stephenson 1992) have been shown to affect recruitment. As a result, it will be important to consider the effects of harvest, pack dynamics, wolf density, and prey availability on recruitment.

Further challenges of estimating recruitment include the size of the wolf population and limited time and funding for monitoring. Currently, MFWP documents recruitment through visual counts of breeding pairs (a male and female wolf with 2 surviving pups by December 31; U.S. Fish and Wildlife Service 1994). These counts, however, are likely incomplete due to the large number of wolves in the population. Federal funding for wolf monitoring in Montana and Idaho is no longer available. States therefore fund their own monitoring programs, and future monitoring will not be able to rely on intensive counts. A breeding pair estimator (Mitchell et al. 2008) could be used to estimate breeding pairs, but this requires knowing pack size; such data are hard to collect given the size of the wolf population. Additionally, the breeding pair metric is an ineffective measure of recruitment because it provides little insight into population growth rate or the level of harvest that could be sustained. Recruitment could be estimated by comparing visual counts at the den site to winter counts via aerial telemetry (Mech et al. 1998) or by marking pups at den sites (Mills et al. 2008). An alternative method could include non-invasive genetic sampling (Ausband et al. 2015) at predicted rendezvous sites (Ausband et al. 2010). These methods, however, may not be feasible on large scales due to budget and staff constraints. Existing monitoring efforts yield insufficient data to estimate recruitment using traditional methods; therefore a new approach is needed that does not rely on extensive data.

1.2 Goals and General Approach

Our objective is to develop an approach to estimate recruitment that is more tractable, cost effective, and biologically credible than the breeding pair metric. Integrated population models can be a useful tool for demographic analyses from limited data sets, and can increase precision in estimates (Besbeas et al. 2002). We will develop a per capita integrated population model (hereafter IPM) to estimate recruitment and evaluate the relationship between recruitment and factors that may cause spatial and temporal variation in wolf recruitment using collar, count and hunter survey data from 2007–2016 in Montana. A generalized linear model can then be used to evaluate variation in recruitment across time and space.

The resulting statistical model will relate covariates and recruitment. It will not, however, improve understanding of the mechanisms that cause recruitment to change. Recruitment depends on a pack's success in breeding and giving birth, as well as litter size and pup survival. Whether a pack successfully breeds and gives birth or not is primarily determined by the survival of the breeding pair in the pack. Conversely, pup survival may be affected by helper presence, prey availability, disease outbreaks, and human-caused mortality (Goyal et al. 1986, Boertje and Stephenson 1992, Johnson et al. 1994, Mech and Goyal 1995, Fuller et al. 2003, Ausband et al. 2015). Unfortunately, there are few data to estimate the contribution of those factors to overall pup recruitment, so we will also develop a mechanistic model of recruitment to theoretically explore the effects of human-caused mortality, prey availability, multiple litters per pack, disease outbreaks, and group size on the different components of recruitment. The probability a pack successfully breeds and reproduces, litter size per pack, and pup survival all determine pup recruitment. Hypotheses about how factors such as disease, harvest, or prey availability affect these parameters can be explored using liner or non-linear models and then multiplied together. Different models can be developed that represent different hypotheses. Those different hypotheses will result in different predictions of recruitment if those hypotheses were correct. The model predictions can be compared to estimated recruitment from the IPM to determine which hypotheses have most support.

1.3 Progress

<u>*Overview:*</u>

We are currently developing the IPM model to estimate recruitment in program R (R Core Team 2014) in a Bayesian framework using package R2jags (Su and Yajima 2015) to communicate with JAGS (Plummer 2003). The model includes a series of sub-models, including a 1) population, 2) group count, 3) survival, and 4) occupancy model (Fig. 5). We are currently simulating data to test the accuracy of the IPM. Once we simulate data we will evaluate how many data (collar and group count data) are needed to maintain reliable estimates of recruitment. Then, we will use hunter survey, group count, and collar data to estimate recruitment across the state of Montana. So far, we have the population and group count models and are fixing occupancy and survival to test a simpler version of the model. The population and group count models are specified as follows:

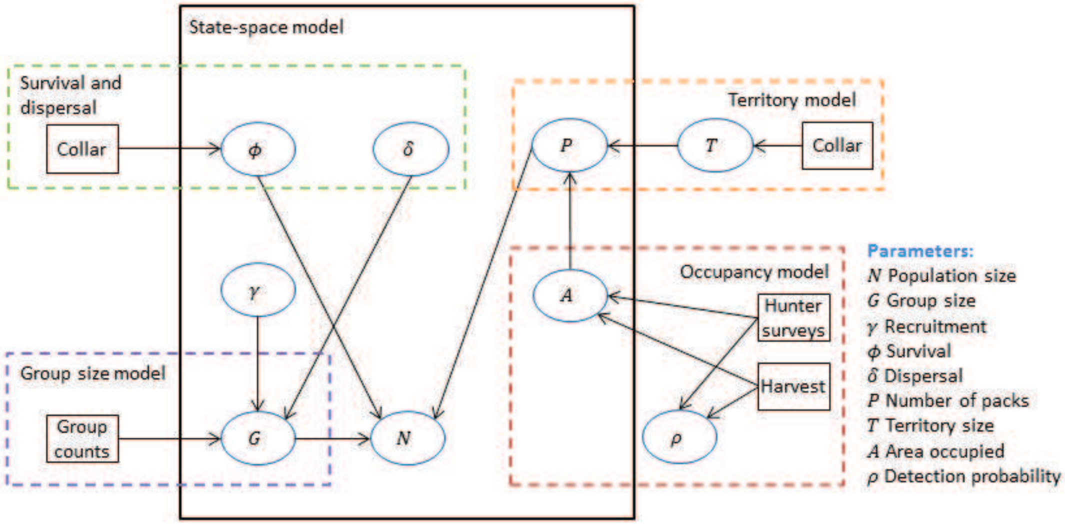

Fig. 5. Directed acyclic graph of a per capita integrated population model for wolves. The boxes represent data sources and the circles represent parameters.

a) Population level model.

We first linked changes in population size to demographic rates. Population size is estimated using the number of packs (P) estimated from POM and mean group size ($\overline{G}$) which is estimated from group counts. The population level model is then

$$P_{k+1,r}\overline{G}_{k+1,r} = P_{kr}\overline{G}_{kr}\phi_{kr}(1+\omega-\varepsilon) + P_{kr}\overline{\gamma}_{kr}$$

where ϕ_{kr} is survival probability that is estimated using collar data, ω is immigration rate into the population as establishment of new packs (i.e., colonization rate), ε is emigration rate as packs leaving the population (i.e., extinction rate), and $\overline{\gamma}_{kr}$ is mean recruitment per pack for year k in region r.

b) Group count model.

We used group count data to estimate mean group size ($\overline{G}$) and mean recruitment per pack ($\overline{\gamma}$). Here, we assume recruitment to be the number of pups produced and that survive 1 year. The group model is

$$G_{k+1,ri} = G_{kri}\phi_{kri}(1+\alpha-\delta) + \gamma_{kri} + \sigma_{kr}$$

where α is immigration rate into a pack, δ is emigration rate from a pack, γ_{kri} is number of pups recruited per pack, and σ_{kr} is process error by year and region.

<u>*Preliminary results:*</u>

With simulated data we know "truth," and can compare our estimates to truth. When we ran the simple model with occupancy and survival fixed, we found that our estimates of mean group size were very accurate (Fig. 6), and our estimates for total population size and recruitment were also accurate using only group count data from 50 packs.

Summary and Next Steps:

In the future we will add the occupancy and survival models and the collar and hunter survey data. We will evaluate the accuracy and precision of these models using different amounts of data (e.g., number of groups with counts or number of collars) to determine the level of precision that corresponds with different amounts of data.

After we explore the model, we will use data from Montana to estimate recruitment across the state and evaluate the factors that cause spatial and temporal variation in recruitment. Then, we will test the model using field-based recruitment data collected in Idaho.

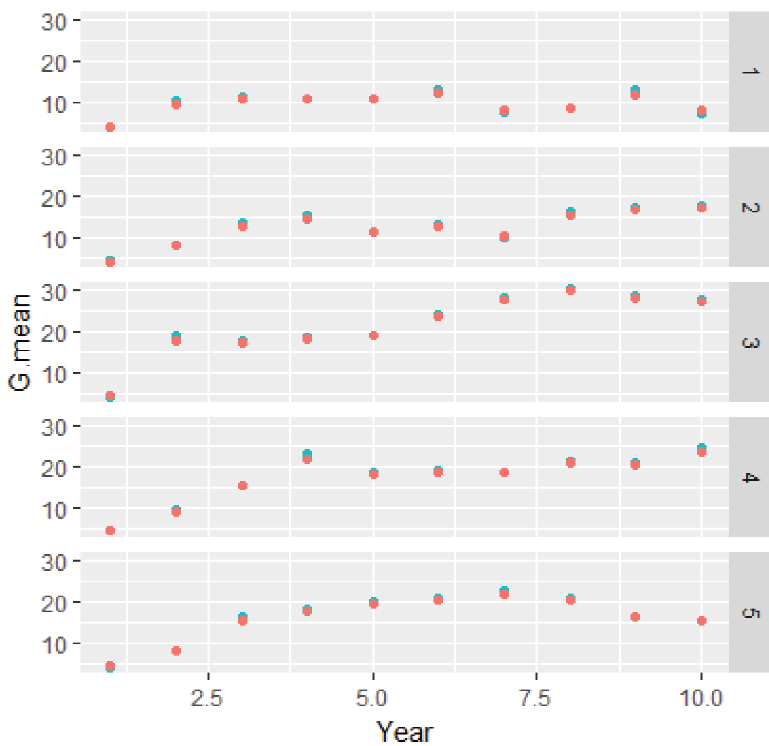

Fig. 6. Estimates (red circles) and truth (blue circles) of mean group size for wolves in Montana in 5 different regions across 10 years. In this analysis, truth was simulated.

Objective 2: ***Improve and maintain calibration of wolf abundance estimates generated through POM.***

2.1 Background

Monitoring is a critical, yet challenging, management tool for gray wolves. Since delisting of wolves in 2011, monitoring results help MFWP set management objectives and communicate with stakeholders and the public. Monitoring any large carnivore is challenging, however, due to their elusive nature and naturally low densities (Boitani et al. 2012). This is particularly true for wolves due to increasing populations, decreasing funding for monitoring, and changing behavioral dynamics with harvest.

Abundance estimates are a key component of monitoring (Bradley et al. 2015). Abundance is currently estimated in Montana with 3 parameters: area occupied, average territory size, and annual average pack size (Fig. 7, Bradley et al. 2015). Area occupied is estimated with a Patch Occupancy Model (POM) based on hunter observations and field surveys (Miller et al. 2013, Bradley et al. 2015). Average territory size is assumed to be 600 km^2 with minimal overlap, based on past work (Rich et al. 2012). Annual average pack size is estimated from monitoring results. Total abundance (N) is then calculated as: N = (area occupied/$\bar{x}$ territory size) × $\bar{x}$ pack.

Whereas estimates of area occupied from POM are expected to be reliable (Miller et al. 2013, Bradley et al. 2015), reliability of abundance estimates hinge on key assumptions about territory size, territory overlap, and pack size (Bradley et al. 2015). Assumptions of fixed territory size and minimal overlap are simplistic; in reality, territories vary spatiotemporally (Uboni et al. 2015). This variability is likely even greater under harvest (Brainerd et al. 2008). Meanwhile, pack size estimates assume all packs are located and accurately counted each year, which is no longer possible due to the number of packs and declining funding for monitoring (Bradley et al. 2015). Since implementation of harvest in 2009, several factors have further compounded these challenges and decreased accuracy of pack size estimates. First, whereas larger packs are generally easier to find and monitor, average pack size has decreased since harvest began (Bradley et al. 2015). Difficult-to-detect smaller packs may be more likely to be missed altogether, biasing estimates of average pack size high. Conversely, incomplete pack counts, especially for larger packs, could bias estimates of average pack size low. Harvest and depredation removals also affect social and dispersal behavior (Adams et al. 2008, Brainerd et al. 2008, Ausband 2015). Additionally, pack turnover is now greater than in populations with less human-caused mortality.

Development of reliable methods to estimate territory size, territory overlap, and pack size is critical for accurate estimates of abundance. One means for developing models to estimate territories and pack sizes is an empirical modeling approach. This approach generally involves measuring and attempting to discern patterns in territory and pack size dynamics (e.g., Rich et al. 2012). Empirical models do not, however, provide an understanding of causal mechanisms, i.e., the underlying processes that shape the system and patterns we observe, such as processes driving decisions carnivores make about where to settle and whether to stay in or leave a social group. Ignoring causal mechanisms may yield models that do not suitably predict conditions beyond the spatiotemporal scale for which they were developed (Mitchell and Powell 2002). Empirical models may also require extensive continued monitoring and data collection to provide sufficient data for predictions.

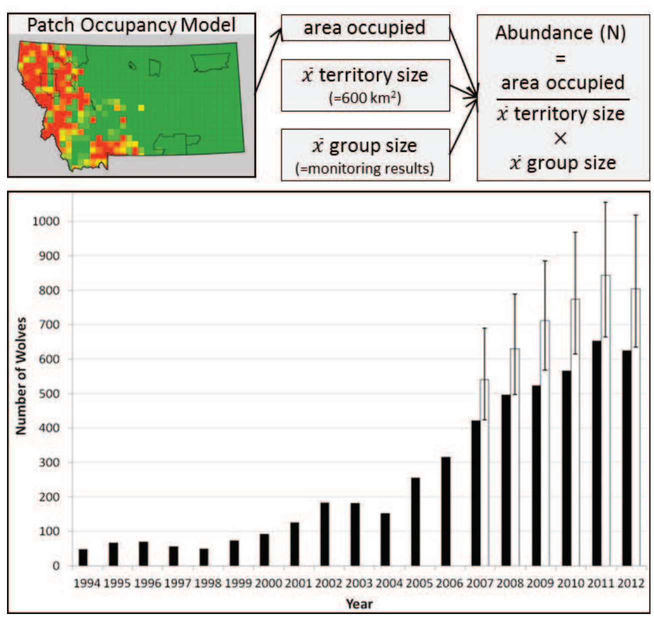

Fig. 7. Example of POM results (red indicates highest occupancy probability, green lowest), and methods for calculating abundance. Graphed abundance since 1994 is based on minimum counts (black bars) and POM-based estimates (white bars). (Adapted from Bradley et al. 2015.)

An alternative method to empirical modeling is a mechanistic modeling approach. Such an approach involves developing theoretical models that capture the hypothesized causal mechanisms structuring the system (Mitchell & Powell 2004, 2012). Predictions from these models can be compared to actual behaviors of animals to identify the model(s) with most support (Mitchell & Powell 2002, 2004, 2007, 2012). Resulting mechanistic models are based on the likely causal mechanisms that shape the system, and thus yield reliable scientific inference and are predictive at any spatiotemporal scale. Importantly, abundant data are not required for predictions.

2.2 Goals and General Approach

Our goal is to develop tools to estimate territory and group size of wolves to calibrate estimates of abundance of wolves in the Northern Rocky Mountains (NRM). To achieve this goal, our steps will be to:

1. **Develop a suite of mechanistic territory models.** These models will capture the potential causal mechanisms we hypothesize structure territories of wolves. We will run simulations to provide general predictions of territorial behavior under each model.
2. **Identify the most predictive territory model for wolves in Montana and Idaho.** We will parameterize the models from Step 1 with data for Montana and Idaho, and use the models to generate specific predictions of territorial behavior under each model. We will then compare these predictions to actual locations of GPS-collared wolves in Montana and Idaho. We will identify the best model as the one that most closely predicts real territorial behavior.
3. **Develop a suite of mechanistic group size models.** These models will capture the potential causal mechanisms we hypothesize structure social behavior of wolves. We will run simulations to provide general predictions of social behavior under each model.
4. **Identify the most predictive group size model for wolves in Montana and Idaho.** We will parameterize the models from Step 3 with data for Montana and Idaho, and use the models to generate specific predictions of social behavior under each model. We will compare these predictions to actual group sizes of wolves in Montana and Idaho as identified through monitoring data. We will identify the best model as the one that most closely predicts actual group sizes.
5. **Calibrate estimates of abundance.** We will use the best models for territory and group size alongside POM to calibrate estimates of abundance of wolves in the NRM.

2.3 Progress

Overview:

We are currently working on Step 1. There are 3 primary components under this step:

a) Develop a suite of mechanistic territory models.

We are designing the models based on theory of carnivore behavior. For example, theory states that carnivores are likely adapted to choose economic territories that maximize benefits of prey against costs such as travel, defense, competition, and predation (Darwin 1859, Brown 1964, Brown and Orians 1970, Emlen and Oring 1977, Krebs and Kacelnik 1991, Adams 2001). Like other carnivores, we also expect that wolves are adapted to defend the smallest territory possible that meets a threshold for survival and reproduction (Mitchell and Powell 2004, 2007, 2012). Each model will capture different ways we hypothesize wolves structure territories based on benefits and costs.

b) Run simulations of the models.

We are using the program NetLogo (Wilensky 1999) to conduct our simulations. In the simulations, the landscape is represented as a continuous grid of patches on which a pack forms a territory (e.g., Fig. 8). Each patch is associated with various benefits of prey, and the pack selects patches based on these benefits while considering costs associated with owning each patch as defined by the model (e.g., costs involving travel, defense, competition with neighboring packs, risk of predation by humans, etc.). The pack must also consider any constraints when forming the territory, such as rugged terrain. In each simulation, packs acquire patches for territories as economically as possible by trying to maximize benefits while minimizing costs. Each pack continues to build a territory until it acquires enough resources for survival and reproduction.

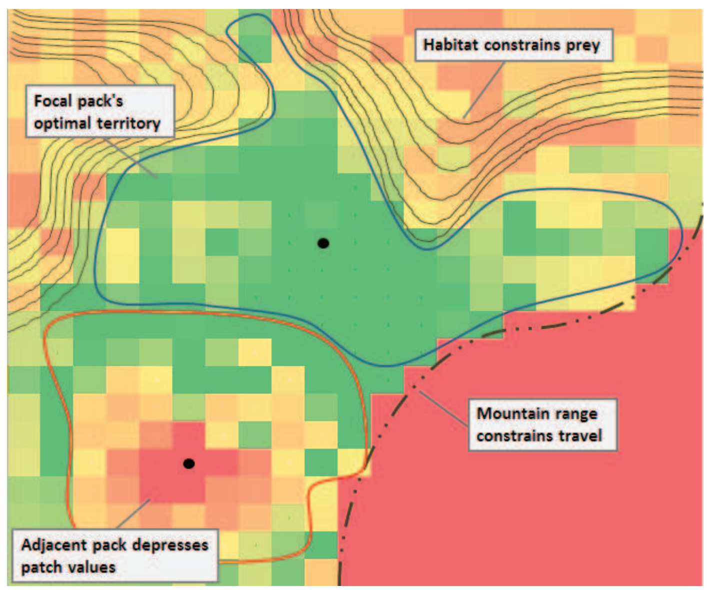

Fig. 8. Example of a simulated landscape. Colors indicate patch value (green = high, red = low), which account for benefits of prey and potential costs of ownership. Here, prey are constrained by topography to valley bottoms in winter. A mountain range negates values beyond it, and neighbors (red outline) depress patch value most heavily in the center of that territory. The blue outline represents the focal pack's optimal territory considering these benefits and costs.

c) Summarize results and make general predictions of territorial behavior that should be observed under each model.

We are developing general predictions of wolf territories under each model. If that model successfully captures wolf behavior then our predictions should be observed in real territories. We are using the program R (R Core Team 2014) to summarize results.

Example Model and Results—Territories Based on Benefits of Prey and Costs of Travel:

Model Explanation: Black bears (*Ursus americanus*) have been shown to structure their home ranges economically based on benefit of food resources and costs of travel (Mitchell and Powell 2012). Therefore, we constructed a model hypothesizing that wolves select territories based on benefits of prey and costs of travel (Fig. 9). We also wanted to evaluate how various prey distributions may affect territorial behavior in this model, so we simulated prey distribution as ranging from random to highly clumped in various landscapes (Fig. 10).

Analyses: We ran 1,200 simulations. In a single iteration, a pack forms a territory on one of these landscapes (e.g., Fig. 11). The pack stops forming its territory once it has met a threshold of resources needed for survival and reproduction (see Fig. 9). We fixed this threshold at 3 different settings to assess the effects of various thresholds. We ran 100 iterations for each of the 4 landscapes and 3 thresholds. We summarized results through various measurements, including A) total territory size (# of patches); B) travel patches (# of patches added as travel corridors to high-value patches); C) territory contiguity (proportion of the territory that was non-travel

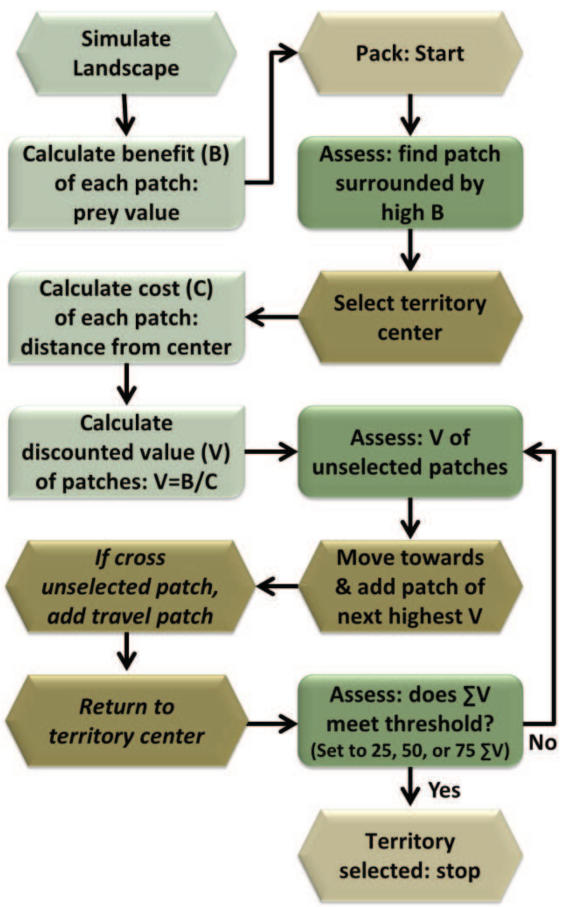

Fig. 9. Structure of territory simulations in the model based on prey and travel costs. A pack selects a territory economically by seeking patches that maximize benefits and minimize costs. It stops once it has met a simulated threshold for survival and reproduction.

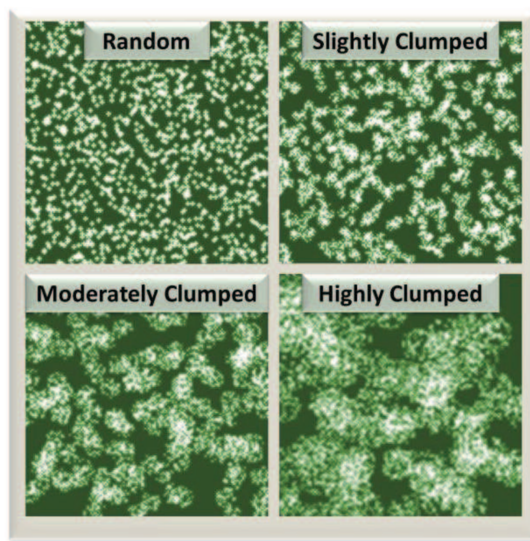

Fig. 10. Example simulated landscapes where prey distribution ranges from random to highly clumped. Lighter areas indicate patches of greater prey benefits. All landscapes have equal total benefits available and are 150x150 patches in size.

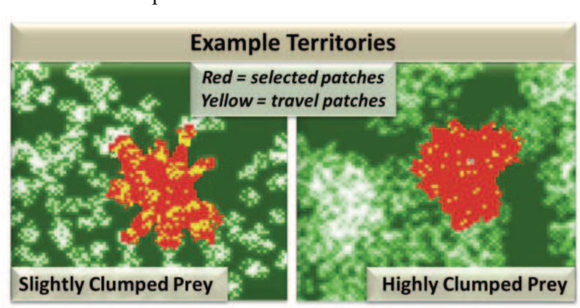

Fig. 11. Example results of 2 iterations showing how packs structured territories on 2 different landscapes.

patches); and D) territory efficiency (amount by which the mean benefits of prey within the territory exceeded the mean benefits of prey available on the landscape). We calculated these results by mean values for each landscape type and threshold level.

Preliminary results: Preliminary results suggest that if wolves structure territories based on benefit of prey and costs of travel, we would see several characteristics that vary according to prey distributions (Fig. 12). Prey distribution would affect territory size: as prey become more clumped, territory size decreases. Travel corridors within the territory also decrease as prey become more clumped, which leads to increased territory contiguity. Additionally, when prey are more clumped the efficiency of territories is higher, meaning that packs are able to select territories that better exceed the mean benefits available on the landscape.

From these results, we may expect territory size to differ regionally and seasonally. For example, wolf territories may be smaller in areas with clumped elk herds compared to areas with more dispersed deer populations. Territory size may also decrease and shift in winter when ungulates are more highly clumped. Seasonal change in territory size will be explored more thoroughly in subsequent models. Ungulate behavior and distribution will thus affect territorial behavior of wolves. Further analyses are ongoing.

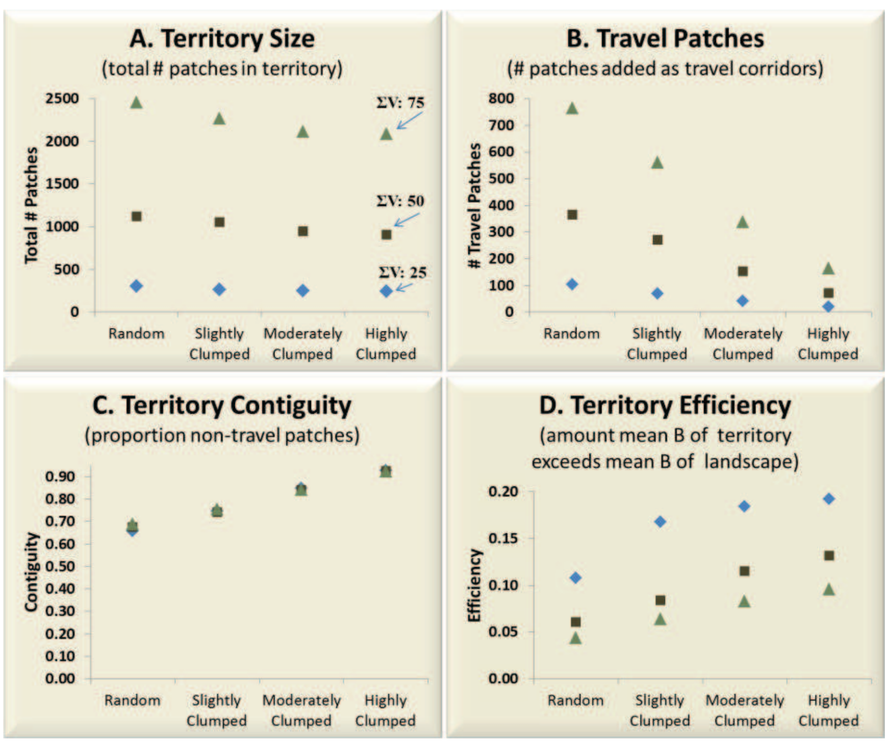

Fig. 12. Preliminary results from a model based on benefits of prey and costs of travel. We summarized results as A) total territory size (# of patches); B) travel patches (# of patches added as travel corridors to high-value patches); C) territory contiguity (proportion of the territory that was non-travel patches); and D) territory efficiency (amount by which the mean benefits of prey within the territory exceeded the mean benefits of prey available on the landscape). Results are summarized for each prey distribution (x-axis) and threshold level (i.e., total resources required for survival and reproduction, as indicated by symbols in A). Territory size decreases as prey distribution becomes more clumped, as do number of travel patches. This leads to increased contiguity. Efficiency is also greater when prey are more clumped. Effects are more pronounced at higher thresholds of resources.

Summary and Next Steps:

Our work to date provides a foundation from which we are building more complex models of territorial behavior. We are continuing to build the suite of territory models by adding levels of complexity and realism. For example, next we will investigate:

- How do other distributions, numbers, and behaviors of prey affect territories?
- How might costs of defense affect territorial behavior?
- How would costs of competition affect territorial behavior?
- How would risk of predation by humans (e.g., through harvest) affect territorial behavior?

Each model will provide general predictions of territorial behavior. In Step 2, we will parameterize the models with real data and generate specific predictions of territorial behavior for wolves in Montana and Idaho. We will then compare these predictions to territories of GPS-collared wolves to identify the most accurate model that predicts real wolf behavior. We will use similar approaches to develop group size models for Steps 3 & 4, as well. Alongside POM, in Step 5 these models will help accurately estimate abundance of wolves through biologically based, spatially explicit predictions for territory size, location, and overlap and group size.

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APPENDIX 4

MONTANA WOLF PACK TABLE

Table A1. Wolf Packs and Population Data for Montana. 2016.

Table A4-1. Montana Wolf Packs and Population Data, 2016.

REF		FWP	RECOV	MIN. ESTIMATED			DOCUMENTED MORTALITIES					KNOWN		CONFIRMED LOSSES[7]			
#	WOLF PACK[1]	Region	AREA	PACK SIZE DEC 2016	Breeding Pair	Count Quality	NATURAL	HUMAN[2]	UNKN[3]	HARVEST[4]	CONTROL[5]	DISPERSED	MISSING[6]	CATTLE	SHEEP	DOGS	OTHER
1	Akokala	1	NWMT	5	Y	G											
2	Ashley	1	NWMT	?	?	.				3							
3	Baptiste	1	NWMT	?	?	.											
4	Bearfite	1	NWMT	4	Y	G				2							
5	Bisson (CSKT)	1	NWMT	2	N	G											
6	Cabinet	1	NWMT	5	Y	G				1							
7	Candy Mountain	1	NWMT	?	?	.											
8	Cilly	1	NWMT	5	Y	G				2							
9	Condon	1	NWMT	3	N	G				6							
10	Corona	1	NWMT	?	?	.				5							
11	Cowell	1	NWMT	5	Y	G											
12	Dutch	1	NWMT	5	Y	G											
13	Echo	1	NWMT	7	Y	G											
14	Firefighter	1	NWMT	5	?	G				3							
15	Flathead Alps	1	NWMT	?	?	.				1							
16	Garden (CSKT)	1	NWMT	3	N	G				1							
17	Grave Creek	1	NWMT	4	Y	G				3							
18	Great Bear	1	NWMT	?	?	.											
19	Great Northern	1	NWMT	?	?	.											
20	Half Moon	1	NWMT	?	?	.				2							
21	Hog Heaven (CSKT)	1	NWMT	3	N	G				1	6			2			
22	Kerr (CSKT)	1	NWMT	1	N	G				1	1			1			
23	Kintla	1	NWMT	5	Y	G											
24	Kootenai	1	NWMT	4	Y	G											
	~~Kootenai North - Combined~~	1	NWMT	.	.	.											
	~~Kootenai South - Combined~~	1	NWMT	.	.	.											
25	Ksanka	1	NWMT	?	?	.					1						

...continued... Table A4-1. Montana Wolf Packs and Population Data, 2016.

REF		FWP	RECOV	MIN. ESTIMATED			DOCUMENTED MORTALITIES					KNOWN		CONFIRMED LOSSES[7]			
#	WOLF PACK[1]	Region	AREA	PACK SIZE DEC 2016	Breeding Pair	Count Quality	NATURAL	HUMAN[2]	UNKN[3]	HARVEST[4]	CONTROL[5]	DISPERSED	MISSING[6]	CATTLE	SHEEP	DOGS	OTHER
26	Lonepine (CSKT)	1	NWMT	2	N	G											
27	Lost Dog	1	NWMT	?	?	.											
28	Lost Girl	1	NWMT	?	?	.											
29	Lost Soul	1	NWMT	?	?	.				2							
30	Lydia	1	NWMT	4	Y	G					2			2			
31	McDonald	1	NWMT	?	?	.											
32	McKay	1	NWMT	?	?	.											
33	Moore	1	NWMT	?	?	.											
34	Mullan	1	NWMT	2	?	G				3							
35	Murphy Lake	1	NWMT	2	N	G		2		3							
36	~~No~~	1	NWMT	0	N	P											
37	Nyack	1	NWMT	?	?	.											
38	O'Brien	1	NWMT	2	N	P											
39	Pierce	1	NWMT	3	N	G				2							
40	Pistol Creek (CSKT)	1	NWMT	2	?	P											
41	Preacher #	1	NWMT	?	?	.											
42	Quintonkon	1	NWMT	?	?	.											
43	Satire	1	NWMT	4	Y	G				3							
44	Silcox	1	NWMT	?	?	.				1							
45	Sleeping Woman (CSKT)	1	NWMT	3	?	G											
46	Smoky	1	NWMT	?	?	.											
47	Solomon Mountain	1	NWMT	6	Y	G											
48	Spotted Bear	1	NWMT	5	Y	G		1									
49	Sundance	1	NWMT	2	N	G				5							
50	Tallulah	1	NWMT	?	?	.											

...continued... Table A4-1. Montana Wolf Packs and Population Data, 2016.

REF		FWP	RECOV	MIN. ESTIMATED			DOCUMENTED MORTALITIES					KNOWN		CONFIRMED LOSSES[7]			
#	WOLF PACK[1]	Region	AREA	PACK SIZE DEC 2016	Breeding Pair	Count Quality	NATURAL	HUMAN[2]	UNKN[3]	HARVEST[4]	CONTROL[5]	DISPERSED	MISSING[6]	CATTLE	SHEEP	DOGS	OTHER
51	Thompson Peak	1	NWMT	?	?	.				1							
52	Tom Meier	1	NWMT	?	?	.				3							
53	Twilight #	1	NWMT	?	?	.											
54	Vermillion	1	NWMT	?	?	.											
55	Weigel	1	NWMT	4	?	G				1							
56	Whale Creek	1	NWMT	2	N	G											
57	Wiggletail #	1	NWMT	?	?	.											
58	Wolf Prairie	1	NWMT	?	?	.				5							
59	Yaak	1	NWMT	?	?	.				4							
60	Alta #	2	CID	3	?	P		1									
61	Ambrose	2	CID	4	?	P				3							
62	Arrastra Creek	2	NWMT	6	Y	M				1							
63	Belmont	2	NWMT	6	Y	G				2							
64	Black Pine	2	CID	?	?	.											
65	Bugle Mountain	2	NWMT	2	?	P											
66	Cache Creek #	2	NWMT	6	Y	G				4							
67	Chamberlain	2	NWMT	3	?	P											
68	Conger Point	2	NWMT	5	?	G				1							
69	DeBorgia #	2	NWMT	4	Y	P											
70	Divide Creek	2	CID	5	Y	G				2							
71	East Fork Rock Creek	2	CID	4	?	M											
72	El Capitan	2	CID	2	?	P											
73	Evaro	2	NWMT	2	?	P											
74	Flint	2	CID	4	Y	G				3		1					
75	Gash Creek #	2	CID	2	?	P											

...continued... Table A4-1. Montana Wolf Packs and Population Data, 2016.

REF		FWP	RECOV	MIN. ESTIMATED			DOCUMENTED MORTALITIES					KNOWN		CONFIRMED LOSSES[7]			
#	WOLF PACK[1]	Region	AREA	PACK SIZE DEC 2016	Breeding Pair	Count Quality	NATURAL	HUMAN[2]	UNKN[3]	HARVEST[4]	CONTROL[5]	DISPERSED	MISSING[6]	CATTLE	SHEEP	DOGS	OTHER
76	Gird Point	2	CID	2	?	P				2							
77	Humbug	2	NWMT	2	N	M					8			1			
78	Inez	2	NWMT	6	Y	G				2							
79	Landers Fork	2	NWMT	2	?	P											
80	Mineral Mountain	2	NWMT	2	?	P											
81	Morrell Mountain	2	NWMT	2	N	G				2							
82	Ninemile	2	NWMT	6	Y	G				3	3			1			
83	Olson Peak	2	NWMT	6	Y	G				4							
84	One Horse #	2	CID	7	Y	G				1				5			
85	Overwhich #	2	CID	4	Y	G			1	1							
86	Petty Creek	2	NWMT	2	?	P											
87	Quartz Creek	2	NWMT	11	Y	G		1									
88	Ross' Fork	2	CID	5	?	M				2							
89	Savenac	2	NWMT	5	?	P				1							
90	Seeley Lake	2	NWMT	5	Y	G			1	1							
91	Silver Lake #	2	NWMT	3	?	P											
92	Sliderock Mtn	2	CID	2	N	P				2							
93	Stonewall Mtn	2	NWMT	4	?	M		1		3							
94	Sula #	2	CID	5	Y	M				1							
95	Sunrise Mountain	2	NWMT	2	N	P				1							
96	Taft	2	NWMT	2	?	M				1							
97	Telephone Butte	2	NWMT	6	Y	G											
98	Tepee Point	2	CID	6	Y	G				2		1					
99	Trapper Peak	2	CID	4	Y	M											
100	Union Peak	2	NWMT	2	?	P				1							

...continued... Table A4-1. Montana Wolf Packs and Population Data, 2016.

REF		FWP	RECOV	MIN. ESTIMATED			DOCUMENTED MORTALITIES					KNOWN		CONFIRMED LOSSES[7]			
#	WOLF PACK[1]	Region	AREA	PACK SIZE DEC 2016	Breeding Pair	Count Quality	NATURAL	HUMAN[2]	UNKN[3]	HARVEST[4]	CONTROL[5]	DISPERSED	MISSING[6]	CATTLE	SHEEP	DOGS	OTHER
101	Watchtower #	2	CID	2	?	P											
102	Anaconda	3	CID	5	?	M				1							
103	Bloody Dick #	3	CID	6	Y	G				2							
104	~~Fool Hen~~	3	CID	0	N	G				4				2			
105	Four Eyes #	3	CID	5	?	G											
106	Highlands	3	GYA	2	?	G				3				1			
107	Pyramid #	3	CID	5	Y	G				2							
108	Thunderbolt	3	NWMT	6	Y	G											
109	Vipond	3	CID	3	?	G				1	2			2			
110	Warmsprings	3	CID	4	Y	G				3				1			
111	Battle Ridge	3	GYA	5	?	G								2			
112	Fridley	3	GYA	?	?	.				3							
113	Hogback	3	GYA	6	Y	G		1		1							
114	~~Parker Peak*~~	3	GYA	0	N	M											
115	Shinglemill	3	GYA	5	?	G				5							
116	Slip n' Slide	3	GYA	5	N	G				6							
117	Steamboat Peak	3	GYA	6	Y	G											
118	Antelope Basin	3	GYA	4	?	M											
119	Beartrap	3	GYA	15	Y	G		2		4							
120	Cedar Creek	3	GYA	4	?	M				2							
121	Centennial	3	GYA	10	Y	G				5							
122	Cougar 2*	3	GYA	4	?	P				1							
123	Hayden*	3	GYA	8	Y	M				2							
124	Meadow Creek	3	GYA	8	Y	G				2		1		2			
125	Price Creek	3	GYA	6	Y	P				7							

...continued... Table A4-1. Montana Wolf Packs and Population Data, 2016.

REF #	WOLF PACK[1]	FWP Region	RECOV AREA	MIN. ESTIMATED PACK SIZE DEC 2016	Breeding Pair	Count Quality	DOCUMENTED MORTALITIES NATURAL	HUMAN[2]	UNKN[3]	HARVEST[4]	CONTROL[5]	KNOWN DISPERSED	MISSING[6]	CONFIRMED LOSSES[7] CATTLE	SHEEP	DOGS	OTHER
126	Sweetwater	3	GYA	2	?	P				1							
127	~~Tanner Pass~~	3	GYA	0	N	M	1			4							
128	Toadflax	3	GYA	2	?	P				4							
129	Bennie	4	NWMT	5	Y	G				1				2			
130	Blowout Mountain	4	NWMT	6	Y	G				6	2			2			
131	Chief Mtn (BFN)	4	NWMT	8	Y	M											
132	Crown Mtn	4	NWMT	3	N	G		1		5	7			3			
133	Deep Creek	4	NWMT	4	Y	G				1							
134	Dog Gun (BFN)	4	NWMT	2	?	P				1							
135	Flesher Pass	4	NWMT	3	?	P		1									
136	Livermore (BFN)	4	NWMT	7	Y	G								2			
137	Looking Glass (BFN)	4	NWMT	2	?	P											
138	Marias	4	NWMT	4	?	P		1									
139	Pretty Prairie	4	NWMT	8	Y	M											
140	Red Shale	4	NWMT	10	Y	G				2							
141	Teton	4	NWMT	6	Y	G		1		3							
142	Baker Mountain	5	GYA	4	?	P				4			2				
143	Rosebud	5	GYA	2	N	G		1			6			7			
	Misc/Lone		NWMT	4				4		38	1			5			
	Misc/Lone		GYA	1			1	3		15	4	1		1	4		
	Misc/Lone		CID	0				2		6	9	1		8	1		
Montana Totals				477	50		2	23	2	255	52	5	2	52	5	0	0

1 Underlined packs are counted as breeding pairs toward Montana state plan goals. CSKT = Flathead Indian Reservation; BFN = Blackfeet Indian Reservation.
2 Excludes wolves killed in control actions to address livestock depredation and lawful public harvest.
3 Does not include pups that disappeared before winter.
4 Number legally harvested by humans in 2016.
5 Agency lethal control. Includes wolves killed by private citizens to defend livestock or under terms of a kill permit.
6 Collared wolves that became missing in 2016.
7 Includes only domestic animals confirmed killed by wolves.
Border pack shared with the State of Idaho; dens in Montana.
* Border pack shared with Yellowstone National Park; more time in Montana